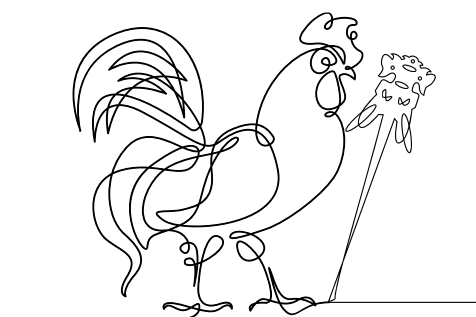




23rd European Symposium
on Poultry Nutrition

ESP
2023

RIMINI/ITALY
JUNE 21 - 24

BOOK OF ABSTRACTS

USB BOOK OF ABSTRACTS SPONSOR





Protect

Protect your flock with confidence



DSM POULTRY SOLUTIONS Protect focus areas



Coccidiosis Control

Enhancing your coccidiosis control program to reduce the reliance on anticoccidials as well as boosting the efficacy of cocci vaccines.



AGP Management

Helping to reduce the reliance on antibiotics towards your production goals.



Welfare Management

Improving the welfare of your flock by helping to manage stressors and their consequences.



MTX Risk Management

Protect your flock investment with effective and targeted mycotoxin risk management.

Identified Challenges

Protecting your birds against health and nutritional challenges at every life stage is essential for successful production. Our comprehensive range of solutions lie at the heart of healthy development and welfare. At DSM, we address the challenges you face to help protect your flocks with confidence.

We can help you to:

- Identify which mycotoxins could alter your flock performance based on your feed ingredients and production system
- Support your alternatives and enhancers for coccidiosis and AGP programs
- Support your flock's welfare to help manage the consequences of common stressors



Benefits for you

- Reduce therapeutic costs due to coccidiosis and challenges with secondary infections
- Confidence in anticoccidial rotations programs to increase livability
- Bring the performance back to potential

PI_PoultryCampaign_Protect_P_EN_2022_AWA



Because it's all about life.

The greatest global challenge is to ensure food security. Eight billion human lives depend on it. However, it matters how we source animal protein. Because it has consequences that affect animals, humans – and ultimately the entire planet. There is only one way to do it right: using science. Only well thought through, evidence-based solutions can establish a truly sustainable and secure food supply.

Sciencing the global food challenge. | evonik.com/animal-nutrition





LYSOFORTE® EXTEND

Optimizing nutrient digestibility
and enzyme activity for
greater cost savings

More information?

Scan the QR code
or visit the webpage:

[kemin.com/
nutrient-absorption](https://kemin.com/nutrient-absorption)



KEMIN

© Kemin Industries, Inc. and its group of companies 2023. All rights reserved. *™ Trademarks of Kemin Industries, Inc., U.S.A.
Certain statements, product labeling and claims may differ by geography or as required by government requirements.

WHAT YOU'RE MADE OF MATTERS.

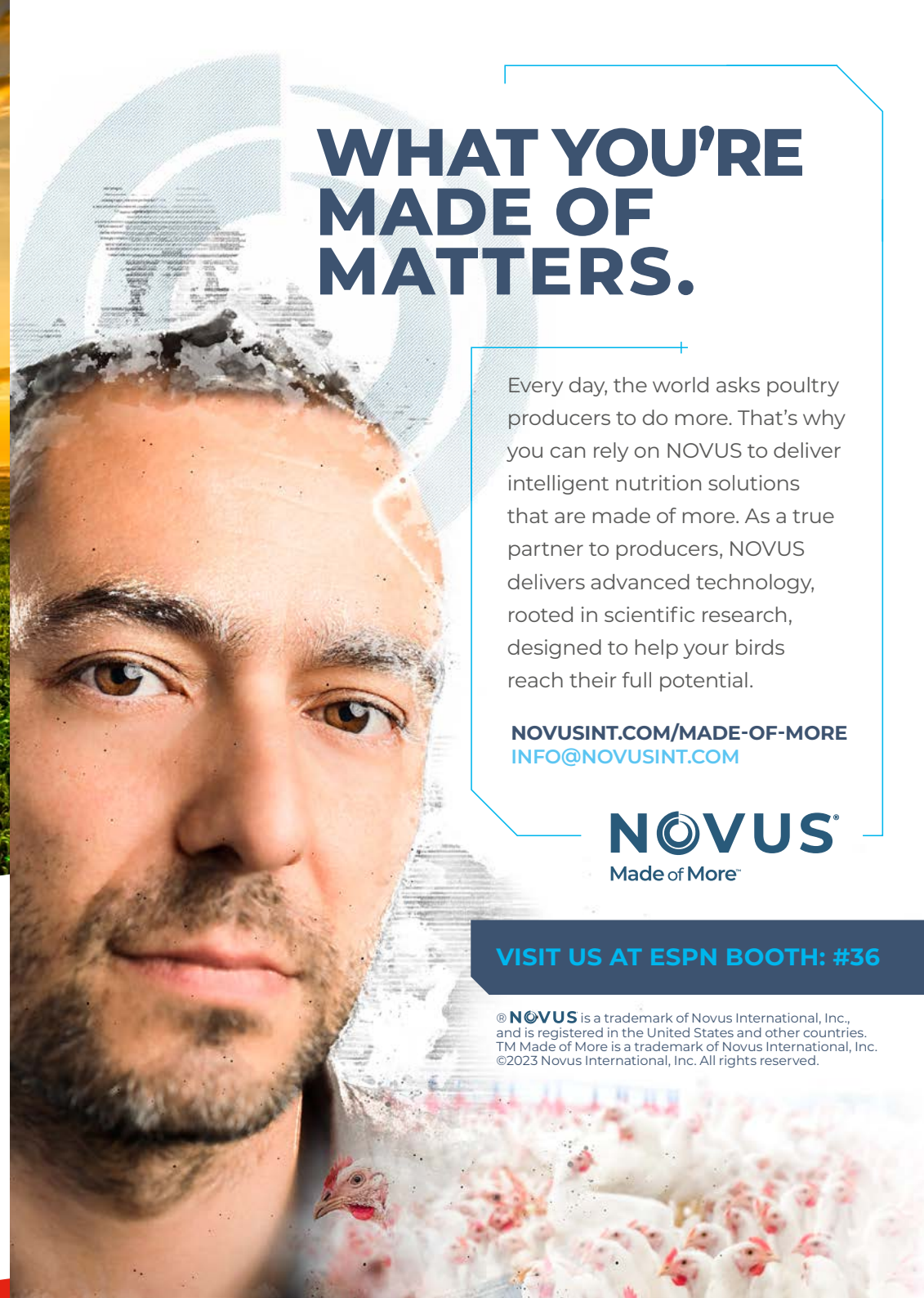
Every day, the world asks poultry producers to do more. That's why you can rely on NOVUS to deliver intelligent nutrition solutions that are made of more. As a true partner to producers, NOVUS delivers advanced technology, rooted in scientific research, designed to help your birds reach their full potential.

NOVUSINT.COM/MADE-OF-MORE
INFO@NOVUSINT.COM

NOVUS
Made of More™

VISIT US AT ESPN BOOTH: #36

® **NOVUS** is a trademark of Novus International, Inc., and is registered in the United States and other countries. TM Made of More is a trademark of Novus International, Inc. ©2023 Novus International, Inc. All rights reserved.



Gastrivix™ Avi
Experience the
magic of growth

Inspired by nature

- A unique solution combining the benefits of valeric acid and butyric acid
- Supports and improves animal performance
- Supplement naturally occurring organic acids that strengthen gut integrity

www.gastrivix.com



Life science to improve animal care



By mastering microbiota and immunity, Phileo's probiotics and posbiotics are designed to optimise feed efficiency, maximise growth performance, enhance animal natural defences and mitigate the effect of multifactorial stress.

Act with nature for animal care.



Want to maintain optimal feed intake in young poultry?

Alphasoy™ Gold is the functional protein that gives young poultry the best start in life!

- Delivers consistent quality nutrition
- Primes the immune system
- Drives body weight gain
- Creates the optimal gut-health environment



LESS WASTE – MORE RESULTS



β-Mannans increase feed costs by wasting energy.

The feed-induced immune response (FIIR) that they cause, diverts energy away from growth and negatively impacts bird health -wasting up to 3% of the total energy from feed¹.

Hemicell HT™ breaks down β-Mannans BEFORE they can trigger a FIIR.

Hemicell HT™ saves energy & removes the cost of β-mannans

1. Daskiran M, et al. (2004) An Evaluation of Endo-β-D-mannanase (Hemicell) Effects on Broiler Performance and Energy Use in Diets Varying in β-mannan Content. Poultry Sci. 83: 662-668. 2. Hemicell EMEA field experience. Data on file. 3. Poulsen K. (2021) Effects of Hemicell on Intestinal Health in broilers analyzed in 44 Experiences. Data on file. 4. David Zhu. (2021) Meta-analysis of HTSi for 24 Hemicell Trials in APAC. Data on file. Hemicell, Elanco and the diagonal bar logo are trademarks of Elanco or its affiliates. © 2023 Elanco or its affiliates. Date preparation: 02/2023 PM-GLB-MAR-23-0042



If there's a way to improve,
we find it.



vetagro.com

Together, Let's Prove the Power of Partnership.

Something powerful happens when shared expertise, care and nutritional performance come together. Suddenly, obstacles feel more like growth opportunities. That is the transformational power of partnership.



Scan to partner with us.
#PowerOfZinpro



NUTRITIONAL ADDITIVES AND SUPPLEMENTS

ADISSEO'S SOLUTIONS ARE DESIGNED TO SUPPORT PRODUCERS IN ALL PRODUCTION STAGES. THE FEED ADDITIVES WE OFFER PLAY A PIVOTAL ROLE IN OPTIMISING PERFORMANCE AND PROFITABILITY.



agrimprove
we farm ideas

Agrimprove is **the functional feed ingredients brand** of Royal Agrifirm Group, a cooperative of over 10,000 Dutch farmers. In support of farmers worldwide, we develop new ideas in **animal health and nutrition**, and grow these ideas into tangible improvement strategies that add value throughout the agri-food chain.

agrimprove.com



 **EARLYFEED**
right from the start

Earlyfeed is the **young animal nutrition** brand of Royal Agrifirm Group. With a complete approach, we **maximize the animals' genetic potential** through a healthy and profitable rearing strategy. With a strong scientific background and an advanced product portfolio, our expert advisors help our customers to raise healthy, resilient, and well-performing animals.

EARLYFEED.EU

Barentz.

Always a better solution.



Innovative & sustainable solutions for:

- ⊙ Emission reduction
- ⊙ Alternative proteins
- ⊙ Performance driven
- ⊙ Health & well-being



www.barentz.com/animal-nutrition

 **BASF**
We create chemistry

Natuphos® E
Natugrain® TS
Natupulse® TS



Enzymes to fully utilize the
potential of your feed

The science of sustainable feed that succeeds



animal-nutrition@basf.com

From feed to farm to fork to the future



As demand for more sustainably produced animal protein grows, so does the performance of our comprehensive portfolio of efficient, sustainable, high-quality ingredients and digital solutions.

- Carotenoids
- Conjugated Linoleic Acid
- Enzymes
- Glycinates
- Monoglycerides
- Mycotoxin Binders
- Organic Acids
- Vitamins
- Digital applications

The science of sustainable feed that succeeds

FOR THE ANIMALS WITH NEW SUPERIOR PRODUCTS



CJ BIO is the only company offering 8 essential Amino Acids for global feed industry. L-Lysine, L-Methionine, L-Tryptophan, L-Threonine, L-Valine, L-Arginine, L-Histidine, L-Isoleucine. These fermentation based feed amino acids fall under the brand name "BestAmino"



Recharge your poultry gut health strategies.

Known for their robust pathogen reduction properties and health benefits, α -monoglycerides are an effective alternative to antibiotics. Combined with organic acids, they enhance gut health in poultry.

Eastman Entero-Nova™ and Eastman Protaq™ solutions include short- and medium-chain fatty acid glycerides and are effective in both feed and water applications.

Eastman.com/AnimalNutrition



Maximize your energy value

Maxilys®

Unlocking more energy from your feed

Proven
return on
investment
5.5 to 6.0



Further information contact the Innovad®
Poultry Team at info@innovad-global.com
www.innovad-global.com



Enteric Health Solutions



Our comprehensive portfolio of safe and effective intestinal health solutions is proven to help optimize flock health and performance.

visit www.PAHC.com

Phibro
ANIMAL HEALTH CORPORATION

Magni-Phi / Integri-Phi / Aviax^{5%} / Aviax^{Plus} / Coxistac^{12%} / MicroLife^{PRIME} / Nicarmix²⁵

Not all products may be available in all markets

PL022123N16Phibro Animal Health Corporation. Phibro, Phibro logo design, Healthy Animals. Healthy Food. Healthy World., Magni-Phi, Integri-Phi, Nicarmix, Aviax, Aviax Plus, Coxistac and MicroLife are trademarks owned by or licensed to Phibro Animal Health Corporation or its affiliates.

HEALTHY ANIMALS. HEALTHY FOOD. HEALTHY WORLD.®

PRODUCTION
EFFICIENCY



Production Efficiency: When performance matters

VISIT US
BOOTH 11



Optimised
performance



Reduced
production costs



Lower production
footprint

Learn more, visit www.selko.com

trouw nutrition
a Nutreco company

10

YEAR
ANNIVERSARY

To nurture
our world and
humankind by
advancing care
for animals



zoetis

Saviotan Feed

MORE NATURE TO LIFE

MORE NATURE TO LIFE

100% Natural and Pure Chestnut extract
for a sustainable animal husbandry



Compatible with
organic farming



Planet friendly



Suitable in antibiotic-free
feeding strategies

SAVIOLIFE

Viale Lombardia, 29
46019, Viadana (MN) - Italy
Tel: +39 0375 7871
E-Mail: info@saviolife.com
Web: www.saviolife.com/en



saviolife



una^{italia}
 UNIONE NAZIONALE
 FILIERE AGROALIMENTARI
 CARNI E UOVA

La voce dall'avicoltura italiana

Rappresentare, tutelare e promuovere le filiere agroalimentari italiane delle carni e delle uova: è questa la mission di Unaitalia, associazione di categoria che rappresenta oltre il 90% della filiera avicunicola nazionale, 100% integrata e made in Italy.



 MADE IN ITALY

TABLE OF CONTENTS

Welcome	XXVIII
Committees.....	XXXII
Host Organizations.....	XXXIII
Sponsors.....	XXXIV
Keynote Lectures	1
Oral Presentations	85
Poster Presentations.....	113
Author's Index.....	427



WELCOME TO 23rd ESPN

The 23rd European Symposium on Poultry Nutrition - ESPN 2023 will be held from June 21 - 24, 2023 at the Palacongressi di Rimini, Italy. The Organiser of the Symposium is the Italian Branch of the World's Poultry Science Association.

Rimini is a perfect location, after the pandemia of COVID-19, because of it is one of the most famous European tourist locations and since the mid-1970's it has become an important congress destination. Rimini is an Italian dynamic, open, easily accessible and technological "plug & play" city, located on the Northeastern coast facing the Adriatic sea. It has been one of the most important cities of the ancient Roman Empire and to day it is a flourishing center for congresses and trade fairs as already discussed. The new and technologically advanced Palacongressi di Rimini is one of the larger in Italy. The new Trade Exhibition Complex, an array of steel, glass and fountains designed by famous architects, is one of the foremost in Europe.

Founded by the Romans in 268 B.C., Rimini has been the scene of many disputes in its two-thousand-year history. Significant traces of the city's past remain today: the Arch of Augustus (27 B.C.), the Tiberius bridge (21 A.D.), the Roman Amphitheatre (2 A.D.), and the Malatesta Temple, one of the finest examples of Renaissance architecture anywhere in Italy. Today, the old town is full of charm and vitality. Not to be missed is a visit to Domus, an archaeological excavation site of a Roman Surgeon's House, inaugurated in 2007.

Rimini is city of food and wine culture and along the streets you can find many kiosks where it is difficult to resist buying and tasting the real PIADINA a typical thin Italian flatbread served filled with a variety of cheeses, cold cuts and vegetables.

Rimini is city of cinema and it is representative of Federico Fellini's world of fantasy. Hollywood awarded this film director (born in Rimini on 20th January 1920) 5 Oscars and in his famous films, his past life in Rimini recurs again and again. Rimini continues to celebrate his work. La Dolce Vita (1960), 8½ (Otto e Mezzo, 1963), Amarcord (1974) just to mention a few of his masterpieces.

The Symposium is the most significant forum for the information exchange in the field of poultry nutrition issues in Europe, and it is one of the most influential gatherings of their kind in the world. It provides a unique opportunity to present scientific and technical achievements in poultry nutrition to get new information in science having direct impact from lectures and discussions with leading poultry scientist in very new area of poultry nutrition and poultry nutrition industry.

We are very pleasure to give the welcome to many attendees including both poultry research scientists and practitioners, leading speakers from across the world joining together to explore the past, share the present and helping to forge the future of poultry meat science.

We very much look forward to welcoming you in Rimini in June 2023 to share and discuss about technologies, information about what happened during the last 4 years after the last 22nd ESPN of Gdansk of Poland. Many thanks to all of those who will contribute and join us for making the congress possible, therefore on behalf of the Local Organizing Committee I gladly our best welcome you to participate.

Join us at the ESPN 2023!

Prof. Martino Cassandro
President of WPSA Italian branch
Chairperson of the LOC of 23rd ESPN



WELCOME FROM WORKING GROUP 2, WPSA

On behalf of Working Group 2 (WG2), it is with great pleasure that I welcome all participants to the 23rd European Symposium on Poultry Nutrition (ESPN), which will be held in Rimini, Italy during June 21-24, 2023. WG2 is pleased to extend a warm welcome to all the delegates attending ESPN this year, especially since this symposium had to be postponed by two years due to the widespread Corona pandemic that shook the world in March 2020. In the midst of major changes happening across the globe, it is essential to continue with significant events such as ESPN. This symposium emphasizes on science, professionalism, friendships, and collaboration. These values are crucial to tackling the future challenges in poultry nutrition, which is vital for maintaining a healthy and sustainable poultry production, and for the global food supply.

The ESPN is a popular, scientific event and WG2 has always been active in the planning of the ESPN in close co-operation with the local branches and organising committees in order to assemble an interesting scientific programme of high quality and relevance for delegates from universities and industry. It is highly appreciated that the Italian Branch of WPSA have invited to host the symposium in Rimini. It is not the first time that Italy has hosted the poultry nutrition symposium. Back in 1991, the 8th ESPN was held in Venice-Mestre. WG2 meets regularly in connection with the ESPN or during The European Conferences and World poultry congresses. At present, the WG2 has 30 members representing 19 European countries.

The format of the Symposium will follow the traditional combination of plenary lectures, discussion of the lectures by the delegates in smaller groups followed by a plenary discussion with the speakers, based on the questions raised in the groups. There are 6 main sessions on the programme with subjects that cover nutrition for both broilers, layers and turkeys, climate changes, nutrition and microbiome, solutions to improve the nutritional value of feed and non-soy protein sources. The last session on Saturday will present different unsolved issues in poultry nutrition. Very importantly, the symposium will include a display of contributed posters and selected posters will be presented by the authors in short communication sessions.

The WG2 has a long history since the first activities were initiated more than 45 years ago. The first ESPN was held in 1977 in Denmark with 73 delegates, and with the exception of 2021, the ESPN has been organised every second year at different locations in Europe and has attracted an increasing number of delegates over the years with an expected number close to 1500 in Rimini. Apart from many delegates from Europe, we also welcome participants from many countries outside Europe, and the sharing of thoughts and experiences among the delegates is an important contribution to the success of the symposium.

I wish you all an enjoyable and rewarding time during the ESPN 2023 in Rimini.

Sanna Steinfeldt, Aarhus University, Denmark
Chair of WG2, WPSA

**WELCOME FROM EUROPEAN FEDERATION, WPSA**

Dear Colleagues and Friends,
dear Guests at the 23rd European Symposium on Poultry Nutrition,

On behalf of the European Federation of the World Poultry Science Association, it is my great pleasure to welcome all of you and be with you in Rimini.

The European Federation of the WPSA aims to establish Working Groups as a platform for specialists to contribute to the dissemination of knowledge in poultry science and, consequently, in poultry industries. Our scientific symposia and conferences allow for the presentation and critical discussion of new insights in poultry science.

This symposium of the WG 2 provides a unique opportunity to present scientific and technical achievements in poultry nutrition offering a bridge between academia and industry. The organiser is the Italian Branch of the WPSA under the presidency of Martino Cassandro. I want to take this opportunity to thank the host of this meeting and I would like to express deep appreciation to all members of the Organizing and Scientific Committees. I know that the conference's success depends ultimately on the many people who have worked in planning and organizing the scientific program and supporting social arrangements. The organisers have developed an attractive scientific programme with numerous key speakers from diverse countries who are well known for their expertise. With the help of the international scientific committee, they have selected amongst numerous abstracts, original work representing both updated reviews and novel information.

The symposia of the Working Groups of the EFWPSA are not only a place for the exchange of knowledge but also serve an important role in forging bonds and mutual understanding and respect between countries and people with different roles in sustainable and efficient poultry production. I'd like to thank each of you for attending the Symposium of the WG 2 and wish you all a great meeting with numerous opportunities to establish friendly relationships and have an enjoyable stay in Rimini.

Estella Prukner-Radovcic
President of the European Federation
of WPSA branches (2018-2024)



Local Organising Committee

Martino Cassandro
 Francesco Biguzzi
 Franco Calini
 Cesare Castellini
 Silvia Cerolini
 Paolo Chignola
 Francesca Corona
 Valentina Ferrante
 Alessandro Franzone
 Nicolaia Iaffaldano
 Margherita Marzoni Fecia Di Cossato
 Massimiliano Petracci
 Ghassan Sayegh
 Achille Schiavone
 Federico Sirri

Scientific Committee

Burton Emily	Narcy Agnes
Brufau Joaquim	Noy Yael
Calini Franco	Pal Laszlo
Ceylan Necmettin	Papesova Lenka
Delezie Evelynne	Peric Lidija
Dublecz Karoly	Rodehutsord Marcus
Feuerstein Dieter	Santoma Gerard
Geraert Pierre-André	Schiavone Achille
Jozefiak Damian	Senkoylu Nizamettin
Kaczmarek Sebastian	Steenfeldt Sanna
Kenny Marcus	Svihus Birger
Koivunen Erja	Uni Zehava
Kwakkel Rene	Waldenstedt Lotta
Langhout Pim	Whitehead Colin
Müller Sabine	Zweifel Ruedi

Chairpersons of Scientific Programme

Franco Calini	Federico Sirri
Massimiliano Petracci	



Associazione Scientifica di Avicoltura
Italian Branch of World's Poultry Science Association

NATIONAL HOST ORGANISATION

Associazione Scientifica di Avicoltura
 Italian Branch of World's Poultry Science Association

**INTERNATIONAL HOST ORGANIZATION**

European Federation of World's Poultry Science Association

**ORGANISING SECRETARIAT**

VET INTERNATIONAL Srl
 Parma & Milano, Italy
info@vetinternational.eu
www.vetinternational.eu



**PALACONGRESSI
 DI RIMINI**

THE VENUE

Via della Fiera 23
 47923 Rimini (RN) Italy

Company Profiles

DSM (DIAMOND)

www.dsm.com

Royal DSM is a global, purpose-led company in Health, Nutrition & Bioscience.

By harnessing science and working in partnership with our customers, we're helping to deliver sustainable animal farming that respects animals, people, and planet. DSM offers a true end-to-end portfolio of poultry nutrition & health solutions for sustainable and profitable poultry farming.

EVONIK (DIAMOND)

www.corporate.evonik.com

We want to help supply a growing world population with healthy and affordable animal protein – while caring deeply about animal welfare and the efficient use of natural resources. Our high-quality products, services and solutions for animal nutrition, animal health and animal farming are based on science and decades of experience.

KEMIN (DIAMOND)

www.kemin.com

Kemin produces ingredients that optimally support integrations, feed and premix producers to raise healthy livestock in a sustainable and profitable way. We offer a wide range of in-house developed, high-quality, and science-based Nutrition, Health and Feed safety solutions, including customized technical support, laboratory services and in-house designed application systems for the feed mill.

NOVUS (DIAMOND)

www.novusint.com

Novus International, Inc. is the intelligent nutrition company. We combine global scientific research with local insights to develop innovative, advanced technology to help protein producers around the world achieve better results. Novus is privately owned by Mitsui & Co., Ltd. and Nippon Soda Co., Ltd. Headquartered in Saint Charles, Missouri, U.S.A. novusint.com

PERSTORP (DIAMOND)

www.perstorp.com

Perstorp Animal Nutrition is an integrated business producing its own raw materials and blends. The company is a global specialist of organic acid-based solutions with almost 60 years of experience. We have a highly knowledgeable and dedicated team that focuses its skills and knowledge on finding new ways to improve gut health and develops next generation solutions that exceed your expectations.

PHILEO by LESAFFRE (DIAMOND)

www.lesaffre.it/phileo-2/

We daily support our partners, from global industry players to family farmers, in their transition towards sustainable good practices. Our rich collection of proprietary probiotic strains allows us to develop evidence-based solutions taking into account animal species' diversity to overcome the increasing complexity of food production.

AB NEO (PLATINUM)

www.ab-neo.com

Leading brand in young animal nutrition With global environmental pressures, AB Neo is proactively researching and creating ground-breaking vital new ingredients to enhance nutritional programmes whilst improving the animal's overall health and performance. Alphasoy Gold is a thermo-mechanical enzyme facilitated processed soy-protein from AB Neo giving young poultry the best start in life.

ELANCO (PLATINUM)

www.elanco.com

Elanco is a global leader in animal health dedicated to innovating and delivering products and services to prevent and treat disease in farm animals and pets, creating value for farmers, pet owners, veterinarians, stakeholders, and society as a whole.

VETAGRO (PLATINUM)

www.vetagro.com

Vetagro is a progressive, science-based company, specializing in feed additive development and production. Since 1982, our headquarters in the Italian food-valley and our subsidiaries around the world have been delivering high-tech, cutting edge and cost-effective solutions in line with the needs of the modern animal feed industry.

ZINPRO (PLATINUM)

www.zinpro.com

For more than 50 years, Zinpro has improved the health and wellbeing of both animals and people as a pioneer in the research and development of performance trace minerals and innovative solutions. Our steady growth has come as a result of quality products, expert staff and a commitment to helping our customers achieve more through science-based trace mineral nutrition.

ADISSEO (GOLD)**www.adisseo.com**

Adisseo is a worldwide leader in nutritional solutions and additives for animal feed. Adisseo serves around 3,900 customers in over 110 different countries.

AGRIFIRM (GOLD)**www.agrifirm.com**

Agrifirm offers two innovative and reliable brands: Agrimprove, our functional feed ingredients range, and Earlyfeed, our young animal feeds.

BARENTZ (GOLD)**www.barentz.com**

Barentz, a global life science ingredients distributor, serving your needs with a broad portfolio of single ingredients, specialties and formulated solutions.

BASF (GOLD)**www.basf.com**

BASF is one of the leading suppliers of feed ingredients for an effective and sustainable animal protein production.

CJ BIO**www.cjbio.net**

CJ BIO is a global producer of Lysine, Threonine, Tryptophan, L-Methionine, Valine, Arginine, Isoleucine, Histidine, SPC, nucleotides and MSG for decades.

EASTMAN (GOLD)**www.eastman.com**

Eastman animal nutrition is committed to remain a trusted provider of poultry feed preservation and hygiene, and gut health solutions.

INNOVAD (GOLD)**www.innovad-global.com**

Innovad creates innovative solutions, to optimize animal performance while offering producers economically viable solutions with the smallest global footprint.

PHIBRO (GOLD)**www.pahc.com**

Phibro Animal Health Corporation is a leading global diversified animal health and nutrition company, headquartered in Teaneck, New Jersey (U.S.A.).

SELKO (GOLD)**www.trouwnutrition.it**

At Selko, the feed additives brand of Nutreco, we develop specialty feed additives to optimise animal performance with decades of experience.

ZOETIS (GOLD)**www.zoetis.com**

As the world's leading animal health company, Zoetis is driven by a singular purpose: to nurture our world and humankind by advancing care for animals.

AB VISTA (SILVER)**www.abvista.com**

AB Vista is a global animal nutrition technology company offering pioneering products and technical services to the global animal feed industry.

ADDICAN (SILVER)**www.addican.com**

ADDICAN is a manufacturer and supplier of premium nutritional products that help animals reach their peak potential across the globe.

AMLAN INTERNATIONAL (SILVER)**www.amlan.com**

Amlan International innovates mineral-based feed additives that optimize the intestinal health of animals; Drive Profits Naturally with Amlan's Unique Mineral Technology.

BIOCHEM (SILVER)**www.biochem.it**

Biochem can help you improve the health and performance of animals. We offer solutions for every species, production segment, and climate zone.

BRENNTAG (SILVER)**www.brenntag.com**

Brenntag is active as solution- and ingredient provider for the total animal nutrition industry in EMEA for more than 25 years.

DELAACON (SILVER)**www.delacon.com**

Unlocking the plant universe for better lives, Delacon and its global network aim at contributing to a healthier and more sustainable world.

DENUCO (SILVER)**www.denuco.com**

Denuco is a dynamic feed additives manufacturer specialized in the development of innovative products that optimize sustainable animal performance.

HERBONIS (SILVER)**www.herbonis.com**

The Swiss company that provides natural solutions for animal nutrition. Nature delivers inspiration. Our science delivers results.

IFF (SILVER)**www.iff.com**

An industry leader in nutritional health solutions with a comprehensive portfolio of feed enzymes, betaine, essential oils and probiotics.

JADIS ADDITIVA (SILVER)**www.jadis-additiva.com**

Jadis Additiva b.v. is an internationally operating organisation focused on the development, sales, and marketing of safe special-purpose feed additives.

JRS (SILVER)**www.jrs.eu**

JRS – producing and marketing of insoluble, functional fiber ARBOCEL. Already low inclusion rates impact poultry health and performance positively.

LEIBER (SILVER)**www.leibergmbh.de**

Leiber develops and produces sustainable, naturally versatile brewers' yeast products that help to improve welfare and efficiency of livestock.

LUCTA (SILVER)**www.lucta.com**

LUCTA, world leader in additives for animal nutrition, designs, manufactures and commercializes a whole range of additives focusing on palatability and welfare.

METEX (SILVER)**www.en.metexanimalnutrition.com**

Metex Animal Nutrition produces and offers solutions such as low carbon amino acids, customized amino acid solutions, functional amino acids, and a biosourced butyrates range.

NATUR-ADD (SILVER)**www.natur-add.com**

Natur-add is an all-in-one internet platform to have access to trials and most comprehensive documentation related to functional feed additives.

PHYTOBIOTICS (SILVER)**www.phytobiotics.com**

Founded in 2000, Phytobiotics has become a global leader in animal nutrition, manufacturing and distributing high-quality feed additives.

SAVIOLIFE (SILVER)**www.saviolife.com**

Saviolife, part of Gruppo Mauro Saviola (Italy), manufactures and proposes the natural 100% chestnut extract rich in hydrolysable tannins: Saviotan® Feed.

SILVATEAM (SILVER)**www.silvateam.it**

169 years old manufacturer of extracts from several botanical species, highly effective ingredients to increase animal performance and wellbeing.



KEYNOTE LECTURES



CONTENT

Plenary Session 1:	3
NUTRITION FOR SUSTAINABILITY IN BROILER, LAYER AND TURKEY PRODUCTION	
The role of nutrition in supporting sustainable poultry production	3
Sustainability and optimal nitrogen nutrition	7
Improving energy utilisation in poultry:	11
Challenges and opportunities	11
Sustainability as related to optimal mineral nutrition	15
Plenary session 2:	18
NUTRITION INTERVENTION FOR CLIMATE CHANGES	
Poultry production impacts: enlarging the picture	18
Observations on Water Quality and Quantity for Poultry	23
Feeding and nutritional strategies for commercial	26
poultry dealing with climate change	26
Plenary Session 3:	30
NUTRITION AND MICROBIOME UNDER CHALLENGING CONDITIONS	
Nutritional and Feeding Strategies for Antibiotic-Free Poultry Production	30
Disentangling the effects of feed composition on the consequences of coccidia infection in broilers	35
Feeding the microbiome	36
Plenary Session 4:	40
SOLUTIONS TO IMPROVE THE NUTRITIONAL VALUE OF FEED	
The effect of fibres in feedstuffs on nutritional value and how to determine it	40
Improving the nutritional value of ingredients through the use of feed enzymes	45
The importance of digestive dynamics in broiler	49
chicken nutrition	49
Plenary Session 5:	54
NON-SOY PROTEIN SOURCES	
Perspective and limits in the use of algae and free amino acids in low protein diets	54
Nutritional conflicts in using processed animal proteins: new perspective on their use	58
Insects in poultry feeding: regulatory issues	61
and productive updates	61
Insects in poultry feeding: translating research	67
outcomes into practice	67
Plenary Session 6:	73
UNSOLVED ISSUES IN POULTRY NUTRITION	
“Oxidative stress in poultry: a holistic overview from the animal to the final consumer”	73
Nutrition of laying hens for an extended laying cycle	76
Economical efficiency in turkey nutrition	80

Plenary Session 1:

NUTRITION FOR SUSTAINABILITY IN BROILER, LAYER AND TURKEY PRODUCTION

THE ROLE OF NUTRITION IN SUPPORTING SUSTAINABLE POULTRY PRODUCTION

Emily Burton

Poultry Research Unit, Nottingham Trent University, UK

emily.burton@ntu.ac.uk

Background

Advancing our knowledge of poultry nutrition has been a globally significant research field for approaching a century. This has enabled poultry to become established as the most efficient of all animals as a protein source. From the 1940s to the 1990s, poultry scientists initially established the concept of apparent metabolisable energy as a basis for feed formulation, before systematically working to establish the requirements for vitamins, amino acids and minerals (Elwinger *et al.*, 2016). Through the 1980s the role of exogenous enzymes in enhancing digestion was investigated and quickly adopted universally through a diverse range of enzymes from alpha galactosidases to xylanases (Bedford *et al.*, 2022). The vast knowledge accumulated on how to meet the nutritional requirements of poultry has allowed researchers to evolve towards use of nutrition to achieve the wider aims of global food security. In parallel to the highly focused advances in poultry nutrition, other researchers were grappling with the seemingly intractable conflict between globalized economic growth and accelerating ecological degradation. In 1983, the UN invited former Prime Minister of Norway, Gro Harlem Brundtland to chair an independent commission to explore this conflict and propose solutions. The chief outcome was the reframing of economic development in a new paradigm: sustainable development; defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). The concept of sustainable development was explained in depth through the discussion of climate change, economic development, and global goals that should be implemented to achieve sustainable development.

The Brundtland Report delineated how economic growth, social equity and environmental balance are essential to create a sustainable development solutions network – utilizing local, national and global development strategies. From this, sustainable development became based on three fundamental pillars: social, economic and environmental. Sustainability clearly exists to find balance between economic, social, and environmental needs, both now and in the future, which makes the three pillars a logical grouping system. However, sustainable development requires a holistic and systemic approach to the three pillars best visualised as a Venn diagram, shown in figure 1 (Royer, 2019).



Figure 1: Sustainable Development

THE THREE PILLARS OF SUSTAINABILITY

The close relationship between researchers and practitioners within the poultry sector ensures that economic viability remains at the heart of innovations in poultry nutrition. However, the environmental and societal pillars of sustainable poultry production are complex and often in conflict. Nutrition has a central role in managing these tensions.

All life is ultimately regulated by natural systems, which makes environmental sustainability the first of the three sustainability pillars. Poultry production sometimes takes a narrow approach to environmental sustainability, with a strong focus on finite resources and environmental impact of poultry manure. However, environmental sustainability focuses holistically on the well-being of the environment. Therefore this pillar includes climate change, water supply, and biodiversity; all of which may be influenced by our nutritional strategies for poultry.

Feed is reported to be the major contributor to the carbon cost associated with poultry products (Leinonen *et al.*, 2012^a; 2012^b). While many elements of environmental impact resulting from our nutritional strategies lack the models and metrics necessary for quantification, carbon cost, more accurately described as global warming potential (GWP) is quantified in an almost overwhelming plethora of life cycle assessment (LCA) models (Alkhtib *et al.*, 2023). While methodologies and databases for calculating GWP are diverse, LCA provides a common unit; CO₂eq (also written as carbon dioxide equivalent, CO₂ equivalent or CO₂e). As the International Monetary Fund continues to promote carbon taxation policies to support global economic stability (Parry, 2019), nutritional evaluations must also include this unit alongside traditional measures (Burton *et al.*, 2021).

Research for social sustainability has been historically overshadowed by concerns for environmental and economic sustainability (Vallance *et al.*, 2011). Drawing societal sustainability into a poultry context, the UN Sustainable Development Goals (SDGs) while providing an excellent framework for applying nutrition as a tool for sustainable poultry production, fail to consider animal welfare (Messerli *et al.*, 2019). However, within the European Union, the emergence of sustainability as a core policy objective (the 'European Green Deal') is shifting the focus and design of agriculture, food and rural policies to include societal sustainability (European Commission, 2019). In food production sectors as highly evolved as eggs and poultry meat, the lack of established social metrics make it challenging to incorporate this element of sustainability into poultry production (Barral and Detang-Dessendre, 2023). Managing the opposing yet interlocked tensions related to environmental, social, and economic aspects of sustainability is one of the most crucial future challenges in the corporate world (Sasse-Werhahn *et al.*, 2020).

CASE STUDY

Consumption of meat was a critical step in human evolution through provision of nicotinamide to support increasing brain size, but continuing to increase human consumption of meat is no longer an evolutionary advantage (Williams and Hill, 2017). In fact, it is widely stated that meat intake must be limited, as overconsumption in many high- and middle-income countries is associated adverse health outcomes (Willet *et al.*, 2019). While there is a lack of evidence that poultry meat specifically contributes to these health issues, the emerging outcome is that Higher Income Countries are re-considering their relationship with animal protein sources and animals used in food production.

Production systems requiring slower growth of poultry such as the Better Chicken Commitment (BCC, 2019) exemplify tensions between the three pillars. The fixed production constraints of the BCC policy address societal sustainability through improved bird welfare and other, more human-centric parameters. This requires breeders and nutritionists to resolve the apparent economic and environmental imbalances related to lower stocking density and slower growth. The many papers presented at ESPN2023 evaluating non-standard feed demonstrates the research drive to mitigate the increased feed volume required for slower growth systems.

ONE HEALTH

Some of the challenges we may positively influence through nutrition are encapsulated by the UN ONE Health approach. One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. The term 'One Health' was first used in early 2003 in association with the emergence of severe acute respiratory disease (SARS) and the spread of highly pathogenic avian influenza H5N1. One Health became established conceptually through the 'Manhattan Principles' which clearly recognised the link between human and animal health and the threats that diseases pose to food supplies and economies (Cook *et al.*, 2004). The nutritional focus on strategies to enhance poultry gut health to reduce reliance on antibiotics is a powerful example of One Health in practice (La Ragione and Burton, 2023).

NUTRITION IN THE FUTURE

To ensure the poultry sector continues to thrive, nutritionists need to support poultry producers in acting as ambassadors, offering producers new tools to address the requirements of society while continuing to deliver high quality protein with very low environmental impact. As sustainability models progress from a 'cradle to grave' approach to adopt circular and networked economics (a 'cradle to cradle' approach) in managing resources and environmental impact, it is likely nutritionists will have to re-imagine the type of materials we consider for use in feed. As we evaluate each candidate material, nutritionists must keep one eye on the past to learn from historical errors and one eye on the future, to scan ahead for unintended consequences of our decision-making.

An arising skill requirement for poultry nutritionists is application of life cycle analysis to feeding trials and diet formation. Where feed formulation previously reconciled nutrient supply against economic cost, now carbon cost must be considered as a third dimension. A second emerging skill is public communication: nutritionists must be able summarise our sustainability achievements in formats that can be fed into social media streams by those in the poultry supply chain holding consumer relationships. A final competency for nutritionists to maximally support the poultry industry is to maintain awareness of changing societal needs and consider them with a growth mindset (Dweck, 2006); seeking to understand and use nutrition to address underpinning values rather than focusing on the (frequently incorrect) details that accompany these societal messages. In addition to these skills, it is clear the nutrition vanguard must adopt a holistic view of sustainability that considers societal elements alongside environmental and economic in order to realise the enormous potential of poultry nutrition in supporting sustainability development.

CONCLUSION

It is now more important than ever that nutrition continues to facilitate global production of high-quality protein from the lowest possible natural resource use, but we need to work within the context of the three sustainability pillars. The pillars of sustainability help us recognise everything is connected; actions and impacts must be balanced; and no individual, organization, or nation operates by itself. One Health offers a collaborative and multi-disciplinary approach, cutting across boundaries of animal, human, and environmental health, that recognises that the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent.

Much of our current nutrition research directly addresses global challenges such as antimicrobial resistance, food safety and promoting the health and integrity of our natural ecosystems. Poultry nutritionists must develop new skills and approaches to maximise the contribution of nutrition to sustainable food production, and ensure the contribution is universally recognised. Using the language of the three sustainability pillars to contextualise sustainable poultry nutrition will allow our stakeholders to better understand the co-benefits, risks, trade-offs and opportunities to advance sustainable nutritional solutions.

REFERENCES

1. Alkhtib, A., Burton, E., Wilson, P.B., Scholey, D. And Bentley, J., (2023). Effect of life cycle inventory choices and nutritional variation on carbon footprint of broiler meat production. *Journal of Cleaner Production*, 383: 135463. ISSN 0959-6526
2. BCC, 2019 Better Chicken Commitment <https://betterchickencommitment.com/policy/> Accessed 2 May 2023. Bedford, M., Gary Partridge, G., Carrie L Walk, C. & Milan Hruby, M. (2022). *Enzymes in Farm Animal Nutrition*, 3rd Ed. CABI Publishing.
3. Barral, S., & Detang-Dessendre, C. (2023). Reforming the Common Agricultural Policy (2023–2027): multidisciplinary views. *Rev Agric Food Environ Stud* 104: 47–50. <https://doi.org/10.1007/s41130-023-00191-9>
4. Brennan, M., Hennessy E., & Meredith D. (2022). Putting social into agricultural sustainability: Integrating assessments of quality of life and wellbeing into farm sustainability indicators. *Sociologica Ruralis* doi.org/10.1111/soru.12417.
5. Brundtland, G.H. (1987) Our Common Future: Report of the World Commission on Environment and Development. Geneva, UN-Dokument A/42/427. <http://www.un-documents.net/ocf-ov.htm>
6. Burton, E., Scholey, D., Alkhtib, A. & Williams, P. (2021). Use of an ethanol bio-refinery product as a soy bean alternative in diets for fast-growing meat production species: a circular economy approach. *Sustainability*, 13 (19): 11019. ISSN 2071-1050.
7. Dweck, C. S. (2006). *Mindset: The new psychology of success*. Random House.
8. Elwinger, K., Fisher, C., Jeroch, H., Sauveur, B., Tiller, H., & Whitehead, C. (2016). A brief history of poultry nutrition over the last hundred years. *World's Poultry Science Journal*, 72(4), 701-720. doi:10.1017/S004393391600074X
9. European Commission. (2019). Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal. COM (2019) 640 final, 24 p. + Annex. https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF
10. La Ragione R. & Burton, E. (2023). Moving beyond antibiotic usage to support the health and productivity of commercially reared poultry. In: *Pre and probiotics, nutrition, veterinary and production perspectives*. CABI Publishing.
11. Leinonen I, Williams AG, Wiseman J, Guy J, Kyriazakis I. (2012a) Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: egg production systems. *Poult Sci*. 91:26-40. doi: 10.3382/ps.2011-01635.
12. Leinonen I, Williams AG, Wiseman J, Guy J, Kyriazakis I. (2012b) Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: broiler production systems. *Poult Sci*. 91:8-25. doi: 10.3382/ps.2011-01634.
13. Messerli, P., Murniningtyas, E., Eloundou-Enyegue, P., Foli, E.G., Furman, E., Glassman, A., Hernández Licona, G., Kim, E.M., Lutz, W., Moatti, J.P. and Richardson, K., (2019). Global sustainable development report 2019: the future is now—science for achieving sustainable development.
14. Royer, Pierre. (2019). Circular Economy, utopia or promising new business model? An evaluation of Circular Economy efficiency against environmental challenges. 10.13140/RG.2.2.31586.27842.
15. Sasse-Werhahn, L., Bachmann, C. & Habisch, A. (2020). Managing Tensions in Corporate Sustainability Through a Practical Wisdom Lens. *J Bus Ethics* 163, 53–66. <https://doi.org/10.1007/s10551-018-3994-z>
16. Vallance, S, Perkins, H, Dixon, J (2011). What is social sustainability? A clarification of concepts. *Geoforum*, 42: 342-348 <https://doi.org/10.1016/j.geoforum.2011.01.002>.
17. William, R., Karesh, B. and Osofsky S. (2004). *Wildlife Conservation Society One World-One Health: Building Interdisciplinary Bridges*. http://www.oneworldonehealth.org/sept2004/owoh_sept04.html Accessed 05 May 2023.
18. Williams A., Hill L., (2017). Meat and Nicotinamide: A Causal Role in Human Evolution, History, and Demographics. *Int J Tryptophan Res*. 10:1178646917704661. doi: 10.1177/1178646917704661.

Plenary Session 1:

NUTRITION FOR SUSTAINABILITY IN BROILER, LAYER AND TURKEY PRODUCTION

SUSTAINABILITY AND OPTIMAL NITROGEN NUTRITION

Wolfgang Siegert

Department of Animal Science, Georg-August-University Göttingen, Germany

w.siegert@uni-hohenheim.de

inst450@uni-hohenheim.de

INTRODUCTION

Poultry meat and eggs currently are the most common animal-based foods worldwide. Production of animal-based food requires land area and water, mainly through the production of feed crops.¹ Hence, arable land and water for feed cropping is expected to become an increasingly scarce resource. Another aspect is the environmental impact of animal farming, which has led to growing concerns over the past decades. Feed production and emissions from excreta represent the major impacts of animal farming in this regard.² Major environmentally relevant impacts of feed production include energy consumption of crop farming and transport, emissions from the fields, and the consequences of land-use change when crops are cultivated on converted forests or grasslands. Regarding excreta, the major environmentally relevant impacts include nitrogenous emissions (ammonia, nitrates, nitrous oxide), phosphorus emissions, or fine particles. These emissions contribute to climate change, acidification, eutrophication, and pollution of air and water.

Aims of farm animal nutrition research include to minimise the negative effects of farm animal husbandry on the environment, to ensure animal health and well-being as well as to contribute to global food availability. Investigations identifying requirements for nitrogenous compounds, mainly amino acids (AA), and evaluating feed ingredients and feed additives contribute to these aims.³ Animal nutrition research allows to reduce the needed amount of feed crops and the environmental impact of poultry farming. A key figure to assess the efficiency of the production of animal-based food is the nitrogen (N) utilisation efficiency (NUE), which is the N accretion in body weight or eggs relative to the N intake. Increasing the NUE results in less feed protein needed and reduced N excretion per produced animal-based food.

This contribution aims to summarise the current knowledge on increasing the NUE in the context of saving feed crops and reducing the environmental impact. A focus is set on an increasingly precise alignment of the supply with and the requirement for digestible AA. Conflict-of-aims among sustainability goals are worked out.

INFLUENCES ON THE NITROGEN UTILISATION EFFICIENCY

The dietary supply below and above the requirement of poultry for digestible AA usually leads to decreased NUE. Consequences of a deficient supply with one or more AA include performance loss, increased degradation of non-limiting AA because they cannot be used for protein synthesis. An excess supply causes decreased NUE because excess AA are degraded by the animal.⁴ In both cases, more N is excreted relative to the intake.

Phase-feeding

Phase-feeding is widely applied in practice; thus, it is only mentioned shortly for completeness. Recommended AA concentrations in diets decrease considerably throughout a production period of laying and growing poultry, mainly because of the changing energy requirement. The alignment of recommended and actual dietary AA concentrations is closer the more phases are implemented. This approach reduces surpluses in AA supply and, hence, increases NUE.

Increasing knowledge on amino acid requirements

The requirement for essential AA has been investigated extensively since the middle of the last century. The increasingly advancing knowledge of the requirement for essential AA has enabled the reduction dietary CP, thereby avoiding essential AA deficiency. Current practical recommendations for 1–21-day-old broiler chickens usually range between 21–23% CP^{5,6}, yielding in about 55% NUE.

Practical feeding experiments show that dietary CP in this age range can be reduced to 19% without performance loss while the estimated NUE increased to more than 60%.⁷ Such low CP concentrations are rare in current commercial diets. Cost of free AA contribute to that because the inclusion of free AA increases the lower dietary CP is. Nonetheless, based on current knowledge, dietary CP can be reduced to 15–16% without performance loss in maize/soybean meal-based diets without performance loss.⁸ Glycine or serine need to be supplemented to such diets because these AA become growth-limiting when dietary CP is below 19%.⁹ In the future, less than 15% of dietary CP may be achievable without performance loss when the next-limiting AA is determined. Although not unequivocally clear, recent experiments indicated that dietary asparagine may limit growth in such diets.^{10,11}

The measured NUE determined for broiler chickens fed diets with ~16% CP was 75% to more than 80%.^{10,11} Therefore, NUE could be ~20 percentage points (pp) higher than the nowadays standard. According to a meta-analysis, decreasing dietary CP from 21% to 16% reduces N excretion by approximately two thirds.¹² The potential of CP reduction to decrease N emissions is higher than the potential to decrease N excretion. The urine-N contributes more to ammonia and nitrous oxide emissions than N excreted via the faeces. When dietary CP is reduced while the requirement for AA is met, urinary N excretion relative to N in faeces becomes lower.

Increasing knowledge on amino acid digestibility

Knowledge of precaecal AA digestibility is a prerequisite for formulating diets according to the requirement of the animals for digestible AA. Increasing AA digestibility increases NUE provided that dietary CP is reduced so that the supply of digestible AA remains unchanged. An increase in AA digestibility without reduction of dietary CP increases N excretion via the urine and decreases N excretion via the faeces. This shift in excretion routes does not affect the total N excretion. Hence, NUE remains unaffected but the higher proportion of N excreted via the urine contributes to higher ammonia and nitrous oxide emissions.

When AA digestibility is varied by an influence not related to the feed ingredients providing AA (such as supplemented enzymes), increasing AA digestibility raises NUE in a linear manner.¹³ This increase in NUE is only attributed to the limiting AA in the diet, although supplemented enzymes can increase the digestibility of all AA. An increase in the digestibility of non-limiting AA increases N excretion via the urine, leading to the downsides mentioned earlier in this contribution. This effect can be avoided by using free AA so that supplemented enzymes increase the digestibility of several AA that are provided exactly according to the requirement for digestible AA.

The extent to which AA digestibility influences NUE depends on the ratio of the limiting AA to CP (AA/CP ratio) in a diet. The higher this ratio, the more CP not related to the limiting AA can be spared by increasing the digestibility of the limiting AA. Consequences of increasing the digestibility of lysine as the limiting AA by 1 pp in practical laying hen diets were described in a model calculation.¹³ In this model calculation, NUE was increased by 0.36 pp at a lysine/CP ratio of 3.1 and by 0.46 pp at a lysine/CP ratio of 3.9.

Another possibility is to increase AA digestibility by selecting specific variants of a feed ingredient differing in AA digestibility. Consequences on NUE cannot be determined accurately using an equation because AA digestibility and the AA/CP ratio in feed ingredients vary independently. However, the effects of increasing AA digestibility by 1 pp via selection of ingredient variants was approximated in model calculations based on studies on the variation in AA digestibility within ingredients in laying hen diets.¹³ Assuming that the considered ingredient contributed 3 g digestible lysine/kg of diet, the increase in NUE per pp higher lysine digestibility was 5–13 and 0–4 pp of NUE for cereal grains and protein-rich ingredients, respectively.

Taking the variation in AA digestibility into account presupposes that AA digestibility of single feedstuff batches is predictable. In the literature, several attempts were made to predict AA digestibility in studies investigating the variation in digestibility within feed ingredients. The methods of prediction included correlations and multiple regressions between AA digestibility and analysed variables of the feed ingredients, and determination of *in vitro* N solubility. Accuracy of such prediction was limited. Some studies found significant correlations, but such results were not consistent among individual AA or results were not verified on independent data sets. Near infrared reflectance spectroscopy (NIRS) is an attractive tool to determine characteristics of feed ingredients because measurements are quick, simple, and inexpensive. NIRS calibrations for AA digestibility are commercially available, but the underlying reference measurements are not disclosed. It appears highly unlikely that the reference measurements originate from methodologically uniform experiments, thus decreasing the validity of reference measurements to an unknown extent.

Potential to increase the nitrogen utilisation efficiency in current practical diets

Optimising diets by approximating the requirement for digestible AA to increase NUE involves considering the changing requirement for digestible AA throughout the production period, increasing knowledge of the requirement of animals for single nitrogenous nutrients, and increasing predictability of AA digestibility. Changes in needed AA concentrations throughout the production period have been well-known for years. The limitations for practical application of this knowledge are defined by operational constraints, such as feeding technology and availability of transport and storage capacity for diets with different AA concentrations. Given current inaccuracies in prediction of AA digestibility, formulating diets that meet the requirement of more AA than the current standard (e.g., by inclusion of free AA) appears to be a more promising tool to increase the NUE than attempts to increase AA digestibility in the near future. Rapid analysis tools, such as in-line stream NIRS devices, may prospectively enable to estimate AA concentrations of feed ingredients in real-time and to adjust diet composition automatically to achieve aspired dietary AA concentrations, best on a digestible basis.

CRITICAL EVALUATION OF THE GOAL TO MAXIMISE NITROGEN UTILISATION EFFICIENCY

Minimised nitrogen emissions vs. minimised greenhouse gas emissions

Increasing the NUE results in less N excretion and, hence, less formation of the greenhouse gas (GHG) nitrous oxide. Less N excretion further reduces the energy requirement for uric acid formation, which results in less carbon dioxide produced by the metabolism. In addition, less dietary CP and lower energy requirements cause lower GHG emissions from cropping for feed production and transport. However, the need for free AA inclusion to adjust dietary AA concentrations increases the lower dietary CP is and GHG emissions originating from free AA production is a multiple of GHG emissions from plant feedstuff production.¹⁴ Therefore, increasing the NUE by decreasing dietary CP will lead to less GHG emissions related to excreted N but this effect is countered by increasing GHG emissions for free AA production. This results in a conflict-of-aims between minimising GHG emissions and minimising the environmental impact of N emissions and cropping for feed production. A threshold of free AA inclusion for minimised GHG is difficult to identify because of the variation in GHG emissions assigned to feed ingredients. Particularly GHG emissions assigned to free AA differ widely.^{15,16} Nonetheless, reducing dietary CP below the current standard should decrease both GHG and N emissions. This is because free AA inclusion in most cases is too low to make the conflict-of-aims between GHG and N emissions relevant at current, unless very high GHG emissions are assigned to free AA production.¹⁶

Maximised growth vs. maximised nitrogen utilisation efficiency

Prioritised goals of poultry feed formulation may shift in the future. Recently, studies determined an increasing NUE when performance of broiler chickens was reduced as a consequence of AA deficiency.^{8,11} This outcome probably is explained by maximised AA utilisation efficiency (increment in

AA accretion per increment in AA intake) at an AA intake level below what is needed for maximised AA accretion. This phenomenon was exemplarily found for methionine¹⁷ and lysine¹⁸ in broiler chickens. Potential explanations for these results include a lower muscle protein turnover in the state of AA deficiency.¹⁹ Increased NUE at an AA supply that does not allow for maximum performance results in a conflict between maximised growth and maximised NUE. At present, high growth performance commonly is considered most important for diet formulation, and reduced nutrient excretion is the next highest priority. However, future economic and ecological constraints may lead to priority changes in the industry. Submaximal growth might be accepted when maximising utilisation of protein sources or minimising emissions emerges as more economically beneficial than maximising growth. Reasons for that may include higher prices of protein sources and increasingly strict fertiliser legislation that determines the animal production volume of a farm.

Maximised global food availability vs. maximised nitrogen utilisation efficiency

A maximised NUE is to be pursued when the major aim of feed formulation is to reduce environmental effects of excreted N. When the major aim of feed formulation is global food availability, a maximised NUE is only beneficial if feed ingredients are used that are not consumed by humans. Lower NUE, for instance in consequence of low AA digestibility, can be accepted for the aim of global food availability when ingredients hardly consumed by humans are used because other components can be consumed directly by humans without transformation losses.

CONCLUSIONS

The NUE is a key figure to assess the sustainability of optimal N nutrition because increasing the NUE implies decreasing environmental issues of N excretion and decreasing field crop production needed to produce animal-based food. However, reduced NUE may be accepted when other sustainability goals are prioritised, like minimising GHG emissions or maximising global food availability. Among the feeding strategies to increase NUE, formulating diets that meet the requirement of more AA than the current standard (e.g., by inclusion of free AA) appears easiest to be put into practice in the near future. Possibilities to increase NUE by considering AA digestibility currently are limited due to low predictability.

REFERENCES

- 1 Mottet & Tempio. 2017. Worlds Poult Sci J 73: 245–256.
- 2 Gerber et al. 2013. Rome, FAO, ISBN 9789251079201.
- 3 Gesellschaft für Ernährungsphysiologie. 2017. Proc Soc Nutr Phys 26: 218–224.
- 4 Simon. 2020. In: Jeroch et al., eds. ISBN 783825287634.
- 5 Aviagen. 2019. Ross 308 broiler nutrition specifications.
- 6 Deutsche Landwirtschafts-Gesellschaft. 2017. DLG Merkblatt 406.
- 7 Lemme et al. 2019. J Appl Poult Res 28: 867–880.
- 8 Hofmann et al. 2019. J Nutr 149: 1122–1132.
- 9 Siegert & Rodehutscord. 2019. Br Poult Sci 60: 579–588.
- 10 Ibrahim et al. 2023. Proc Soc Nutr Phys 32: 25.
- 11 Hofmann et al. 2020. Poult Sci 99: 6848–6858.
- 12 Cappelaere et al. 2021. Front Vet Sci 8: 689259.
- 13 Siegert. 2022. Habilitation thesis <http://opus.uni-hohenheim.de/volltexte/2022/2054>
- 14 Mosnier et al. 2011. Animal 5: 1972–1983.
- 15 Lammers et al. 2010. J Anim Sci 88: 1204–1212.
- 16 van Harn et al. 2017. Wageningen Livestock Research Report 1033.
- 17 Fatufe et al. 2005. Arch Anim Nutr 59: 181–190.
- 18 Fatufe et al. 2004. Poult Sci 83: 1314–1324.
- 19 Tesseraud et al. 1992. Reprod Nutr Dev 32: 163–171.

Plenary Session 1:

NUTRITION FOR SUSTAINABILITY IN BROILER, LAYER AND TURKEY PRODUCTION

IMPROVING ENERGY UTILISATION IN POULTRY: CHALLENGES AND OPPORTUNITIES

Fifi Zaefarian

School of Agriculture and Environment, Massey University, New Zealand

f.zaefariani@massey.ac.nz

INTRODUCTION

Energy is not a nutrient, but a property that some nutrients (carbohydrates, lipids and protein) possess. Dietary energy represents the costliest component in poultry feed formulations and is the first component to be considered when the diets are being balanced. Dietary energy also controls the feed intake, which is the major driver of bird growth. Therefore, an accurate evaluation of the available energy content of ingredients is important for precise and cost-effective feed formulations (Abdollahi et al., 2021).

Different energy systems have been suggested over the years. Apparent metabolisable energy (AME), N-corrected AME (AMEn; Hill and Anderson, 1958), net energy (NE; Swick et al., 2013; Wu et al., 2020), and true ileal digestible energy (TIDE; Khalil et al., 2020, 2022) are the examples of energy systems. Each energy system has its own merits and drawbacks. However, The AMEn is widely used as the default value to express the available energy of feed ingredients and for describing the energy requirements of birds. Energy contents of feed ingredients can be obtained from published table values, prediction equations, or in vivo assays. Predictive equations and in vivo assays are useful and provide a better alternative than tabulated values. Table values are the basis of feed formulation under most practical conditions. However, the wide variability among published data on the energy value of many ingredients limits their applicability. These variabilities are due to the various factors such as different methodologies, age of bird, genotype, feed form, ingredient characteristics, and presence of anti-nutritional factors (ANFs). Therefore, knowledge about these factors could help nutritionist to accurately evaluate the available energy content of ingredients and apply the best strategy to improve energy utilisation. Key strategies to enhance the utilisation of energy from feed ingredients are those ones that can improve carbohydrate, protein and fat digestibility of the diets. Application of feed additives (exogenous enzymes, emulsifiers, prebiotics, and probiotics) have shown to have positive effect on nutrient digestibility.

The aims of the present review are 2-fold: 1) to address the challenges and limitations encountered by the poultry nutritionist when using energy values of feed ingredients, and 2) to suggest the strategies and opportunities that can be applied to improve the energy value of feed ingredients and enhance the precision of feed formulation and production efficiency.

ENERGY SYSTEMS AVAILABLE FOR FEED FORMULATION

The AME system has become the most common system to express the energy requirements for birds and evaluate the available energy of ingredients and diets as it is simple, straightforward and considers most of the energy losses after the digestion and metabolism. Correcting AME values to zero N retention (AMEn) for modern fast-growing broilers penalises the energy value of all feed ingredients that contribute to body protein deposition. The magnitude of decline in energy value due to zero N correction varies depending on the protein content and quality of the ingredient, imposing a heavy penalty to the protein sources with a higher protein quality (Abdollahi et al., 2021). The NE system has received some attention recently as an alternative for the standard AME system in feed formulation for broilers (Swick et al., 2013; Wu et al., 2020). Net energy represents the effective energy for birds used for body maintenance and various forms of production, and it can be defined as the ME minus the energy losses for heat increment, which is the increase in heat production after consumption of food, digestion, metabolism, and excretion of wastes. However, the NE system has been criticised for several reasons.

Most importantly, the NE method relies on the precise measurements of AME, so any error in the AME procedure will be reflected in the NE measurement. Another potential energy system might be ileal digestible energy (IDE). A switch of available energy measurement to IDE will overcome the limitations of AME and also align energy availability with the current trend of using digestible content of nutrients in feed formulations. Researchers at Massey University recently proposed a novel approach to quantify ileal endogenous energy losses in broiler chickens and provided data on the TIDE of some common cereals (Khalil et al., 2020, 2022). Strong positive correlations were observed between the TIDE and ileal digestibility of nutrients than those with the AME or AMEn.

FACTORS INFLUENCING ENERGY CONTRIBUTION OF INGREDIENTS

Age of the birds and genotype

Utilisation of energy by birds of different ages changes according to how ingredients are processed by the digestive enzymes at the different stages of the bird's life. Some of the available tables provide different energy values for birds at different ages (INRA, 2002; CVB, 2016; Feedipedia, 2017; Rostagno et al., 2017); however, other tables do not distinguish between ages (WPSA, 1986; NRC, 1994). In recent studies, Khalil et al. (2021, 2022a,b) suggested that, age of broiler has a substantial impact on the AMEn values of cereal grains. These results question the validity of applying a single AME or AMEn value for broilers of different ages, which can under- or over-estimate the energy utilisation. Therefore, to improve the precision of feed formulations and production efficiency, age-dependent AME and AMEn values may need to be considered when formulating broiler diets.

Digestibility and utilisation of nutrients and energy vary between bird types and are dependent on the strain of bird (Yegani and Korver, 2012). These variabilities may be due to the differences in the developments of the digestive system organs and/or endogenous nutrient or energy losses. This difference in gastrointestinal development may influence nutrient utilisation, which has implications on the formulation of feeds for slow-growing chickens; feeds formulated for slow growers are commonly based on nutritional data derived from fast-growing strains. Most of the current energy requirements listed in the published tables are provided in generic terms (NRC, 1994; Rostagno et al., 2017; Evonik, 2016), or are provided for specific commercial strains of broiler (Aviagen, 2009; Hubbard, 2011). However, there is a lack of information on the influence of poultry genotypes on the AME values of many ingredients.

Feed form

Processing feed affects not only feed intake, but also gastrointestinal tract development, specifically the gizzard, resulting in changes in nutrient utilisation and microbial profile. The effects of pelleting on the energy content of diets are inconsistent and depend on different factors such as ingredient type used in the diet, heat applied and particle size (Mateos et al., 2012). It has been reported that feeding birds on pelleted diets reduces the AME values compared to mash diets and is attributed to the starch overload in the gut and possible starch retrogradation forming resistant starch (Svihus, 2001). Abdollahi et al. (2013) showed that pelleting reduced the AME value of a wheat-based diet by 0.70 MJ/kg compared to the mash form. However, pelleting showed no effect on the AME value for a maize-based diet. Similarly, Amerah et al. (2007) reported that pelleting reduced the AMEn of a wheat-based diet from 12.5 MJ/kg to 11.8 MJ/kg compared to the mash form. In contrast, pelleting might increase the energy utilisation of certain ingredients, as heat and mechanical pressure in the pellet die can disrupt the structure of the cell walls, thus releasing some nutrients such as lipids contained in the oil bodies of oil-containing ingredients (Jiménez-Moreno et al., 2009).

Ingredients type and presence of anti-nutritional factors

Variations in the chemical composition of ingredients can significantly influence the digestibility and availability of nutrients, and hence, these variations can affect the AME values of ingredients. This variation has been explained as the differences in the proportions and the percentages of the major nutrients: protein, fat, and carbohydrates, which are responsible for significant variation in the birds'

abilities to utilise energy from different substances (Yegani and Korve, 2012).

There are various types of ANFs in poultry feeds that affect energy utilisation. These ANFs not only affect AME values, but also affect birds' gastrointestinal tract function. Non starch polysaccharides (NSPs) are the main ANFs in cereal sources. They are non-degradable substances and remain undigested by the endogenous enzymes in the gastrointestinal tract of birds. The detrimental and anti-nutritional effects of NSPs on dietary AME are due to their potential to increase the digesta viscosity, hence negatively affecting the digestibility of nutrients and ultimately, energy utilisation (Choct, 2015). The adverse effects of NSPs can be exaggerated by processing, as pelleting at a high temperature can solubilise the insoluble NSP fractions in wheat and barley, leading to higher viscosity of the digesta compared to the unprocessed form of feed, hence reducing digestibility and AME values (Mateos et al., 2019).

Dietary supplementation of exogenous enzymes can reduce the negative effect of ANFs on nutrient digestibility, whilst leaving fewer nutrients to the hindgut, where they would be used by microbiomes to proliferate. It has been reported that enzymes have more pronounced effect in the feed ingredient with high content of ANFs (Yegani and Korver, 2012).

CONCLUSIONS

Although the ME system is currently used as a default method, but NE or TIDE could be used as potential energy systems in feed formulations, as they reported to be more predictive of bird performance and nutrient digestibility than the ME system. However, the suitability of TIDE for application in broiler feed formulations merits further research investment.

The application of age-appropriate AMEn data might enable the poultry industry to improve the precision of feed formulations, broiler performance, profitability and sustainability of poultry production. In commercial practice, pellets are the commonly used feed form in broiler production. Thus, the application of existing AME or AMEn data derived from mash diets to industry situation might result in over- or under-estimation of the available energy content of feed ingredients.

Presence of ANFs in feed ingredients and low secretion of endogenous enzymes can cause low nutrient digestibility and energy utilisation of feed ingredients. Supplementation of diets with feed additives such as exogenous enzymes, probiotics, prebiotics, and emulsifiers have been reported to increase nutrient digestibility and absorption, enhance intestinal health and function, and subsequently increase energy value of the feed ingredients.

REFERENCES

1. Abdollahi MR, Ravindran V, Svihus B. 2013. *Animal Feed Science and Technology* 186: 193-203.
2. Abdollahi MR, Wiltafsky-Martin M, Ravindran V. 2021. *Animals* 11(8): 2174.
3. Amerah AM, Ravindran V, Lentle RG, Thomas DG. 2007. *Poultry Science* 86(12): 2615-2623.
4. Aviagen. 2009. Aviagen, Scotland, UK.
5. Choct M. 2015. *Animal Production Science* 55(12): 1360-1366.
6. CVB. 2016.
7. Evonik Industries. 2016.
8. Feedipedia. 2017.
9. Hill FW, Anderson DL. 1958. *Journal of Nutrition* 64: 587-603.
10. Hubbard LLC. 2011.
11. INRA. 2002.
12. Jiménez-Moreno E, González-Alvarado JM, Lázaro R, Mateos GG. 2009. *Poultry Science* 88(9):1925-1933.
13. Khalil MM, Abdollahi MR, Zaefarian F, Chrystal PV, Ravindran V. 2021. *Poultry Science* 100(9): 101288.
14. Khalil MM, Abdollahi MR, Zaefarian F, Chrystal PV, Ravindran V. 2022a. *Animals* 12(2): 183.
15. Khalil MM, Abdollahi MR, Zaefarian F, Chrystal PV, Ravindran V. 2022b. *Poultry Science* 101(7): 101948.

16. Mateos GG, Cámara L, Fondevila G, Lázaro RP. 2019. Journal of Applied Poultry Research 28(3): 506-525.
17. Mateos, GG, Jiménez-Moreno E, Serrano MP, Lázaro RP. 2012. Journal of Applied Poultry Research 21(1): 156-174.
18. NRC. 1994. National Academies Press.
19. Rostagno HS, Albino LFT, Donzele JL, Gomes PC, Oliveira RF, Lopes DC, ... Euclides RF. 2017.
20. Svihus B. 2001. Animal Feed Science and Technology 92(1-2): 45-49.
21. Swick, RA, Wu SB, Zuo J, Rodgers N, Barekataan MR, Choct M. 2013. Animal Production Science 53(11): 1231-1237.
22. WPSA. 1989.
23. Wu SB, Choct M, Pesti G. 2020. Poultry science 99(1): 385-406.
24. Yegani M, Korver DR. 2012. Canadian Journal of Animal Science 92(3): 261-273.

Plenary Session 1:

NUTRITION FOR SUSTAINABILITY IN BROILER, LAYER AND TURKEY PRODUCTION

SUSTAINABILITY AS RELATED TO OPTIMAL MINERAL NUTRITION

Roselina Angel¹, Kyle Venter², Wenting Li¹

¹ University of Maryland, 8127 Regents Drive, College Park, MD, USA, 20742.

² Neuro Livestock Research, Kameeldrift, Brits, South Africa

rangel@umd.edu

As we learn more about the negative impacts of calcium (**Ca**) on availability of phosphorus (**P**) and that of other nutrients, it highlights how little we know about Ca requirements, digestibility of Ca in ingredients, and their impacts on P and micromineral digestibility (Angel, 2019). To optimize dietary P, copper (**Cu**) and zinc (**Zn**) utilization from the diet, phytic acid or its salt (phytate) needs to be dephosphorylated, at least partially. As phytate is dephosphorylated, its chelating capacity towards mineral cations greatly decreases (Lonnerdal, 2002). To maximize dephosphorylation of dietary phytic acid or its salt (phytate) and minimize potential chelation with mineral cations and other charged nutrients, dietary Ca management must be optimized. By managing Ca supply in the diet, microminerals and P are better digested and absorbed and thus excretion is decreased.

Work on understanding ingredients that supply Ca in the diet (Kim et al., 2019; David et al., 2019; Li et al., 2021) and on Ca requirements of broilers (David et al., 2021, 2022, 2023; Walk et al., 2021, 2022; Angel et al., 2022) has resulted in a clear understanding that if Ca nutrition is optimized, phosphate use can be minimized. Therefore, the standardized ileal digestible (**SID**) of Ca in ingredients (Anwar et al., 2016 a, b, c; Li et al., 2021) is needed to optimize phytase efficacy and P digestibility. In most plant-based broiler diets, limestone (**LS**) contributes between 30 and 75% of the dietary Ca. Because LS are so variable in their characteristics (Galini et al., 2022) and Ca digestibility (Anwar et al., 2016 a, c; Kim et al., 2019; Li et al., 2021), understanding LS Ca digestibility and the factors that influence it (Li et al., 2021, Angel et al., 2022) allows for optimizing the selection of the main Ca source in broiler diets and this in turn will result in improvements in SID P, due partly through better exogenous phytase efficacy (Kim et al., 2019; Li et al., 2021).

Poultry nutritionists have used total Ca to a form of “available” (a) P ratio in the diet with measures of “availability” of P in ingredients being (available, digestible and retainable). However, we continue to use total Ca to formulate poultry diets, define requirements and give matrix values to phytase. Phytase, does not generate additional total Ca to the diet, rather, it catalyzes the stepwise removal of phosphate from phytic acid or its salts (Wyss et al., 1999), releases phosphates and phytate bound Ca and/or microminerals, making the total Ca, Zn, and Cu more “available”. To date, the limitations for using a digestible Ca (dCa) system have been: 1) lack of comprehensive ingredient SID Ca database; 2) low robustness in the dataset (SID Ca available in most cases based on 1 value for an ingredient); and more importantly 3) the immense variability in SID Ca from LS (Anwar et al., 2016 a, c; Kim et al., 2018; Angel 2019; Li et al., 2021). The impact of adding LS with different geologies and dynamic (over several time points) solubilities on apparent P digestibility of the diet the LS is added to, was showcased by Kim et al. (2018). These authors showed that changing only the LS added to the same basal broiler diet could change apparent P digestibility from 23.1 to 65.5% in the absence of phytase and from 45.0 to 90.7% when 1000 U of a phytase was added per kg of diet. Understanding the impact of LS source on P digestibility of the diet is the key to be able to formulate to dP requirements of broilers and minimizing P excretions.

In recent years, research has shown that Ca digestibility in broilers varies dramatically depending on the Ca source, solubility and source (geology) of LS, as well as dietary phytate and phytase

concentration use in the diet (Anwar et al., 2016c; Angel, 2019; Kim et al., 2019; Li et al., 2021). With the knowledge that Ca digestibility which can be altered by the aforementioned dietary factors can affect P digestibility, the specification of Ca requirements for broilers as total Ca in the diet becomes obsolete, as does the adherence to a fixed ratio of total Ca to dP. Thus, the importance of understanding LS Ca digestibility, and LS Ca interactions with phytate becomes essential if a dCa system is to work.

When comparing LS from the same source, a reduction in particle size from 0.8 mm geometric mean diameter (**GMD**) to 0.15 mm GMD reduced SID Ca of the LS from 49.2% to 38.1% (Li et al., 2021). Importantly, Kim et al. (2019), reported that differences in GMD alone could only explain <40% of the observed differences in Ca digestibility from LS; and differences in LS geology, solubility and physical/chemical characteristics were equally as important in their potential effects on Ca digestibility. Kim et al. (2019) showed that predictions of Ca digestibility could have an r^2 of 0.98. But it is important to note that this was a preliminary study involving only 4 LS and that true validation of the equation with sample data not used to develop the equation was not possible at the time. The authors (Kim et al., 2019) state “the prediction equations should be interpreted with care especially in cases beyond the scope of current study”. Additional work has been carried out that now involved more than 51 limestone samples. Data from these studies (7 studies) have been used to develop prediction equations for SID Ca in limestone and SID P in diets the limestones are added to, when diets contain “high” levels of phytase (Angel et al., unpublished). The prediction equations have been used to predict SID Ca and P in data set points not used to develop the prediction equations and compared with *in vivo* results, and errors associated with the predictions are + or - 4% of actual values. These prediction equations now allow us to predict SID Ca in limestones based on laboratory analyzable factors (LS solubility at 5, 15 and 30 min; GMD, Ca and Mg as well as diet phytate concentration). They also allow us to predict the potential impact the LS on the SID P of the diet in the presence or absence of a “high” dose of phytase and thus have a variable phytase matrix that reflects the potential impact of LS characteristics on phytase efficacy (Angel et al., unpublished).

Requirements based on dCa and dP are now available. Although not robust yet, dCa for several ingredients are now available. A dCa system will allow for supplying sufficient quantities of Ca at tissue level to optimize growth and physiological processes. This in turn will result in lower LS in the diet, better dephosphorylation of phytate, less chelation's with mineral cations and thus better digestibility of Ca, P, Zn, Cu among others. Ultimately resulting in a lower excretion of P, Cu and Zn can be expected.

REFERENCES

1. ANGEL, R. (2019) Proc Australian Poult Sci Symp, Sydney, pp 51-56.
2. ANGEL, R., LI, W., LI, and PLUMSTEAD, P.W. (2022) Proc WPC, Paris, pp 324 - 334.
3. ANWAR, N.M., RAVINDRAN, V., MOREL, P., MOREL, C., RAVINDRAN, G. and COWIESON, A.J. (2016a) Anim Feed Sic and Tech 213:142-147.
4. ANWAR, N.M., RAVINDRAN, V., MOREL, P., MOREL, C., RAVINDRAN, G. and COWIESON, A.J. (2016b) Poult Sci 95:70-76.
5. ANWAR, N.M., RAVINDRAN, V., MOREL, P., MOREL, C., RAVINDRAN, G. and COWIESON, A.J. (2016c) Brit Poult Sci 57:707-713.
6. DAVID, L.S., ABDOLLAHI, R., RAVINDRAN, G., WALK, C.L. and RAVINDRAN, V. (2019) Poult Sci 98: 5582-5589.
7. DAVID, L.S., ABDOLLAHI, R., BEDFORD, M.R. and RAVINDRAN, V. (2021) Poult Sci 100:1-19.
8. DAVID, L.S., ABDOLLAHI, R., BEDFORD, M.R. and RAVINDRAN, V. (2022) Poult Sci 101:102135.
9. DAVID, L.S., ABDOLLAHI, R., BEDFORD, M.R. and RAVINDRAN, V. (2023) Poult Sci 102:102492.
10. KIM, S.W., LI, W., ANGEL, R. and PLUMSTEAD, P.W. (2019) Poult Sci 98:6837-6848.

11. LI, W., ANGEL, R., PLUMSTEAD, P.W. and ENTING H. (2021) Poult Sci 100:900-909
12. GALINI, S., MEREU, A., LI, W., PLUMSTEAD, P.W., ANGEL, R., WILKS, G., and DERSJANT-LI, Y. (2022) J Appl Anim Nut 10:19-30.
13. LONNERDAL, B. (2002) Inter J Food Sci and Tech 37:749-758
14. WALK, C.L., WANG, Z., WANG, S., WU, J., SORBARA, J O.B. and ZHANG, J. (2021) Poult Sci 100:101364.
15. WALK, C.L., WANG, Z., WANG, S., WU, J., SORBARA, J.O.B. and ZHANG, J. (2022) Poult Sci 101:1011836.
16. WYSS, M., BRUGGER, R., KRONENBERGER, A., REMY, R., FIMBEL, R., OESTERHELT, G., LEHMANN, M., and VAN LOON, A. P. G. M. (1999) Appl Environ Micro 65:367-373.

Plenary session 2:

NUTRITION INTERVENTION FOR CLIMATE CHANGES

POULTRY PRODUCTION IMPACTS: ENLARGING THE PICTURE

Simone Bastianoni, Nicoletta Patrizi and Anna Ruini

Ecodynamics Group - University of Siena. Piazzetta Enzo Tiezzi, 1 - 53100 Siena (Italy)

simone.bastianoni@unisi.it

INTRODUCTION

Minimizing the environmental impact of poultry industry is gaining higher interest due to raising world population and meat demand. The ONE Health approach to animal production (Alders and Tomley, 2022) and the United Nations 17 Sustainable Development Goals (UN, 2015) call for a holistic approach that look at all aspects of sustainability.

Usually, sustainability is depicted as the junction point of three partially intersecting circles: environment, economy, and society (Barbier, 1987)

; however, this representation does not explain any of the cause-effects linkages among the three components. Therefore, we have developed a more logical/consequential sustainability representation based on an Input-State-Output (I-S-O) framework. It sets straight the economy's dependence on societal organization, environmental resources, and ecosystem services (Pulselli et al. 2015) by showing the cause-effect relations, interactions, and feedback among the environment, society and the economy (represented in Figure 1 by arrows going backwards).

The environment is society's input; as for all living systems, consumption derives from the environment and should be under its limits. Society, which is the *state* of our framework, prospers if it succeeds in using in the best possible way the inputs of various kinds that derive from the environment; it organises and generates an *output*, *the economy*, that produces and distributes the goods and services needed by the society itself.

Qualitatively, feedback between the environment, society, and the economy can be positive (thus contributing to the whole system's health and development) or negative (thus destabilising the system and potentially disrupting its development).

From a quantitative point of view, sustainability is challenging to measure per se: it is an ideal state and propriety of the overall system. What can be measured is the distance from the ideal point of sustainability, i.e. unsustainability, and it can be quantified through systems indicators. A good starting point to try to overcome the sustainability dilemma and have quantitative data is offered by H. Daly's principles of sustainability: 1) resources should be used at a rate that allows their re-formation (sustainable yield); 2) wastes should be produced at a rate which allows the environment to absorb them. It is possible to quantify what is used and/or what is released too fast and too much into the environment (Daly, 1990). These necessary conditions show that unsustainability is related to the total amount of available resources and waste produced (and the speed of their formation/production). Therefore, any assessment of environmental sustainability must include (at least) two aspects: one related to the use of natural resources (e.g. the renewability of a product extended to the whole value chain), the other to the feedback that the production system drives back to the environment, (e.g. their impacts).

The I-S-O framework can depict the area of interest of different methodologies/indicators, highlight their investigation potentialities and help define what kind of information each of them can provide. Furthermore, using this framework, we can establish overlapping and complementarities among indicators useful to stimulate and optimize efforts in identifying and collecting statistical information and data for policies.

LIFE CYCLE ASSESSMENT

Life Cycle Assessment (LCA) is an environmental systems analysis tool which help provide relevant information on the environmental consequences of different production systems. ISO 14040:2006

and ISO 14044:2006 are the standards that describe the principles and framework for Life Cycle Assessment implementation.

LCA enables the evaluation of products' environmental burdens through their entire life cycle, from cradle to grave: starting from the resources extraction, going through the production of material, product parts and the product itself, until the use phase and end-of-life management (ISO, 2006).

As depicted in Figure 1, LCA interest is in the "technosphere": starts with human intervention and measures its effects (feedbacks) on the environment. It does not account for the resource itself, its availability or renewability. It concentrates on the different impacts a production process will likely have locally and globally. LCA is a perfect candidate for measuring the second of Herman Daly's principles.

EMERGY EVALUATION

Emergy is defined as the solar energy, directly and indirectly, required to produce a product or a service. The unit of solar emergy is the solar emergy Joule (seJ) (Odum, 1996). Emergy evaluation assigns a value to products and services by converting them into solar emergy equivalents. This common denominator enables different resources, whether energy or matter, to be measured and compared. The emergy of different products is assessed by multiplying the mass or energy of inputs by a transformation coefficient called *Unit Emergy Value* (UEV). UEV is the solar emergy required, directly or indirectly, to make 1 unit (e.g. J or g) of a product. By definition, the solar emergy Em of a product or process is:

$$Em = \sum_{i=1}^n E_i UEV_i \quad (1)$$

where E_i is the energy (or mass if UEV_i is in seJ/g) content of the i th independent input flow to the process, and UEV_i is the unit emergy value of the i th input flow.

Emergy evaluation helps quantify Herman Daly's first necessary condition for sustainable development. It can be used to define guidelines for the consumption of resources compatible with their formation times, since it deals with both biosphere and technosphere (Figure 1).

Emergy can be regarded as the solar emergy necessary to sustain a system; the greater the total emergy flow required for obtaining a product, the greater the consumption of solar emergy necessary for its re-formation once it has been used, and thus the greater its past and present environmental cost.

According to Odum (1996) and based on their provenance and regeneration times, flows of resources can be: a) emergy flows related to local renewable resources (R); b) emergy flows related to local non-renewable resources (N); c) emergy flows related to goods and services purchased outside the study system (F). Besides UEV, other emergy-related indicators may be used to characterize emergy results based on these different emergy flows. To this aim, common indicators considered in the assessment of agricultural and agricultural residues productions are the percentage of renewable inputs (%R), *Emergy Flow Density* (ED) and *Emergy Yield Ratio* (EYR) (Ulgiati et al., 1995). The first indicator highlights the contribution of renewable resources in producing the output considered with respect to the whole emergy supporting flow and is calculated as $\%R = R/Em$. ED accounts for the emergy flow during a specific time interval (usually a year) divided by the area of the production system, thus giving a measure of the concentration of resource use in that area. Finally, the EYR is calculated as Em/F and expresses a process's ability to use local renewable and non-renewable resources by investing a unit of outside resources.

Emergy is a most valuable addition to LCA, that provides a complementary donor-side perspective, a unified measure of the provision of environmental support, and an indication of the work of the environment that would be needed to replace what is consumed (Raugei et al., 2014).

Differences between emergy evaluation and LCA inventories

Setting the boundaries for LCA is regulated by ISO 14040 standards. The "cradle" is typically the

human investment, in terms of energy and material, needed to collect raw materials. The “grave” is typically where the production process assessed ends. In the case of poultry, the analysis often ends at the gate of the farm or the slaughterhouse.

In emergy evaluation, the grave usually is the same as the LCA. Conversely, the cradle is much farther: the solar energy received by all the systems directly and indirectly involved in the production. All the natural processes of agriculture are considered, and inputs such as rain, heat from the ground, water, and soil are included in the inventory per se. Also, human labour is an input of emergy evaluation since many inputs of direct and (especially) indirect solar energy are required to maintain a human life: human work can be substituted by machinery and energy, included in the evaluation. All the inputs carry a certain level of renewability: agricultural crops, since they require renewable inputs (e.g. sunlight and rain) and non-renewable ones (e.g. fossil fuels for the tractors or chemical fertilizers), will have a certain level of renewability resulting from the amount of emergy required from the different inputs.

POULTRY AND ENVIRONMENTAL SUSTAINABILITY ASSESSMENT

LCA applied to poultry shows very well its potentiality: apart from direct ones, chickens’ impacts are mostly connected to feed production. Typically impacts on climate (GWP) shows that fodder production is the highest contributors for broilers poultry. Manure is usually the most important item for Acidification Potential and Eutrophication Potential. All these factors can be improved by the adoption of proper diets (Kebreab et al., 2016).

Emergy evaluation has been applied to poultry showing that the efficiency of transforming solar energy from the photosynthesis of the fodder until the final output (inversely proportional to UEVs) is very similar in conventional and organic chicken or in favor of the conventional, depending on the location and technological level of the rearing system. Instead the level of renewability of the whole value chain is quite different: around 15% for conventional and between 38% and 50% for organic.

These results poses a fundamental question also on the reliability of the “functional unit”, usually a mass unit of chicken meat. When dividing all the inputs or impacts by the mass of chicken meat we assume that all the chicken meat is equal, implying an equality also of nutrient factors for humans. For example there is evidence that meat from pastured-based poultry may contain additional nutritional benefits such as lower fat content and higher vitamin and mineral contents (Sossidou et al., 2015). Also animal welfare can be very different according to the rearing system adopted.

It can be observed that in assessing agriculture productions, due to its user side perspective, LCA boundaries can be considered from “cradle to gate” where the cradle is the point of human intervention. Neglecting, in this way, the enabling role of the overall context and prerequisite for the production, namely the work of the biosphere. LCA cannot account for the “work” done by ecosystems in providing renewable resources needed for the agriculture value chain (such as sun, rain, wind, and earth heat). Renewable resources sustaining the agricultural production do not produce impact, it is why LCA do not assess their contribution. It can be maintained that LCA treats and assess all the production chains as if they were industrial processes neglecting that agriculture can take place thanks to the fundamental role of ecosystems. In addition, the large majority of LCA takes as a functional unit, the product itself, thus providing results in terms of potential impact based on the productivity for both agriculture in strict sense products (crops, fruit, vegetables) and the livestock (poultry, cattle). This approach leads to results (in the large majority of studies) for the product obtained from conventional practices with lower environmental burdens than the organic ones. In fact, by considering productivity as the guiding principle of production all the remaining aspects (such as quality) cannot be considered. Conventional production chains, in general, produces per unit of area, a larger amount of product and having a high denominator (production) leads to reduce the relevance of the numerator (total emissions).

Moreover, poultry production, like most agricultural and rearing productions, has the main product

(chicken meat) and co-products (chicken manure) to be carefully considered during the assessment. The majority of LCA evaluation uses allocation methods to break down input flows among products and co-products, even though the ISO discourages this practice. This fact introduces arbitrariness since the results of assessments can be very different according to the type of allocation adopted (Mondello et al., 2018).

Emergy evaluation, thanks to its donor side perspective, can account for both the biosphere and technosphere contribution for the same product and production chain; On the other side it does not account for the impacts of production systems. Thus, emergy evaluation can be considered as the ideal complement of LCA as sustainability indicator for any nature based production chain, e.g. agriculture, rearing, forestry and all the subsequent production systems. The unique ability of emergy evaluation in considering the contribution of renewable resources gives an insight into the quality of a product and, in particular, of agricultural/livestock products. If an agricultural product results in a high value of renewability it means that the amount of flow that sustains its chain from outside the system (F) is low, and the human contribution is lower compared to the biosphere ones. In addition, emergy evaluation can highlight the role of the context (territorial system) and benefit of the agricultural production by providing the amount of past and present solar energy per unit of area.

CONCLUDING REMARKS

In synthesis, it can be maintained that due to its systems perspective, emergy evaluation assesses the ultimate energy required for the production of agricultural productions enabling a proper and consistent assessment of the biosphere’s “work”, especially relevant when assessing the sustainability of agriculture/livestock production. On the other side, LCA has the ability to account for drawbacks to the biosphere due to a production chain whatever the nature of the production chain.

Nevertheless, as remarked by Bastianoni et al., (2008), the complexity and multiple nature of a system can be properly assessed and considered only by jointly using indicators that have complementary features. The joint use of emergy evaluation and LCA has been already proven to be a winning solution because the combined reading of their results provides a comprehensive assessment of environmental sustainability of the system under study.

REFERENCES

1. Alders R., F. Tomley, 2022. Animal Board Invited Opinion Paper: Planet, people and poultry - more and better data needed to get the balance right. *Animal*, 16, 100560.
2. Barbier E., 1987. The concept of sustainable economic development. *Environ Conserv* 14:101-110.
3. Bastianoni, S., Pulselli, F. M., Focardi, S., Tiezzi, E. B., Gramatica, P., 2008. Correlations and complementarities in data and methods through Principal Components Analysis (PCA) applied to the results of the SPIn-Eco Project. *Journal of environmental management*, 86(2), 419-426.
4. Daly HE, 1990. Toward some operational principles of sustainable development, *Ecol Econ* 2: 1-6.
5. ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework
6. ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines
7. E. Kebreab, A. Liedke, D. Caro, S. Deimling, M. Binder, M. Finkbeiner, 2016. Environmental impact of using specialty feed ingredients in swine and poultry production: A life cycle assessment. *Journal of Animal Science*, Volume 94, Issue 6, 2664–2681.
8. Mondello G., R. Salomone, E. Neri, N. Patrizi, S. Bastianoni, F. Lanuzza, 2018. Environmental hot-spots and improvement scenarios for Tuscan “Pecorino” cheese using Life Cycle Assessment. *Journal of Cleaner Production* 195 810-820.
9. Odum, H.T., 1996. Environmental accounting. *Emergy and Environmental Decision Making*. John Wiley & Sons, INC, p.370.

10. Pulselli F. M., L. Coscieme, L. Neri, A. Regoli, P. C. Sutton, A. Lemmi, S. Bastianoni, 2015, The World Economy in a cube: A more rational structural representation of Sustainability, *Glob Environ Chan* 35: 41–51.
11. Raugei, M., Rugani, B., Benetto, E., Ingwersen, W.W., 2014. Integrating emergy into LCA: potential added value and lingering obstacles. *Ecological Modelling*, 271, 4-9.
12. Sossidou, E.N., Castellini, C., Dal Bosco, A. and Grashorn M.A., 2015, Effects of pasture management on poultry welfare and meat quality in organic poultry production systems. *World's Poultry Science Journal*, 71, 375-384.
13. United Nations, 2015. Transforming our World: The 2030 Agenda for Sustainable Development
14. Ulgiati S., MT Brown, S Bastianoni, N Marchettini, 1995. Emergy-based indices and ratios to evaluate the sustainable use of resources. *Ecological Engineering*, 5, 519-531.

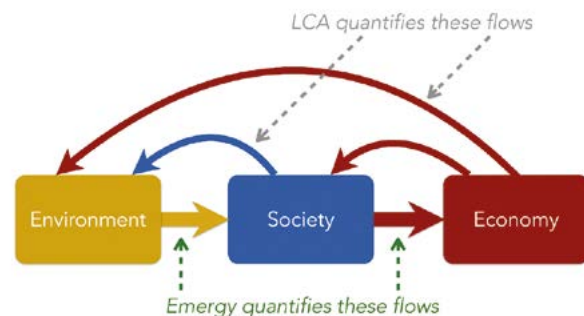


Figure 1. A consequential/logic view of sustainability. Dotted arrows show the area of interest of LCA and emergy evaluation.

Plenary session 2:

NUTRITION INTERVENTION FOR CLIMATE CHANGES

OBSERVATIONS ON WATER QUALITY AND QUANTITY FOR POULTRY

Susan E. Watkins

Center of Excellence for Poultry Science, University of Arkansas, Arkansas, USA

swatkin@uark.edu

Water is the single greatest nutrient input in poultry production. Yet due to its relatively inexpensive cost compared to protein or energy requirements, water quality has received little research attention since the introduction of nipple drinkers in the early nineties. Improved efficiencies in genetics, diets and environment plus the dominance of antibiotic free production models are all factors contributing to the need for poultry operations to implement water programs which monitor and control quality and quantity. Identify vulnerable points in water systems such as filters, storage, injection points and develop an action plan tailored to the operation which assures quality and quantity parameters remain acceptable for supporting cost efficient performance. Water management programs should include consistent testing from source to last drinker in the production system to assure water quality starts acceptable and remains acceptable. A thorough understanding of each operations water supplies, both quality parameters and water management tools like distribution pipes, storage tanks and drinker function, are the first steps in assuring water meets acceptable standards. Most water systems require some form of corrective action such as filtration, water softeners, system cleaning or consistent use of sanitizers to prevent factors that are detrimental to quality and quantity. Verification and documentation complete a successful water program. The biggest hurdle for operations with multiple production sites is to not become focused on a “one size fits all solution” but rather accept that all water supplies and systems are unique and efforts should be directed towards identifying and implementing programs that best fit the budget and situation. While solutions, particularly for mineral control or sanitation can be expensive, the costs are more often than not, are recouped by improvements in performance and bird health.

Over the years, the Center of Excellence for Poultry Science CORE Analytical Water Lab has analyzed thousands of poultry drinking water samples for mineral, pH and bacteria. Sampling areas have included sources, storage tanks, drinkers, and pre and post treatments. Regarding bird performance and these analyses, the following observations have been noted. Overall, birds are tolerant of average levels of most contaminants, well above the accepted standards. Exceptions to this include sodium and chloride levels which if over 200 ppm or mg/l (each or either) will cause loose droppings and levels greater than 400 ppm will impair weight gains, feed efficiencies and egg production. Sodium and chloride in the water can be compensated for by adjusting dietary sodium and chloride levels. Some breeds are more sensitive than others so work with your genetic company to determine appropriate dietary adjustments. Excessively high levels of salt in the water (>800 ppm) requires corrective action such as reverse osmosis or diluting the water supply with another source. The birds are fairly tolerant of iron, manganese or sulfate in the water but these are a concern due to the pathogenic bacteria which thrive when these nutrients are present in the water supply and allowed to build up in the distribution pipes, storage tanks or filters. The presence of these minerals increases the risk of *pseudomonas*, *Salmonella*, *E. Coli* and other pathogens. Along with these mineral contaminants, calcium and magnesium are a concern because of their tendency to create scale or mineral deposits in pipes causing volume restrictions. Scale issues can occur in any number of areas in water systems leading to a pinch point that causes inadequate water volume for the birds. Susceptible scale buildup points are regulators, bends in

pipes, pressure reducers, cool cell systems or distribution pipes. Iron, manganese and sulfates can be managed by oxidizing with an oxidizer such as chlorine or chlorine dioxide at the appropriate pH (>7), allowing retention time and then filtering. Hydrogen peroxide is often used as the oxidizer for sulfates because of the higher level required (2.7 to 1). to maximize the oxidation process for this mineral. Hydrogen peroxide does not create bitterness issues that are common with elevated uses of chlorine sources. Other common water issues include acid water. This water has virtually no dissolved minerals and a low pH, usually below 4. Water needs buffering capacity so this can be corrected by adding sodium bicarbonate or soda ash to the water to “neutralize it”. A last common challenge is failure to understand the natural buffering capacity of water in the form of how much alkalinity is present and attempting to lower the pH with organic acids that are not designed to decrease pH in the presence of elevated alkalinity. Organic acids are wonderful gut health and antimicrobial tools but they are weak acids which cannot lower the pH of water that has significant alkalinity. Adding more and more organic acid in the attempt to achieve a reduced pH when water has more than 150-200 ppm of alkalinity can lead to wasted product and water that may have an unacceptable taste for the birds.

The best advice about microbial contamination is NEVER assume the quality is acceptable. Verify microbial quality with consistent testing and monitoring. Regarding bacteria, poultry water supplies should have no coliforms or E. coli present and maintaining optimal microbial quality can become more difficult when there are more than 10,000 cfu/ml aerobic plate count bacteria (APC) present. This level of APC alone does not mean that water quality is bad, it's just an indicator that conditions are favorable for exponential increases in the bacteria present, including pathogens like *Bordetella*, *Staphylococcus*, or *Pseudomonas*. Unlike many human water supplies, poultry drinking water systems are more vulnerable to bacterial contamination rapidly increasing (1 E. coli can become trillions in 24 hours at 90 F) due to the presence of the previously mentioned minerals but also because of the slow flows, stagnant flow periods and pinch points that can harbor biofilm. Our greatest challenge as an industry is critically assessing how or when we add products to water supplies. We must do a better job of understanding the implications of vaccination programs as well as the use of organic acids, probiotics and nutraceuticals. What monitoring tools do we implement to assure these products are not sacrificing water quality leading to microbial blooms that create gut integrity or respiratory issues for vulnerable flocks? All of these factors interact with the naturally occurring water contaminants to create unique conditions that should be monitored for each operation.

Implementing consistent water sanitation has been one of the greatest accomplishments for water management in the industry in the last twenty years. Thorough cleaning of water systems when no birds are present is the critical step in assuring daily water sanitation programs are successful. This requires utilizing products at an appropriate concentration left adequate time to maximize the removal of the biofilm present without damaging the equipment. Inadequate concentration or cleaning time are both failures to the process. To determine what works best, swab water lines pre and post line cleaning (swab different lines) to quantify the presence of biofilm.

In the presence of birds, chlorination is still an excellent tool for controlling microbial contamination in drinking water but it has its limitations. It works best as hypochlorous acid and this form of chlorine is dominant when the water pH is 5-7. If water pH needs to be adjusted, separate acid injector from chlorine injector and assure the first product is thoroughly blended into the water prior to the second injection site. Otherwise, the acid may cause “gassing off” of the chlorine. Chlorine works best when the water is free of turbidity (suspended minerals), the water system is free of biofilm and the chlorine product is fresh and has been properly handled to minimize deterioration of chlorine residual. Adding more chlorine product to achieve a desired residual may result in bitter water that causes birds to drink less so be mindful of how much product is being added into the water, particularly the dry calcium hypochlorite sources that are often allowed

to slowly dissolve into the water stream. Chlorine dioxide works well at a higher pH (8 pH) but chlorine dioxide's sanitizing effect tends to be optimal when it is made onsite by using systems which force blend a clean (contaminant free) inorganic acid with sodium chlorite. This process maximizes the conversion of sodium chlorite to chlorine dioxide (60-80% conversion). Hydrogen peroxide and peracetic acid (PAA) have gained popularity as a daily water sanitizer, particularly the stabilized products which maintain an effective sanitizing residual in the water for extended periods of time, such as days. This is helpful for young flocks who do not move much water through the system. Regardless of what daily water sanitation program is implemented, take time to correlate a sanitizer residual with a confirmed level of microbes present in the water. Two ppm of chlorine means nothing unless there is some confirmation that 2 ppm of chlorine residual in the water is correlated with no bacteria present in the water sample. Then and only then, is the water sanitation monitoring program a success.

A discussion on water systems is not complete without a focus on monitoring water quantity. So many factors can impact how much available water is present for birds and there is no question, if birds do not have enough water, performance will suffer. Monitor throughout the system to assure adequate gallons or liters per minute are available. Confirm that the drinkers are delivering the appropriate amounts throughout the life of the flock. Use drinker manufacturers' guidelines for determining what should be available at each age or stage of production. Since we know one advantage to years of genetic selection is meat birds consume more feed and water faster, confirm that drinker flows are not too restrictive for young birds. Monitor filters to assure mineral buildup does not cause unnecessary reductions in flow. This problem is very common and easily overlooked. If barn filters must be frequently changed each flock, consider investing in filtration technology that can better handle the amount of contaminant and volume of water. Unless farm staff are very diligent in changing dirty filters, filtration upgrades almost always pay for themselves the first year due to better weight gains, feed conversions or egg numbers. Confirm that injection technology is appropriately matched to peak water demand. An undersized injector is an instant restriction point and it doesn't take flocks long to learn they have limited access to water so birds limit feed intake. Implement descaling procedures for water supplies with more than 80-100 ppm of calcium, magnesium, iron, sulfates and/or manganese and natural pH over 7.5. It is very likely this type of water has sediment scale buildup throughout the water distribution system which limits water supply. One last point, assure water temperature is never allowed to become warm. Even new chicks prefer cooler water over water that is similar to their body temperature. Water lines located under heaters may need flushing on a regular basis during the first few days to keep water temperature more palatable.

In conclusion, water is an essential nutrient that cannot be taken for granted when addressing quality and quantity. A consistent and thorough evaluation program is critical for assuring water supports optimal flock performance.

Plenary session 2:

NUTRITION INTERVENTION FOR CLIMATE CHANGES

FEEDING AND NUTRITIONAL STRATEGIES FOR COMMERCIAL POULTRY DEALING WITH CLIMATE CHANGE*Rajesh Jha and Birendra Mishra**Department of Human Nutrition, Food, and Animal Sciences, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, HI, USA**rjha@hawaii.edu***EFFECTS OF CLIMATE CHANGES ON POULTRY HEALTH AND PRODUCTION**

The earth's average temperature has risen 1.1 to 1.6°F over the past century and is projected to rise another 0.5 to 8.6°F over the next hundred years (Lenssen et al., 2019). Climate change is a global issue affecting livestock production, including poultry. Climate change directly affects poultry production through heat stress and indirectly by promoting an environment for diseases. Among the livestock species, poultry is more prone to heat stress because of higher body temperature, the presence of feathers, and the absence of sweat glands. Heat stress is one of the major environmental stressors in the poultry industry, resulting in a substantial economic loss by altering the poultry's health and production. Due to a higher metabolic rate, they produce more body heat and cellular free radicals and are prone to heat stress. Heat stress significantly decreases feed intake and body weight and increases the feed conversion ratio (FCR) in broilers (Wasti et al., 2021). Heat stress negatively affects feed intake, body weight, and egg production in laying hens (Wasti et al., 2020). Hens under heat stress had higher cortisol levels, reduced estradiol and progesterone levels, and induced ovarian follicular atresia, reducing ovulatory follicles and egg production (Li et al., 2020). Hens under heat stress also displayed panting to reduce body temperature resulting in respiratory alkalosis. The elevated blood pH causes poor bioavailability of calcium for eggshell biomineralization, resulting in poor eggshell quality. Heat stress negatively affects gut health, including altering the morphometric of the gastrointestinal tract, cecal volatile fatty acid production, and expression of heat shock, antioxidant, immune, and tight junction-related genes (Wasti et al., 2021). Exposure to a high temperature negatively impacts the poultry's intestinal microbial ecology, specifically by decreasing the species' abundance (Rostagno, 2020; Wasti et al., 2021), affecting poultry performance.

STRATEGIES TO MITIGATE THE ADVERSE EFFECTS OF HEAT STRESS

Climate change due to global warming is a threat to the poultry industry. Because of heat stress, the poultry industry faces increased production costs, severely altering the meat and egg quality. Many studies have revealed that high environmental temperature causes oxidative stress by producing excessive reactive oxygen species (ROS) and decreasing cellular antioxidants (Mishra and Jha, 2019). Previous studies in poultry have shown that heat stress is associated with cellular oxidative stress. The oxidative stress in poultry is associated with severe health disorders, poor growth performances, and economic losses. As oxidative stress is downstream of heat stress on poultry health and production, several feeding and nutritional strategies have been implemented to mitigate heat stress-induced oxidative stress in poultry.

Feeding strategies for mitigating heat stress

Feeding strategies like restricted feeding, wet or dual feeding, and adding fat to diets have been widely studied and found to reduce the deleterious effects of heat stress (Wasti et al., 2020). Restricted feeding during the hotter period of the day reduces the metabolic rate of birds. Feed restriction reduces rectal temperature, minimizes mortality, and decreases abdominal fat in

heat-stressed broilers and layers. As this approach results in a reduced growth rate and delayed marketing age of the birds, it is not widely practiced in the poultry industry. Feed restriction results in overcrowding and rush at a re-feeding time, resulting in additional mortality. Thus, the dual feeding regime ensures that birds can feed throughout the day. The thermic effects of proteins are higher than carbohydrates and produce higher metabolic heat. Therefore, the protein-rich diet is provided during the cooler period, and the energy-rich diet during the warmer period to reduce body temperature and mortality in the heat-stressed broilers.

Due to heat stress, birds lose water through respiration, and water intake is markedly increased to restore thermoregulatory balance (Wasti et al., 2020). Wet feed also reduces viscosity in the gut resulting in the faster passage of the feed. Wet feeding promotes digestion, improves the absorption of nutrients from the gut, and accelerates the action of the digestive enzyme on the feed. In broilers, wet feeding enhanced the feed intake, body weight, and weight of the gastrointestinal tract (GIT). In laying hens, wet feeding increases dry matter intake, egg weight, and egg production (Li et al., 2020). Although this approach is beneficial in managing heat stress, it is less common among poultry producers due to the risk of fungal growth in the wet feed.

Higher energy diets (fats) produce lower heat increment during metabolism than protein and carbohydrates. Fat supplementation in the poultry diet increases nutrient utilization in the GIT and also helps to increase the energy value of the other feed constituents and increase feed intake in heat-stressed broilers and layers. Essential oil supplementation in the diet relieved the negative effects of chronic heat stress on broiler and layer's performance.

Nutritional strategies in mitigating heat stress**Supplementation of Electrolytes and Osmolytes**

Panting in heat-stressed birds alters the blood plasma's acid-base balance, ultimately leading to respiratory alkalosis. In heat-stressed birds, sodium and potassium supplementation is favored to increase the blood pH and HCO_3^- . Supplementation of NaHCO_3 improved eggshell quality in layers and growth performances in broilers during heat stress. Besides including these salts in the diet, supplementation of 0.2% NH_4Cl or 0.15% KCl, 0.6% KCl, 0.2% NaHCO_3 , and carbonated water in drinking water also improved the performance of the heat-stressed broilers.

Osmolytes such as Betaine and Taurine are widely used in the poultry diet to alleviate the heat stress effects. Betaine plays a vital role in regulating the cellular osmotic environment, preventing dehydration by increasing the water-holding capacity of the cell. During heat stress, betaine supplementation improved poultry's feed intake, carcass trait, and egg production parameters. In laying hens, supplementing betaine and vitamin C improved laying performance during chronic heat stress. In roosters, betaine supplementation improved sperm concentration and livability, seminal plasma total antioxidant capacity, fertility, and welfare under heat stress.

Taurine plays a role in antioxidant action, bile acid conjugation, maintenance of calcium homeostasis, osmoregulation, and membrane stabilization. Supplementation of taurine in the drinking water demonstrated significant improvement in the final body weight of chronic heat-stressed broilers. Supplementation of taurine in broilers under heat stress improved jejunal morphology, decreased serum ghrelin concentrations, increased somatostatin, and peptide concentrations YY in the duodenum, and increased the expression of appetite-related genes. In addition, taurine supplementation in the laying hen enhanced oviductal health.

Supplementation of Vitamins and Minerals

Vitamins are essential to the poultry diet due to their health benefits, including growth performance, enhancing immunity, and alleviating oxidative stress. During heat stress, birds cannot synthesize enough vitamins. Therefore, supplementation of specific vitamins (vitamin -E, -A, and -C) as an antioxidant in poultry diet is beneficial in mitigating heat stress effects on broilers' and layers' health and performances. Vitamin A is the most effective antioxidant at low oxygen tensions,

which is found to reduce singlet oxygen, neutralize thiyl radicals, and combine with and stabilize peroxy radicals. Vitamin E is a fat-soluble vitamin with antioxidant activity and helps scavenge free radicals produced inside the cell. Vitamin E regulates inflammatory signaling, and the production of prostaglandins, cytokines, and leukotrienes and improves the phagocytic activity of macrophages in broiler chickens. Vitamin C protects against oxidative stress by scavenging ROS and protecting cells from oxidative damage. Vitamin C also improves immunity by enhancing the differentiation and proliferation of T and B cells. One of the major consequences of heat stress is an increase in mineral excretion and a lowering of these key nutrient levels in the circulating bloodstream and liver. Supplementation of Zinc, Chromium, and Selenium in poultry diet is highly beneficial in maintaining the redox system, birds' performance, and product quality.

Supplementation of Phytochemicals

Phytogenic feed additives have been reported to alleviate the negative consequences of heat stress. Phytochemicals, such as Lycopene, Resveratrol, Epigallocatechin gallate (EGCG), Curcumin, dried plum (DP), and microalgae, have been studied in poultry under heat stress (Wasti et al., 2020; Mullenix et al., 2021). Supplementation of lycopene in heat-stressed broilers improved the cumulative feed intake, body weight, and FCR. Lycopene improved the level of antioxidant enzymes such as superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) in broilers. In laying hens, dietary lycopene supplementation improved oxidative status, enhanced egg vitamin levels, and improved the egg's oxidative stability and yolk color.

Supplementation of resveratrol improved the average daily gain, decreased the rectal temperature, and lowered the level of corticosterone, adrenocorticotropin hormone, cholesterol, and MDA in yellow-feather broilers under heat stress. Resveratrol also improved gut health parameters such as microbial profile, villus-crypt structure, and expression of the tight junction and adherence junction-related genes in the heat-stressed broilers. In laying hens, resveratrol supplementation improved egg production, reduced the total serum cholesterol and triglycerides, reduced egg cholesterol content, improved antioxidant activity, and improved egg sensory scores. The EGCG is the polyphenol in green tea extract with high antioxidant and anti-inflammatory properties. EGCG supplementation increased body weight, feed intake, serum total protein level, glucose, and alkaline phosphatase activity in heat-stressed birds. Also, dietary inclusion of EGCG improved body weight and antioxidant enzymes (GSH-Px, SOD, and catalase) in the liver and serum of heat-stressed broiler birds.

Curcumin is the primary polyphenol extracted from turmeric and possesses antioxidant and anti-inflammatory properties. Curcumin supplementation improves the growth performance of heat-stressed broiler chickens. Curcumin fortification reduced the mitochondrial MDA level; reduced the ROS production by increasing the activity of Mn-SOD, GSH-Px, Glutathione S-transferase and increased gene expression of thioredoxin-2 and peroxiredoxin-3 during heat stress in broilers. In laying hens, dietary curcumin supplementation improved the laying performance, egg quality, antioxidant enzyme activity, and immune function during heat stress.

Dried plum contains a higher amount of antioxidants (fat-soluble carotenoids, alpha-tocopherol, etc.), polyphenolic compounds (chlorogenic acids, proanthocyanidins, etc.), sorbitol, and fibers. DP is a good source of several vitamins (vitamins A, C, K1, B1, B2, and niacin) and minerals (Ca, K, Mg, Se, and Zn). Besides its antioxidant role, DP has several beneficial effects on gut health, calcium metabolism, and immune function. The dietary supplementation of DP significantly improved the body weight, average daily gain, average feed intake, FCR, ileum histomorphology, cecal VFA production, and expression of heat shock, antioxidant, immune, and tight junction related genes in the heat-stressed birds. Moreover, DP also improved the relative abundance of beneficial bacteria in the chicken gut (Wasti et al., 2021). Thus, considering the benefits, the dietary supplementation of DP can be considered as a potential strategy to mitigate the adverse effects of heat stress in poultry.

Microalgae (*Spirulina platensis*) is rich in antioxidants and have several health benefits. The dietary supplementation of microalgae significantly improved the body weight, average daily gain, average feed intake, FCR, ileum histomorphology, cecal VFA production, and expression of heat shock, antioxidant, immune, and tight junction-related genes in the heat-stressed birds (Mullenix et al., 2021, unpublished data from our lab). Gut microbial metagenomics showed a higher alpha diversity in the heat-stressed birds supplemented with microalgae (unpublished data from our lab).

CONCLUSION AND FUTURE DIRECTION

Because of climate change, the detrimental consequences of heat stress on poultry health and production will likely continue. Commercial poultry breeds cannot withstand heat stress, resulting in substantial economic losses to the industry, which triggers food security issues. Therefore, there is a critical need to develop heat-tolerant breeds and feeding and nutritional strategies to minimize the adverse effects of heat stress on poultry production.

REFERENCES

1. Lenssen, N, Schmidt G, Hansen J, Menne M, Persin A, Ruedy R, and Zyss D, (2019). Improvements in the GISTEMP uncertainty model. *Journal Of Geophysical Research-Atmospheres* 124 (12) 6307-6326.
2. Li GM, Liu LP, Yin B, Liu YY, Dong WW, Gong S, Zhang J, Tan JH. Heat stress decreases egg production of laying hens by inducing apoptosis of follicular cells via activating the FasL/Fas and TNF- α systems (2020). *Poultry Science* 99(11):6084-6093.
3. Mishra B, and Jha R. (2019). Oxidative stress in the poultry gut: Potential challenges and intervention. *Frontiers in Veterinary Science*, section Animal Nutrition and Metabolism. *Frontiers in veterinary science in Animal Nutrition and Metabolism section*; 6: 60.
4. Mullenix GJ, Greene ES, Emami NK, Tellez-Isaias G, Bottje WG, Erf GF, Kidd MT and Dridi S (2021). *Spirulina platensis* inclusion reverses circulating pro-inflammatory (Chemo)cytokine profiles in broilers fed low-protein diets. *Frontiers in Veterinary Science* 8:640968.
5. Rostagno MH. Effects of heat stress on the gut health of poultry. *Journal of Anim Science*, 98(4).
6. Wasti S, Sah N, and Mishra B. (2020). Impact of heat stress on poultry health and performances, and potential mitigation strategies. *Animals*, 10, 1266.
7. Wasti S, Sah N, Singh AK, Lee CN, Jha R, and Mishra B. (2021). Dietary supplementation of alpha-lipoic acid mitigates the negative effects of heat stress in broilers. *PLOS ONE* 16(7): e0254936.
8. Wasti S, Sah N, Singh AK, Lee CN, Jha R, and Mishra B. (2021). Dietary supplementation of dried plum: A novel strategy to mitigate heat stress in broiler chickens. *Journal of Animal Science and Biotechnology* 12:58.

Plenary Session 3:

NUTRITION AND MICROBIOME UNDER CHALLENGING CONDITIONS

NUTRITIONAL AND FEEDING STRATEGIES FOR ANTIBIOTIC-FREE POULTRY PRODUCTION

Edgar Orlando Oviedo-Rondón

Prestage Department of Poultry Science, North Carolina State University, Raleigh, NC

eooviedo@ncsu.edu

INTRODUCTION

Antibiotic-free (ABF) poultry production has multiplied worldwide. The motives are different in each country or region. They can vary between governmental regulations as a precaution for antimicrobial resistance, local consumer pressure, or the exportation of poultry products to countries with regulations for foodstuffs free of antibiotics or its metabolites. In some areas of the world, ABF is still difficult to accept for some poultry producers, technical personnel, and farmers. But some poultry companies in many countries voluntarily decided to produce without antibiotic growth-promoters (AGPs) two decades ago. Several producers can already claim successful ABF production. However, reaching productivity, health, livability, food safety, and environmental impacts similar to conventional systems with AGPs is still a challenge for many. Data from AgriStats (the largest benchmarking company in the USA) indicates a clear gap in productivity aspects between ABF programs and traditional production systems.

On the other hand, it is also important to remember that AGPs have not always been effective in preventing diseases, even when applying high dosage rates of AGPs and ionophores or adding combinations of multiple products. In some farms, gut and respiratory health issues are frequent independently of using AGPs, ionophores, chemical coccidiostats, or alternative feed additives. The evidence indicates that the feed additive *per se* is not the solution to some potential performance and health issues primarily related to feed and water quality, housing infrastructure, environmental stress, and management. Bacterial and mycoplasma resistance to certain antibiotics (Nhung *et al.*, 2017) and *Eimeria* resistance to some coccidiostats (Chapman and Rathinam, 2022) were already evident in many areas of the world decades before ABF became popular. Consequently, transitioning to ABF systems could also be considered an alternative to more sustainable and efficient production for those who have not yet done so.

There are several categories of ABF production around the world. A standard label Certification used by many poultry producers worldwide is raised without antibiotics (RWA) because birds may receive antibiotics *in ovo* or at hatch with vaccines. In the USA, ionophore coccidiostats are classified as AGP, and consequently, not even those ionophore products are used as feed additives in some of these ABF programs. The American industry has voluntarily chosen to grow more than half of the broilers in systems targeting the requirements of the "No-Antibiotics-Ever" (NAE) label description regulated by the US Department of Agriculture (USDA). Nevertheless, when diseases happen, and birds need to be treated, these flocks are not sold with this label. The NAE production is more challenging to maintain, and total production costs are higher than ABF. However, these NAE systems keep growing in the USA (Figure 1) in the total number of chickens produced (Rennier Associates Inc., 2022; AgriStats, 2023). However, there is some seasonality in the number of flocks that finish in this NAE program.

ACHIEVING SUSTAINABLE ABF PRODUCTION

Changing to ABF programs depend on a decision related to the withdrawal of feed additives. But it is already proven by experience in many companies that maintaining similar productivity, poultry health and welfare, and food safety requires multiple interventions in the production system (Smith, 2011, 2019). This presentation is focused on nutritional and feeding strategies. However,

the first take-home message is that, independently of all improvements we can make in nutrition, feed manufacturing, and feeding, they will not be enough to achieve optimal ABF production. Breeder intestinal health and enhanced maternal immunity, optimum incubation practices, improved housing infrastructure, proper ventilation, optimum house environmental control, management, frequent disposition of mortality, biosecurity, effective vaccination programs, and water quality are also fundamental to achieving sustainable ABF systems.

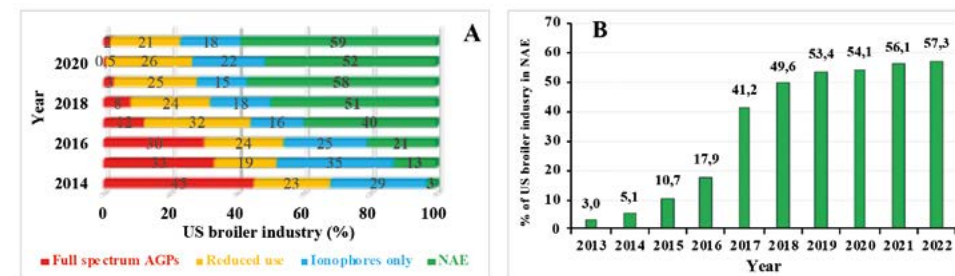


Figure 1A Distribution of the US broiler industry according to marketing program with either full use of all antibiotic growth-promoters (AGPs), reduced use, use of only ionophores or Non-Antibiotics Ever (NAE), (Source: Rennier Associates Inc., May 2022). **B.** Percentage of the US broiler industry production raising under NAE programs (Source: AgriStats Inc. 6510 Mutual Dr, Fort Wayne, IN 46825).

The reduction in AGP use is easy to obtain by withdrawing or restricting the use of specific products. Still, many times fails to minimize the use of molecules that could increase multi-antimicrobial resistance. For example, Nunan (2022) reported that in the United Kingdom, the British Poultry Council reported that the use of medically-important antibiotics reduced by 85% between 2013 and 2017 from 94 tons to 14 tons. In contrast, the use of ionophores increased from 209 tons to 281 tons in the same period, causing the overall antibiotic use to barely change in the same period. Higher use of ionophores in the UK (265 tons in 2019) is related to a higher incidence of gut health problems, necrotic enteritis, and coccidiosis. The lack of AGPs did not cause these issues. They are due to prevalent feed, housing, biosecurity, and litter management problems that should be controlled with other strategies (Smith, 2011, 2019; Cervantes and McDougald, 2023).

It is observed worldwide that despite having the best housing infrastructure and management practices, there is a seasonality in poultry health issues and productivity. The seasonal effect could depend on the weather but may be related to higher stocking density forced by market conditions or chicks of lower quality from eggs stored for a long time. In the USA, AgriStats reports indicate that between January and March, flock livability decreases. The calorie conversion to meat worsens, and the days to reach the target weight for processing increase in the same period. The seasonality is similar in traditional, ABF, or NAE programs, but the harmful effects are generally worst in NAE flocks. This data and observations worldwide provide clear evidence that nutrition and feeding cannot always mitigate these problems. But, nutritional and feeding strategies should consider seasonalities.

On the other hand, water, the most essential nutrient, can modify the animal response to any diet. The nutritionist should keep in mind the effects of water availability, temperature, physicochemical properties, and microbiological quality. In specific farms and regions, water factors could be the leading cause of eventual gut health issues, and no feed intervention can solve them completely. Adding probiotics, prebiotics, essential oils, organic acids, electrolytes, minerals like copper sulfate, and vitamins to the water lines for several days may cause clogging, increased algae and bacteria, and damage water equipment. These products should be included in the feed.

NUTRITIONAL AND FEEDING STRATEGIES

Poultry flocks raised in ABF programs have potentially more microbial and immunological challenges, dysbiosis, and mucosal inflammation. The protein turnover and energy needs are potentially higher. Therefore, from the nutritional standpoint, it is vital to enhance gizzard and intestinal development early in life, stimulate an early development of a healthy gut microbiome, and minimize contamination and development of pathogenic bacteria and protozoa. The following are critical nutritional and feeding points to consider in ABF production.

FEED FORMULATION

- Design a feeding program with more dietary phases but avoiding changes near the peaks of coccidia infection or age periods with the most common management stress or dysbiosis events.
- Select ingredients with higher digestibility, a lower potential to increase gut viscosity, and minor risks of Clostridial or Salmonella contamination, especially in the pre-starter and starter diets. This generally means lower inclusion of animal-origin feedstuffs and more vegetarian diets.
- Avoid protein excess, but guarantee optimum levels of essential amino acids by using more crystalline sources.
- Include descriptive fiber parameters like ADF, insoluble, and soluble fiber in the feed formulation matrix. Implement a minimum level of ADF or insoluble dietary fiber (minimum of 2% and maximum of 3%) and a maximum of soluble fiber (no more than 20 to 30% of total dietary fiber). The ADF/NDF ratio in the feed should be kept at a minimum of 0.37 to achieve optimum gut development, nutrient digestibility, and performance (Nursiam *et al.*, 2022).
- Account for all calcium sources in the diet and limit its inclusion to requirement levels.
- Keep a dietary electrolyte balance (Na+K – Cl) between 200 and 250 mEq/kg and adjust depending on water mineral content.

FEEDSTUFF QUALITY

- Improve description of feedstuff energy values, nutrient digestibility, and nutrient and antinutrient contents using rapid methods like the NIRS calibration models available and identify its variability.
- Control fungi and mycotoxin contamination and insect infestation in the whole system.
- If possible, use fat sources with better digestibility rich in medium-chain fatty acids (lauric, caprylic, and capric) like palm kernel oil, coconut oil, or even insect oil.
- Avoid rancidity in all ingredients rich in fatty acids (peroxide values ideally max. 5-10 mEq O₂/kg, TBARS 2-3 mg MDA/kg, and p-Anisidine value below 5).
- Limit the inclusion of soybean sources with trypsin inhibitor levels higher than 4.5 mg/g, and avoid overprocessed soy products.
- Select or request soybean meal with a geometric mean particle size (d_{gw}) of a minimum of 900 mm (minimize particles lower than 250 mm or higher than 1,700 mm).
- Choose trace minerals with higher bioavailability. Organic Zn, Cu, and Mn bring health benefits.

FEED ADDITIVE SELECTION

- Seed the gut with probiotics and prebiotics, including these products in pre-starter and starter diets.
- Include exogenous enzymes according to substrate concentration to improve digestibility or minimize antinutrient effects. All diets may benefit from phytase at higher levels and xylanase.
- Use additives to modulate gut microbiota and have anti-inflammatory properties like plant extracts, essential oils, polyphenols, and higher levels of vitamins A, E, D, and C, especially in the seasons with a higher incidence of health outbreaks.
- Provide gut mucosa integrity with butyric acid, mycotoxin binders, or detoxifiers.

- Emulsifiers, lipotropic, and bile salts may play a role in protecting liver function.
- Establish an effective coccidia control program according to the ABF program selected (Smith, 2019; Cervantes and McDougald, 2023).

FEED MANUFACTURING

- Grind ingredients coarse targeting a minimum d_{gw} of 700 mm for starter diets, 850 mm for grower diets, 1,000 for finisher diets, and at least 1,250 for breeders and layers. But, minimize variability (S_{gw}) in particle distribution and particles smaller than 250 mm for broilers and 500 mm for hens.
- Try the inclusion of whole grains. Positive results have been observed, including between 5 to 15% whole wheat (Sadati *et al.*, 2022) and 2.5 to 5% whole corn (Ovi *et al.*, 2021) in pelleted diets.
- Use physical or chemical methods to decrease bacterial load in feed (Huss *et al.*, 2018).
- Avoid pelleting temperatures higher than 90°C to minimize deleterious Maillard reactions.

FEEDING PRACTICES

- Try to increase feeding phases to meet nutrient needs closely and avoid nutrient intake excess.
- Maximize feed intake during the first hours post-placement using additional lights or higher intensity near feeders, paper on the floor, and supplemental feeders.
- Consider using control feeding programs or intermittent lighting programs to slow down feed intake and improve crop retention time and foregut digestion.
- Control house feed inventories to avoid periods of feed withdrawal.

MISSING KNOWLEDGE The nutritional concepts needed to improve poultry nutrition in general but essential to improve ABF production are 1) the kinetics of starch and protein digestibility; values of rapid and slow starch digestion, resistant starch, damaged starch, and amylose-to-amylopectin ratios to apply them in feed formulation; 2) Optimum values of starch and fiber parameters; 3) Net energy values for each feed ingredient and feeding phase; 4) Digestible calcium values; 5) More accurate NIRS curves to predict digestibility and energy values; and 6) True protein for feed formulation.

CONCLUSIONS

The nutritional and feeding strategies can be planned to address the challenges observed in ABF and NAE production. However, breeder, hatchery, infrastructure, and husbandry interventions are necessary. Diet formulation, feedstuff quality, additive selection, and feed manufacturing should be targeted to maximize gizzard and intestinal development, stimulate a healthy microbiome, minimize contamination and infection, and maintain gut physiology. Feeding practices can aid in minimizing issues of early feed intake and fast feed intake later on.

REFERENCES

1. Cervantes, H.M., and L.R. McDougald, 2023. Raising broiler chickens without ionophore anticoccidials. *J. Appl. Poult. Res.* 100347. doi.org/10.1016/j.japr.2023.100347
2. Chapman, H.D., and T. Rathinam. 2022. Focused review: The role of drug combinations for the control of coccidiosis in commercially reared chickens. *Int. J. Parasitol.: Drugs Drug Resist.* doi.org/10.1016/j.ijpddr.2022.01.001
3. Huss, A., R. Cochrane, C. Jones, and G. G. Atungulu. 2017. Physical and chemical methods for the reduction of biological hazards in animal feeds. *Food and Feed Safety Systems and Analysis*, pp. 83–95. doi: 10.1016/B978-0-12-811835-1.00005-1
4. Nhung, N.T., N. Chansiripornchai, and J. J. Carrique-Mas. 2017. Antimicrobial resistance in bacterial poultry pathogens: a review. *Front. Vet. Sci.* 4: 126. doi.org/10.3389/fvets.2017.00126

5. Nunan, C., 2022. Ending routine farm antibiotic use in Europe. Achieving responsible farm antibiotic use through improving animal health and welfare in pig and poultry production. https://www.saveourantibiotics.org/media/2019/report_ending-routine-farm-antibiotic-use-in-europe_final_january2022-1.pdf
6. Ovi, F. K., C. Bortoluzzi, T. J. Applegate, C. R. Starkey, K. S. Macklin, A. Morey, and W. J. Pacheco. 2021. Effects of prepelleting whole corn inclusion on broiler performance, intestinal microbiota, and carcass characteristics. *J. Appl. Poult. Res.* 30(2): 100114. doi.org/10.1016/j.japr.2020.100114
7. Sadati, M. M., V. Rezaeipour, and R. Abdollahpour. 2022. Efficacy of whole wheat grain in combination with acidified drinking water on growth performance, gizzard development, intestinal morphology, and microbial population of broiler chickens. *Livest. Sci.* 259: 104911. doi.org/10.1016/j.livsci.2022.104911
8. Smith, J. A., 2011. Experiences with drug-free broiler production. *Poult. Sci.* 90(11): 2670-2678. doi.org/10.3382/ps.2010-01032
9. Smith, J. A. 2019. Broiler production without antibiotics: United States field perspectives. *Anim. Feed Sci. Technol* 250: 93-98. doi.org/10.1016/j.anifeedsci.2018.04.027

Plenary Session 3:

NUTRITION AND MICROBIOME UNDER CHALLENGING CONDITIONS

DISENTANGLING THE EFFECTS OF FEED COMPOSITION ON THE CONSEQUENCES OF COCCIDIA INFECTION IN BROILERS

*Ilias Kyriazakis**Institute for Global Food Security Queen's University, Belfast UK**i.kyriazakis@qub.ac.uk*

Concerns about the sustainable control of coccidiosis in broilers have renewed efforts towards understanding the effect of nutrient resources on the consequences of the infection. Currently, however, there is some confusion about how to feed infected birds during the course of (subclinical) infection and what to expect from it. It is suggested that this confusion arises from the lack of consideration of the time scale of the infection and its consequences. We have found it useful to investigate these effects by dividing the infection into its **prepatent, acute and recovery phases**. During the **prepatent phase** of infection (first 3-5 days) infected and uninfected birds respond identically to feed composition. The main effects of coccidiosis occur during the **acute phase** which lasts approximately for 7 days. During this phase feed intake is reduced (anorexia), and nutrient resource digestibility and utilization decline. Investigations into the effects of nutrient resources (feed energy and protein contents) during this phase suggest that through the reductions in feed intake, birds seem to target a nutrient resource intake, which appears to be beneficial for infection outcomes, while at the same time they avoid excess protein intake. The consequence of this is that through dietary manipulation the extent of anorexia can also be manipulated and resistance to infection can be enhanced, as the number of coccidia oocyst excreted can be reduced. Finally, there is consistent evidence that during the **recovery phase** of the infection, birds benefit from feeds of high nutrient content, such as CP or amino acids, which allow for catch up growth. Depending on feed composition the catch up growth can be complete or incomplete. It is suggested that by looking at the different phases of the coccidia infection, the effects of feed composition on the infection and its consequences can be disentangled.

Plenary Session 3:

NUTRITION AND MICROBIOME UNDER CHALLENGING CONDITIONS

FEEDING THE MICROBIOME

Richard Ducatelle, Evy Goossens, Venessa Eeckhaut & Filip Van Immerseel

Livestock Gut Health Team
 Faculty of Veterinary Medicine
 Ghent University, Belgium
 richard.ducatelle@ugent.be

INTRODUCTION

Bacteria have been on this planet for millions of years before the vertebrates evolved. Thus vertebrates emerged in a world that was already conquered by the microbes. When considering the animals microbiome, we are thus looking at millions of years of coevolution. It is therefore not surprising that the interactions between both kingdoms are extremely complex. When considering, however, that the building blocks of a bacterial cell (i.e. amino acids, nucleic acids, lipids, trace minerals, etc) are remarkably similar to the building blocks of an animal or a human cell, it can be inferred that both bacteria and higher organisms compete for the same nutrients. In order to avoid such competition, absorption of nutrients in higher organisms occurs in a secluded space, namely the intestinal tract. Indeed, in the small intestine, where the actual digestion and absorption takes place, a large spectrum of control mechanisms keeps the density of bacteria remarkably low, mostly below 10^3 per gram. In the caeca of birds and in the caecum and colon of mammals, however, bacteria are not only tolerated but even they are supported and fed by the host, through the secretion of large amounts of mucins. These mucins are used as nutrient source by specialized bacterial species such as *Akkermansia muciniphila*, which cross-feed to other bacterial species in order to preserve the individuals core microbiome during episodes of starvation (Such et al., 2019). When feed is available, most of the digestible fraction is absorbed in the small intestine, thus leaving only the undigestible fraction for the microbes that live in the lower intestinal tract. Expansion of the microbial population in the small intestine, especially in the duodenum and jejunum, is inhibited by powerful host antibacterial defense mechanisms which include not only specific anti-bacterial peptides and proteins, but also non-specific inhibiting substances such as the acid produced in the proventriculus. The latter can be bactericidal but it can also induce the 'viable-but-non-culturable-state' (Geirnaert et al., 2014), allowing bacteria to pass through the small intestine in a metabolically inactive state.

MICROBIOTA OF THE LOWER INTESTINAL TRACT AND THEIR NATURAL SUBSTRATES

In the lower intestinal tract of poultry, there appears to be a specific spatial distribution of microbial families and functions, with members of the Lactobacillaceae family dominating in the ileum at densities up to 10^9 active bacteria per gram, and the Oscillisporaceae (formerly: Ruminococcaceae) and Lachnospiraceae families making up the majority of the bacteria in the caeca, which has an even denser population of 10^{11} bacteria per gram (Rychlik, 2020). Members of the Lactobacillaceae and Oscillospiraceae families and of the Bacteroidota phylum are involved in the primary degradation of the undigestible fraction of the feed, which is largely composed of non-starch polysaccharides (NSP) from the cell walls of plant cells. The NSP fraction of feed has been neglected for a long time in animal nutrition research, first of all because it is undigestible and thus often considered as a 'filler', and secondly because the analytical techniques for accurately determining their composition are lacking. This has changed in the last decades (Knudsen, 2001). The NSP fraction of most chicken feed formulas is composed of complex arabinoxylans, beta-glucans, mannans and cellulose, which

often form dense and intertwined networks of mostly insoluble fiber. It is therefore not surprising that the breakdown of these fibers for use as microbial nutrients requires the concerted actions of many different microbes. Additional substrates for the microbiota in the caeca are proteins from the host (from secreted enzymes and detached cells) and uric acid (by antiperistaltic waves ascending from the cloaca) which constitute important nitrogen sources. Many of the intermediate metabolites and even more so the end metabolites of microbial fermentation are taken up by the host mucosa through a receptor-mediated process. They constitute a source of energy (such as the short chain fatty acids) and a source of signals informing the host about the prevailing conditions in the intestinal tract. They are also an source of B-vitamins. Positive signals such as butyrate and propionate will have beneficial effects on the intestinal mucosal architecture and function, whereas negative signals such as hydrogen sulfide will cause epithelial damage.

DYSBIOSIS

Today's feed formulas for broilers are characterized by a very high energy and protein density, which is needed to fulfill the ever increasing requirements of broiler breeds which have been selected since more than half a century for high feed intake. The ingredients used in these formulas are derived from high yielding crops with a relatively low and variable NSP content. By feeding broilers in this way, we unintentionally starve the microbiome of their lower intestinal tract. In addition, high performing broilers require feed with a high density of essential nutrients such as essential amino acids. Since an 'all vegetable' diet usually has a certain degree of amino acid imbalance, the feed formulas usually contain excess protein used to compensate for certain essential amino acid deficits. This may lead to incomplete digestion and absorption of the protein fraction, with ensuing excess protein entering the caeca. This is one of the main triggers of a shift in the caecal microbiota composition, commonly denominated dysbiosis. Dysbiosis is worse when pathogens, such as *Eimeria acervulina* or *Eimeria maxima* disturb the digestion and absorption of nutrients in the small intestine. It can get worse also in case of feed formulas containing poorly digestible ingredients or in case of poorly available nutrients due to the 'caging' effect. Dysbiosis is characterized not only by a shift in the microbiota, but also by increased permeability of the intestinal barrier and inflammation (Ducatelle et al., 2023). The microbiota shift typically shows a dramatic reduction in butyrate producers, usually accompanied by an expansion of the phylum of the Proteobacteria. The inflammation which accompanies the dysbiosis triggers further damage to the mucosal barrier, thus initiating a vicious circle of mucosal leakage, inflammation and microbial imbalance, which ultimately may increase the moisture content of faeces and cause wet litter. When the situation has degraded to that point, however, it is difficult to revert it and performance losses can be considerable. Therefore, efforts are made to support the microbiota in the lower intestinal tract of broilers from the start. Hereafter, an overview is given of the currently available tools to support (feed) the microbiome.

FEEDING THE MICROBIOME THROUGH INGREDIENT CHOICE

The undigestible (NSP) fraction of the raw materials used to formulate the feed is the natural substrate for the microbiota in the lower intestinal tract. It is difficult, however, to steer the microbiota through selecting specific ingredients for the feed formula, because the NSP fraction in the ingredients is variable and the analytical techniques available for routine analyses of NSP are insufficiently refined to allow prediction of the effects on the microbiota. Moreover, ingredient choice is meant to cover the primary nutritional needs of the birds and the NSP fraction just comes with it.

FEEDING THE MICROBIOME USING ENZYME SUPPLEMENTS

The immature microbiome of young broilers usually is established rather slowly and late during the

rearing process (Rychlik, 2020). Especially many of the primary degraders of fiber (e.g. Bacteroidota) may be lacking. This is the main reason why the industry has invested in the design of fiber-degrading enzymes as feed supplements. There is a choice of fiber-degrading NSP-ases available today, including xylanases, arabino-furanosidases, mannanases, cellulases, glucuronidases, all of which can take care of the primary degradation of different types of NSPs (Derqaoui et al., 2022). For several of these, a beneficial effect on the caecal microbiota has been reported (Ducatelle et al., 2022). It appears to be preferable for the enzymes to only partially degrade the fiber and leave the final steps of degradation to the microbiota, to the point that enzymatic degradation down to the monosaccharide level may even be a disadvantage, since the monosaccharides appear to reduce the growth rate of the birds (Peng et al., 2004). It has been shown indeed that xylanase degradation of the arabinoxylan fraction of wheat to a degree of polymerization of around 30 provides an optimal substrate for the caecal microbiota of young broilers (Yacoubi et al., 2018). Currently studies are ongoing to investigate the effects of combining different NSPases. Preliminary results indicate that an enzyme targeting one type of NSP may improve the availability of another type of NSP, thus underlining the importance of untangling the complex NSP network of the plant cell walls.

PREBIOTICS FOR FEEDING THE MICROBIOME

Partially degraded NSPs are most commonly used as prebiotics. They can be directly supplied to the birds in order to provide a readily available source of nutrients for the microbiome. In this context it was shown already some years ago that directly fed xylooligosaccharides support the growth of Lactobacillaceae which cross-feed to the Lachnospiraceae (De Maesschalck et al., 2015). In some cases even the mere purification of single NSP without degradation may even be sufficient to trigger a prebiotic effect, as has been shown for pure amorphous cellulose in young broiler chicks (De Maesschalck et al., 2019).

CONCLUSION

A range of different feeding strategies are currently available which allow to steer and support the beneficial gut microbiota in chickens. Some may be complementary, supporting different microbial metabolic pathways, while others are not. The challenge for the nutritionists and veterinarians is to make rational choices in order to improve the health and performance of the birds.

REFERENCES

1. De Maesschalck C, Eeckhaut V, Maertens L, De Lange L, Marschal L, Daube G, et al. (2019). Amorphous cellulose feed supplement alter the broiler caecal microbiome. **Poultry Science** 98, 3811-3817.
2. De Maesschalck C, Eeckhaut V, Maertens L, De Lange L, Marschal L, Nezer C, et al. (2015). The effects of xylo-oligosaccharides on performance and microbiota in broiler chickens. **Applied & Environmental Microbiology** 81, 5880-5888.
3. Derqaoui S, Oukessou M & Nassik S (2022). NSPases: can those exogenous enzymes really constitute natural growth cofactors in broiler chickens? **International Journal of Advanced Research** 10, 450-464.
4. Ducatelle R, Goossens E, Eeckhaut V & Van Immerseel F (2023). Poultry gut health and beyond. **Animal Nutrition** (in press).
5. Ducatelle R, Van Immerseel F, Eeckhaut V & Goossens E (2022). Enzymes and the microbiome in the post-antibiotic era. In: *Enzymes in farm animal nutrition*. 3rd ed. M. Bedford, G.G. Partridge, M. Hruby & C.L. Walk, eds CAB International, 254-264.
6. Geirnaert A, Steyaert A, Eeckhaut V, Debruyne B, Arends JBA, Van Immerseel F et al. (2014). *Butyricoccus pulliaecorum*, a butyrate producer with probiotic potential, is intrinsically tolerant to stomach and small intestine conditions. **Anaerobe** 30, 70-74.

7. Knudsen KEB (2001). The nutritional significance of "dietary fibre" analysis. **Animal Feed Science and Technology** 90, 3-20.
8. Peng YL, Guo YM & Yuan JM (2004). Effect of feeding xylose on the growth of broilers and nutrient digestibility as well as absorption of xylose in the portal-drained viscera. **Asian-Australasian Journal of Animal Sciences** 17, 1123-1130.
9. Rychlik I (2020). Composition and function of chicken gut microbiota. **Animals** 10, 103.
10. Such N, Farkas V, Koltay IA, Rawash MA, Dublec K & Molar A (2019). Wheat bran supplementation increases the abundance of *Akkermansia muciniphila* whereas single strain probiotic *Clostridium butyricum* fails to influence caecal microflora composition of broiler chickens. **Proceeding of the 18th BOKU symposium in animal nutrition**, 189-192.
11. Yacoubi N, Saulnier L, Bonnin E, Devillard E, Eeckhaut V, Rhayat L, et al. (2018). Short chain arabinoxylans prepared from enzymatically treated wheat grain exert prebiotic effects during the broiler starter period. **Poultry Science** 97, 412-424.

Plenary Session 4:

SOLUTIONS TO IMPROVE THE NUTRITIONAL VALUE OF FEED

THE EFFECT OF FIBRES IN FEEDSTUFFS ON NUTRITIONAL VALUE AND HOW TO DETERMINE IT

Knud Erik Bach Knudsen, Tofuko Awori Woyengo and Sanna Steinfeldt

Department of Animal and Veterinary Sciences, Aarhus University, Denmark

knuderik.bachknudsen@anis.au.dk

INTRODUCTION

The nutritional value of a feed refers to “the amount of nutrients contained in a feed that can be utilized by the animal” and its estimation consequently involve how well the nutrients are digested and utilized by the animals. In poultry nutrition, it is well known that content and composition of fibre (non-starch polysaccharides (NSP) and lignin) have a profound influence on nutrient digestibility and utilisation as it represents the largest part of the feed that cannot be digested by endogenous enzymes. Fibre can also influence nutrient digestibility due to its viscosity associated with soluble NSP and the encapsulation of important nutrients in cell walls (CW) rich in insoluble NSP. However, insoluble NSP may help develop the gizzard and other parts of the gastrointestinal tract and thereby improve the digestibility of nutrients. The main purpose of the present paper is to review the interplay between **NSP** and **fibre** and the digestion processes. Since cereal grains constitute the largest part of the NSP present in the diets for broilers most emphasis will be devoted on cereal NSP.

HOW TO DETERMINE FIBRE?

A broad variety of analytical methods have been used for the analysis of fibre in feeds. The crude fibre method is the oldest fibre methods and still used in the proximate analysis of feeds. The detergent methods were developed by Van Soest and co-workers and were originally developed for the analysis of fibre rich feedstuffs (roughages) but has latter on been applied also to concentrate feeds. More recently the enzymatic-gravimetric AOAC (Association of Official Analytical Chemists) procedures and the enzymatic-chemical Englyst and Uppsala procedures for the analysis of fibre (dietary fibre) have been developed. These latter methods were originally developed for foods but have also been used when analysing feedstuffs. For further information see [1].

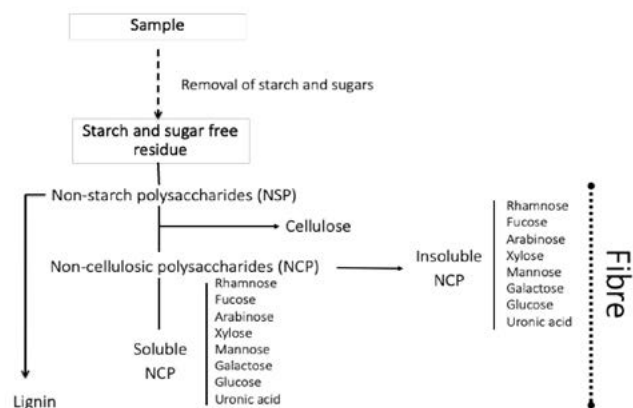


Figure 1. Determination of fibre as non-starch polysaccharides and Klason lignin

The method illustrated in Figure 1 enables separate estimations of cellulose, soluble NCP and insoluble NCP and lignin (Klason) using enzymatic-chemical-gravimetric principles. The method also provides detailed information about the monomeric composition of the NCP fraction. Information concerning polymers making up the NCP fraction can be depicted from the monomeric sugar residues, i.e., NCP arabinose and xylose are markers for arabinoxylan (AX) and NCP glucose for mixed linkage β -glucan in cereals, uronic acids for the backbone in pectin, and arabinose, galactose etc. markers of the side groups in pectic polysaccharides. A comparison of results obtained when analysing the same feedstuffs by the different analytical methods show distinct differences; crude fibre values are much lower than values obtained by the neutral detergent fibre method that is somewhat lower than those obtained by the enzymatic-chemical methods.

EXAMPLES OF FIBRE COMPOSITION OF DIFFERENT FEEDSTUFFS

The NSP and lignin content of feedstuffs varies widely. Cereals have in general a lower concentration of NSP and lignin than protein rich crops whereas co-products from cereals and products from the agro and food industries have higher concentration (Table 1).

Table 1. Non-starch polysaccharide and lignin content (g/kg dry matter) of selected feedstuffs

	Cell	Non-cellulosic polysaccharides						NCP	NSP	KL	Fibre
		Ara	Xyl	Man	Gal	Glc	UA				
<i>Cereals</i>											
Brown rice	1	5	4	1	1	8	2	21 (2)	22 (2)	13	35
Maize	22	22	30	3	5	10	7	75 (9)	97 (9)	11	108
Sorghum	15	17	13	1	3	10	4	51 (4)	66 (4)	16	83
Wheat	20	29	47	3	4	11	5	99 (25)	119 (25)	10	138
Rye	16	36	61	5	5	26	4	136 (42)	152 (42)	21	174
Barley	43	28	56	4	3	47	6	143 (56)	186 (56)	35	221
Oats	82	18	80	3	7	33	10	150 (40)	232 (40)	66	298
<i>Cereal co-products</i>											
Maize bran	83	72	116	4	20	16	44	271 (32)	354 (32)	25	379
Maize feed meal	33	33	48	2	9	10	20	123 (10)	156 (10)	18	174
Maize DDGS	58	52	71	19	13	21	16	192 (34)	250 (34)	39	289
Wheat bran	72	90	148	5	8	35	15	302 (29)	374 (29)	75	449
Wheat middling	19	48	67	8	7	33	10	171 (71)	190 (71)	11	201
Wheat DDGS	50	57	86	16	11	33	8	212 (67)	262 (67)	66	328
Rye bran	39	78	213	3	12	66	10	383 (63)	422 (63)	68	490
Barley hull meal	192	51	184	3	6	25	18	286 (20)	478 (20)	115	594
Oat hull meal	196	28	212	2	9	20	36	309 (13)	505 (13)	148	653
<i>Protein rich feedstuffs</i>											
Soybean meal	62	26	19	13	41	7	48	155 (63)	217 (63)	16	233
Rapeseed meal	52	43	17	6	19	21	61	168 (55)	220 (55)	134	354
Peas	53	26	13	2	7	36	32	127 (52)	180 (52)	12	192
Fava beans	81	24	12	2	6	32	33	109 (50)	190 (50)	20	210
Lupin	131	43	36	9	141	2	39	274 (134)	405 (134)	12	416
Palm cake	73	12	1	309	15	7	19	393 (32)	466 (32)	136	602
Sunflower cake	123	31	59	12	13	17	67	192 (57)	315 (57)	133	448

NCP, non-cellulosic polysaccharides; NSP, non-starch polysaccharides; Cell, cellulose; Ara, arabinose; Xyl, xylose; Man, mannose; Gal, galactose; Glc, glucose; UA, uronic acids; KL, Klason lignin; DDGS, distillers dry grains with soluble. Values in parentheses are soluble NCP/NSP.

Data from own database.

While cellulose is present in all plant CW at different concentration, there is a wide variation in the composition of the non-cellulosic polysaccharides among the feedstuffs. β -Glucan (NCP-glucose) is responsible for the relatively high concentration of soluble NCP in barley and oats and soluble AX (arabinose + xylose) responsible for most of soluble NCP in wheat and rye. In legumes, protein crops and feedstuffs, pectin substances expressed by uronic acids, galactose and arabinose, xyloglucans expressed by xylose and glucose, galactans expressed by galactose in lupin and mannans expressed by mannose in palm cake are the main non-cellulosic polysaccharides responsible for the relative high levels of soluble NCP in these feedstuffs.

NUTRITIONAL EFFECTS OF FIBRE

Diets for broiler chickens have traditionally been based on relatively few feedstuffs like maize and soybean meal. Today, however, several other less expensive energy and protein crops and co-products are frequently being used. Common for the latter group of feedstuffs is that they have a higher content of NSP, are more viscous and have a lower nutrient digestibility and utilisation. The lower nutrient digestibility and utilisation is a consequence of the higher NSP content and is due to the following:

1. The NSP fraction represent the largest part of the feed dry matter not digested by the bird's endogenous enzymes.
2. The viscous nature of some soluble NSP may interfere with the enzymatic digestion processes making them less efficient.
3. The insoluble NSP in some CW structures may encapsulate potentially available nutrients.

NSP is the diet factor with the largest negative effect on nutrient digestibility. In broilers, the digestibility of NSP is influenced by age and the NSP composition but is generally lower in younger than older poultry. In 5-10 d old birds, it has been found that soluble and insoluble AX with low arabinose to xylose ratios were able to enter the caecum but were not extensively fermented by the caecal microbiota, whereas the establishment of a mature microbial community from 21 d of age resulted in an increase in both solubilization of insoluble AX and fermentation of soluble AX at ileum and caecum [2]. Despite low NSP degradation in poultry, the microbiota will nevertheless provide energy to the host. It has been estimated that the upper capacity of NSP fermentation contributed 3-4% of metabolizable energy (ME) and the excretion of organic acids (mainly lactic acid and acetic acid) accounted for up to 2% of ME [3]. Measurable quantities of H_2 was also produced whereas no CH_4 could be detected indicating lack of methanogenic bacteria. Other studies have also shown that variation in the NSP content within individual raw material to a large extent account for the variation in ME content as found for wheat varieties in several studies [4].

The soluble and hydrophilic nature of AX and β -glucan enables the two polymers to disperse relatively easily in the gastrointestinal tract and to increase intestinal viscosity with negative effects on nutrient digestibility and animal performance [5]. The mechanism behind is thought to be inhibition of nutrient digestion by impeding the diffusion of digestive enzymes and their substrate and products. An associated effect is a reduced ability of the gut to physically mix the contents. This has been found to implicate particularly fat digestion and more for saturated than unsaturated fat as vigorous mixing is required for good emulsification, which is a prerequisite for efficient fat digestion. The study of Steinfeldt [6] identified a significant negative relationship between the concentration of AX in wheat varieties and the apparent fat digestibility coefficient measured in excreta. The negative effect of viscosity on nutrient digestibility was further illustrated in the model study of Choct & Annison [7] where a significant negative effect of concentrated wheat AX (pentosans) on the ileal digestibility of starch, protein and lipid was seen. Age plays a role for the negative effect of viscosity on nutrient digestibility; while substantial in broiler chickens up to 21-28 d of age, the effects in older birds are less presumably because in older birds the microbiota can digest and utilize some of the viscous polysaccharides [2].

It has long been known that some CW structures may encapsulate potentially available nutrients and thereby reduce their digestibility [8]. Examples of such CW structures are the aleurone and endosperm cells of cereals and the cotyledon CW of legumes. The aleurone layer is a specific tissue of the cereal endosperm, one layer thick in wheat and rye and three layer thick in barley. The aleurone AX across cereals is largely insoluble and with a lower A/X ratio than in the starchy endosperm in both wheat and barley. The AX of the aleurone cells is also more heavily esterified with ferulic acid dehydridiferulic acids along with *p*-coumaric acid than the AX of the starchy endosperm. The insoluble nature of the aleurone CW makes them resistant to digestion by endogenous enzymes and intact aleurone cells have been identified in excreta from chickens causing a concomitant lower digestibility of protein.

Cotyledon CW of peas, fava beans and other beans can limit the access of endogenous enzymes to starch and protein [9]. The CW of the cotyledon is hydrophilic and primarily composed of pectic polysaccharides, xyloglucans and cellulose and although the NSP in the cotyledon analytically behaves like soluble NSP, it is mostly insoluble under the conditions that persist in the gastrointestinal tract. These properties of legume CW have been found to control *in vitro* rate and extent of starch digestion in peas, common beans, and fava beans. The extent of starch digestion in legumes is far lower than in cereals and particularly in tapioca [10].

In addition to the viscous properties of barley β -glucan, the endosperm CW of barley may also act as a physical barrier to endogenous enzymes, and this may delay the digestion of starch in the small intestine [11]. Partly degradation of the β -glucan via enzyme addition resulted in a more anterior disappearance of starch in the small intestine [11]. There can also be an interaction between the endosperm CW and the insoluble protein matrix as indicated in a study with sorghum and barley. It was found that the rate of starch hydrolysis was significantly higher in barley than sorghum when milled to varying fragment sizes, presumably reflecting a reduced access of α -amylase to the starch granule because of the insoluble protein matrix and the surrounding CW [10]. Thus, endosperm CW from cereals may influence the digestion of starch in some cereals caused by the interaction with the insoluble protein matrix and in others with the viscosity properties of AX and β -glucan.

CONCLUSION

Fibres represent the part of the feed that cannot be digested by endogenous enzymes and has therefore a significant and negative effect on the nutritional value of the feed. Different methods are available for its determination but today it is common to use enzymatic-chemical-gravimetric methods which in addition to the total content also give information of its solubility and, for some type of feedstuffs, the main polysaccharides.

REFERENCES

1. Bach Knudsen, K.E. and H.N. Lærke, *Carbohydrates and lignin in the feed – from sugars to complex composed fibres*, in *Feed Evaluation Science* P. Moughan and W. Hendriks, Editors. 2018, Wageningen Academic Publisher: Wageningen. p. 109-140.
2. Bautil, A., et al., *Age-related arabinoxylan hydrolysis and fermentation in the gastrointestinal tract of broilers fed wheat-based diets*. *Poult Sci*, 2019. 98(10): p. 4606-4621.
3. Jørgensen, H., et al., *The influence of dietary fibre source and level on the development of the gastrointestinal tract, digestibility and energy metabolism in broiler chickens*. *Br J Nutr*, 1996. 75(3): p. 379-95.
4. Annison, G., *Relationship between the levels of soluble nonstarch polysaccharides and the apparent metabolizable energy of wheats assayed in broiler chickens*. *J Agric Food Chem*, 1991. 39: p. 1252-1256.
5. Pettersson, D. and P. Åman, *Enzyme supplementation of a poultry diet containing rye and wheat*. *British Journal of Nutrition*, 1989. 62: p. 139-149.

6. Steinfeldt, S., *The dietary effect of different wheat cultivars for broiler chickens*. Br Poult Sci, 2001. 42(5): p. 595-609.
7. Choct, M. and G. Annison, *The inhibition of nutrient digestion by wheat pentosans*. Br J Nutr, 1992. 67(1): p. 123-32.
8. Classen, H., *Cereal grain starch and exogenous enzymes in poultry diets*. Anim Feed Sci Technol, 1996. 62(1): p. 21-27.
9. Dhital, S., et al., *Intactness of cell wall structure controls the in vitro digestion of starch in legumes*. Food Function, 2016. 7(3): p. 1367-79.
10. Weurding, R.E., et al., *Starch digestion rate in the small intestine of broiler chickens differs among feedstuffs*. J Nutr, 2001. 131(9): p. 2329-35.
11. Hesselman, K. and P. Åman, *The effect of beta-glucanase on the utilization of starch and nitrogen by broiler chickens fed on barley of low or high viscosity*. Anim. Feed Sci. Technol., 1986. 15: p. 83-93.

Plenary Session 4:

SOLUTIONS TO IMPROVE THE NUTRITIONAL VALUE OF FEED

IMPROVING THE NUTRITIONAL VALUE OF INGREDIENTS THROUGH THE USE OF FEED ENZYMES

Michael R. Bedford

AB Vista, Marlborough, Wilts, UK

mike.bedford@Abvista.com

One hundred years ago the broiler chicken industry as we know it today did not exist. Birds were grown in small flocks on small holdings and fed whatever grains and protein sources were at hand, with the result that the diet they received was based on many ingredients, most of which rarely exceeded 20% of the total ration. Modern-day poultry rations are quite different, often being based upon two or three major ingredients making up 70% or more of the total diet. Thus the anti-nutritional factors (ANF) present in an ingredient employed could now present itself at levels hitherto unseen in the past. The majority of ANFs that enzymes address today are fibre, phytate and to a lesser extent proteinaceous ANF's, but for the sake of this short paper the focus will be on the major cereal NSP and phytic acid.

FIBRE

The definition of fibre and the methods used to analyse fibre have evolved significantly and will likely evolve further as more is understood of this largely ignored fraction of a monogastric's diet (Asp, 1987; Bach Knudsen, 2018). The monogastric nutritionist views fibre as a composite entity which can fit into one of three categories; antinutritional (eg viscous soluble polysaccharides, intact fibrous cell walls which encapsulate nutrient contents), beneficial (functional insoluble fibre which stimulates gizzard development, fermentable oligosaccharides), or nutrient diluent (inert non-functional insoluble fibre). We still lack the ability to routinely measure these categories with the current methods at hand due to a lack of information on three-dimensional structures, linkages, size and susceptibility to fermentation. Regardless, it is clear that benefit is derived if the fibre present in the feed ingredients offered is depolymerised, as this reduces the antinutritional and diluent effects of fibre and simultaneously creates more fermentable fibre as a result. Thus, increasing fibre "digestibility" should be the goal of any nutritionist employing a fibre-targeting enzyme.

Table 1. Selected NSP and cellulose content of major feed materials

	Sample n	Total (g/kg)			Soluble (% of total)			g/kg	g/kg
		A+X ¹	B-glucans	Mannan	A+X	B-glucans	Mannan		
Barley	8	77	47	4	13%	52%	30%	4	28
Rye	20	85	20	5	36%	33%	43%	3	12
Triticale	20	55	7	4	23%	14%	30%	3	19
Wheat	20	64	6	2	22%	33%	25%	3	14
Maize	3	52	1	3	10%	10%	67%	7	22
SBM	6	45		13	24%		38%	48	62
RSM	4	60		6	27%		17%	61	52

Adapted from (Rodehutscord *et al.*, 2016) and (Knudsen, 1997).¹Arabinose + xylose residues

The traditional approach to treating fibrous ingredients with enzymes to increase fibre “digestion” is to analyse the NSP sugar components of the fibre and apply enzymes capable of attacking the presumed substrate. Table 1 lists the arabinose + xylose (A+X), B glucan and mannose contents of several typical ingredients used in poultry nutrition and what is clear is that the relative preponderance of A+X is high in all ingredients, including the oilseed meals. However, such an analysis does not definitively identify the fibre type from which the sugars were derived. A+X, for example, is likely mostly derived from arabinoxylans in cereals but in oilseed meals there are significant amounts of arabinans and xyloglucans which contribute to this A+X fraction. Thus, targeting the fibre components of an ingredient needs structural as well as compositional knowledge.

A secondary consideration is the solubility of the fibre fraction. Insoluble fractions, if they remain insoluble throughout the intestinal tract do not take part in the digestion or fermentation process directly but can influence nutrient density of the diet by

1. Binding nutrients
2. Acting as a diluent
3. Speeding up passage rate
4. Stimulating gizzard development

The first 3 activities could be detrimental whereas the 4th would likely be beneficial given that increased gizzard activity is known to improve the digestibility of the entire diet.

Many NSPases can degrade and thereby dissolve variable proportions of ingredient insoluble fibre such that it can be further depolymerised and subsequently fermented or excreted. The extent to which this is accomplished depends upon the feed ingredient. For example the more complex substitutions of the xylan backbone in maize compared with wheat make it less susceptible to the endo-xylanase attack (Dale *et al.*, 2022). The specificity of the enzyme also plays a significant role here as well (Kluepfel *et al.*, 1992). Regardless, NSPase application routinely increases the “digestibility” of the insoluble NSP of an ingredient and diet. Whilst this may reduce the influence the insoluble fibre has on the first 3 properties noted above, it is debatable whether the dissolution of the insoluble fibre by action of an NSPase will significantly influence gizzard development. The pH optima of most NSPase on the market are such that the activity of these enzymes is confined to the crop, small intestine and caeca. Since much of the diet bypasses the crop in the *ad libitum* fed broiler the likelihood of significant activity prior to the gizzard is therefore low and hence the ability of the NSPase to reduce the gizzard stimulating effects of the fibre is limited.

The soluble fibre fraction can influence several facets of the digestive/fermentative process including;

1. Increasing intestinal viscosity (higher molecular weight fractions only)
2. Excessive supply can stimulate bacterial overgrowth and dysbacteriosis
3. Providing fuel for beneficial bacteria (prebiotic effect)
4. Signalling bacteria to produce their own fibre degrading enzymes (stimbiotic effect)
5. Directly influencing the immune system
6. Indirectly influencing the immune system through changing bacterial populations and community structure by all mechanisms noted above

Progressive depolymerisation of soluble fibre can have profound implications for all 6 effects noted above. Provided the provision of smaller, more fermentable fibre structures is not excessive then improvements in nutrient digestion, energy recovery from fibre fermentation and subsequent improvements in intestinal structure if specific volatile fatty acids (eg butyrate) production is enhanced would be expected.

INGREDIENT RESPONSES TO NSPASES

The question at hand is how the addition of specific exogenous fibre degrading enzymes influences the effects of both the insoluble and soluble fibre components arising from the most common feed ingredients. Variation in fibre structure between and within ingredients results in variable rates of dissolution of insoluble and depolymerisation of soluble NSP and hence subsequent performance of the bird. This is just one of the reasons why the response to exogenous NSPases are varied between studies and presents the industry with a conundrum with regards how such products should be evaluated. Regardless of the ingredient, the benefit noted on NSPase use is far greater than the apparent energy value of the fibre digested, suggesting several mechanisms are involved in the response. It is clear from table 1 that the fibre content (soluble and insoluble) of some ingredients, such as maize, is much lower than that in wheat and in particular rye or barley. The implications of this are that the initial anti-nutrient effects of fibre in maize are clearly less than those of wheat, triticale, barley and rye (in ascending order) and as a result, the benefits achieved on use of an NSPase will be more constrained. This is not only because there is less of an ANF effect to overcome, but as a consequence this means that the benefits that accrue from moving insoluble and soluble, viscous NSP towards fermentable oligosaccharides will be more limited as well. In addition to this, the structure of the fibre in maize and particularly sorghum is more complex and substituted than that in other cereals, further limiting the value extracted (Bach Knudsen, 2014). Further evolution of fibre degrading enzymes is necessary if the full value is to be extracted from these more intransigent but commonplace cereals. Whereas the focus of this section has been on the cereal fibre components, equal consideration should also be given to that in the oilseed meal components of the diet but space precludes any coverage in this paper.

PHYTATE

Phytic acid is not only a source of “unavailable” phosphorus but also a significant antinutrient due to its ability to bind to minerals, proteins and any positively charged nutrients and in doing so reduce their digestibility as the complex cannot be absorbed. Thus, the use of a phytase to remove the phosphates from the inositol ring not only presents the animal with an available phosphorus source but also simultaneously reduces the antinutrient capacity of the molecule. In typical monogastric diets the cereal and oilseed meals contribute relatively similar proportions of phytic acid to the total found in the diet. Although phytate, unlike fibre, is clearly chemically defined, its location can vary between ingredients. In maize it is concentrated in the germ, in small grain cereals it is in the aleurone layer and in oilseed meals it is usually located in protein bodies in the cotyledons. Thus, although a phytase identifies phytic acid as its substrate regardless of where it is derived, in its native form in a given ingredient the associated minerals, proteins and physical location may limit its accessibility and thus susceptibility to this enzyme. As a result, the responsiveness of an ingredient (and thus by extension the diet) to added phytase may vary. Furthermore, variation in phytic acid concentration due to genotypic and phenotypic variation (Godoy *et al.*, 2005) means that care must be taken when using higher doses of phytase to ensure that the expected P release does not exceed the phytic acid content of the diet.

Whereas low levels of phytase are capable of releasing significant amounts of phosphate which then becomes available for the host animal to utilise, it will not quantitatively rid the diet of antinutritive phytic acid (InsP6) and indeed will create a whole series of lower ester phosphates (InsP5, 4, 3 and 2). Although these are less antinutritive than InsP6, they are all antinutrients in their own right and as a result the removal of all antinutritive effects of phytic acid by ever increasing doses of phytase is a continuous event, and is only complete when all lower esters are removed. Such an event requires orders of magnitude more phytase than is currently employed commercially which would not be economic today. Nevertheless, as the benefits of a more complete ester removal are understood (Kriseldi *et al.*, 2021), the dose employed commercially

has risen considerably with time. Some recent findings suggest that more comprehensive phytate destruction and provision of inositol can reduce the incidence of some metabolic diseases such as woody breast and femoral head necrosis (Greene *et al.*, 2020). More complete phytate destruction is not only dependent upon enzyme dose or ingredient location. Since phytic acid is more soluble and thus more susceptible to hydrolysis at low pH, any ingredient that increases crop or gizzard retention would be expected to increase the extent of phytate hydrolysis. Such effects have been seen for fibre (cellulose, oat hulls), added fat and coarse grinding of materials (Ballam *et al.*, 1984). However, the higher the dose of phytase employed, the less likely ingredient source, fibre content, particle size, dietary Ca and P level and age of the bird (Beaulac, 2015) is to have on the response noted. Consequently, results become more consistent and predictable as dosage increases, regardless of the ingredients employed. It is envisaged that phytase dosages will increase further over time, enabling more efficient use of resources and more sustainable poultry production which may remove the concern of variable phytate “availability” between ingredients.

REFERENCES

1. Asp, N.-G. (1987). Definition and analysis of dietary fibre. *Scandinavian Journal of Gastroenterology*, 22, 16-20. doi: 10.3109/00365528709095845
2. Bach Knudsen, K.E. (2014). Fiber and nonstarch polysaccharide content and variation in common crops used in broiler diets. *Poultry Science*, 93, 2380-2393. doi: <http://dx.doi.org/10.3382/ps.2014-03902>
3. Bach Knudsen, K.E. (2018). Dietary fibre analyses in a nutritional and physiological context - past and present. *Proceedings of the Society of Nutrition and Physiology*, 27, 189-192.
4. Ballam, G.C., Nelson, T.S. & Kirby, L.K. (1984). Effect of fiber and phytate source and of calcium and phosphorus level on phytate hydrolysis in the chick. *Poultry Science*, 63, 333-338.
5. Beaulac, K. (2015). The effects of graded levels of phytase in broiler diets on growth, intestinal development, and nutrient digestibility. In: University of Saskatchewan.
6. Dale, T., Bedford, M.R., Tucker, G.A., Brameld, J.M. & Parr, T. (2022). The effects of exogenous fibrolytic enzymes on the in vitro generation of xylooligosaccharides and monosaccharides is dependent upon cereal type. *Animal Feed Science and Technology*, 292, 115406. doi: <https://doi.org/10.1016/j.anifeedsci.2022.115406>
7. Godoy, S., Chicco, C., Meschy, F. & Requena, F. (2005). Phytic phosphorus and phytase activity of animal feed ingredients. *Interciencia*, 30, 24-28.
8. Greene, E., Cauble, R., Dhamad, A.E., Kidd, M.T., Kong, B., Howard, S.M., et al. (2020). Muscle Metabolome Profiles in Woody Breast-(un)Affected Broilers: Effects of Quantum Blue Phytase-Enriched Diet. *Frontiers in Veterinary Science*, 7. doi: 10.3389/fvets.2020.00458
9. Kluepfel, D., Daigneault, N., Morosoli, R. & Shareck, F. (1992). Purification and characterization of a new xylanase (xylanase C) produced by *Streptomyces lividans* 66. *Applied Microbiology and Biotechnology*, 36, 626-631. doi: 10.1007/BF00183240
10. Knudsen, K.E.B. (1997). Carbohydrate and lignin contents of plant materials used in animal feeding. *Animal Feed Science and Technology*, 67, 319-338. doi: [https://doi.org/10.1016/S0377-8401\(97\)00009-6](https://doi.org/10.1016/S0377-8401(97)00009-6)
11. Kriseldi, R., Walk, C.L., Bedford, M.R. & Dozier, W.A. (2021). Inositol and gradient phytase supplementation in broiler diets during a 6-week production period: 2. Effects on phytate degradation and inositol liberation in gizzard and ileal digesta contents1. *Poultry Science*, 100, 100899. doi: <https://doi.org/10.1016/j.psj.2020.11.068>
12. Rodehutscord, M., Ruckert, C., Maurer, H.P., Schenkel, H., Schipprack, W., Bach Knudsen, K.E., et al. (2016). Variation in chemical composition and physical characteristics of cereal grains from different genotypes. *Archives of Animal Nutrition*, 70, 87-107.

Plenary Session 4:

SOLUTIONS TO IMPROVE THE NUTRITIONAL VALUE OF FEED

THE IMPORTANCE OF DIGESTIVE DYNAMICS IN BROILER CHICKEN NUTRITION

Sonia Liu^{1,2,*}, Shemil Macelline^{1,2}, Mehdi Toghyani^{1,2} and Peter Selle^{2,3}

¹School of Life and Environmental Sciences, The University of Sydney, Australia

²Poultry Research Foundation, Faculty of Science, The University of Sydney, Australia

³Sydney School of Veterinary Science, The University of Sydney, Australia

*Corresponding author. sonia.liu@sydney.edu.au

DIGESTIVE DYNAMICS MATTER

In typical broiler diets, protein and amino acids are primarily the building blocks of protein and starch and glucose are the principal source of energy. Both are required for optimal growth performance and an appropriate balance of amino acids and glucose should be made available at sites of protein synthesis to generate efficient protein accretion and growth. The various body proteins require a specific profile of amino acids and each gram of protein synthesised demands an energy input of 5.35 kJ for in broiler chickens (Aoyagi *et al.*, 1988). This is the fundamental construct of digestive dynamics. Conventionally, nutrient utilisation in chickens is determined from total tract nutrient digestion and retention or apparent digestibility coefficients based on digesta taken from the terminal ileum. While the later eliminates the confounding effects of hindgut fermentation it overlooks the fact that digestion of protein and starch, absorption of amino acids and glucose principally occurs in duodenum and jejunum (Hurwitz *et al.*, 1972, Riesenfeld *et al.*, 1980). Moreover, the digestion of starch is more rapid than protein. Sorghum is considered to be a slowly digestible source of starch (Giuberti *et al.*, 2012); however, starch digestion rates were nearly 40% faster than protein (3.38 versus 2.46 $\times 10^{-2}$ min⁻¹, Figure 1) in birds offered conventional, sorghum-based diets in Liu *et al.* (2013c). Digestive dynamics consider the extent, rate and site of nutrient digestion along the small intestine and the bilateral, post-enteral bioavailability of amino acids and glucose. The fundamental premise is that balanced quantities of amino acids and glucose should be made available at the sites of protein synthesis to drive efficient protein deposition and growth performance (Liu and Selle, 2017).

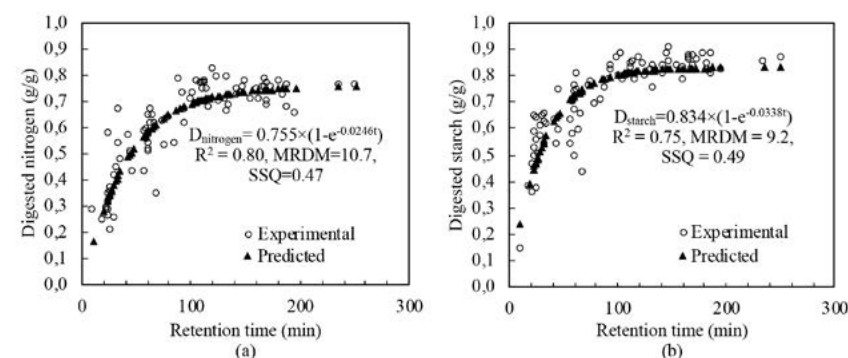


Figure 1 Protein (N) and starch digestion in sorghum-based broiler diets (Liu *et al.*, 2013c)

The 20 proteinogenic amino acids have different rates of absorption. Amino acids with larger nonpolar side chains, such as methionine, isoleucine, valine, leucine, tryptophan and phenylalanine are absorbed rapidly, whereas amino acids with polar side chains, such as glutamic acid, aspartic acid and arginine, and glycine, are absorbed slowly (Tasaki and Takahashi, 1966). Melnick *et al.* (1946) suggested that for optimum utilisation of dietary proteins, all essential amino acids must be liberated and absorbed as a result of digestion at rates permitting mutual supplementation. Subsequently, Gupta *et al.* (1958) compared digestion of different proteins and amino acid mixtures and confirmed that essential amino acids must be present simultaneously at sites of protein synthesis for efficient utilisation of dietary protein. Liu *et al.* (2013d) reported negative correlation between rates of starch digestion and retention of N, where rapid starch digestion rates depressed N retention. It was concluded by Liu and Selle (2015) digestion rates of starch and protein are correlated with feed conversion efficiency in sorghum-based broiler diets and rapidly digestible protein or slowly digestible starch benefits feed efficiency. Subsequently, correlations between growth performance and jejunal and ileal starch:protein disappearance rate ratios were reported in several studies (Truong *et al.*, 2015, 2016, Sydenham *et al.*, 2017).

RECENT UPDATES AND REMAINING CHALLENGES

Digestion rate in feed formulation, is it possible?

Since the correlation between FCR, nitrogen retention and digestion rates of starch and protein were established in sorghum-based diets (Liu and Selle, 2015), the relevance of digestive dynamics was confirmed in diets based on wheat and maize (Liu *et al.*, 2014). Determinations of digestion rates in a range of feed ingredients have been completed (Bryan *et al.*, 2019a, 2019b, Macelline *et al.*, 2020b, Toghyani *et al.*, 2020, Selle *et al.*, 2021). Furthermore, Liu *et al.* (2020) formulated diets containing six ratios of starch to protein digestion rates ranging from 1.567 to 2.453 (Table 1), but with similar amino acid profiles and energy densities. The experimental diets were offered to broiler chickens from 7 to 35 days post-hatch. Quadratic relationships ($P < 0.01$) between starch and protein digestion rates, and their ratios, with feed conversion ratio (FCR) were detected. The predicted optimal FCR of 1.446 was achieved from a starch digestion rate of 3.31 min^{-1} . An optimal FCR of 1.450 was predicted with a protein digestion rate of 2.02 min^{-1} or with a starch:protein digestion rate ratio of 1.663. Increasing protein digestion rates, or decreasing starch digestion rates, or narrowing starch and protein digestion rate ratios tended to improve feed conversion efficiency. This outcome is consistent with earlier concepts of starch and protein digestion rates and demonstrated the feasibility of incorporating starch and protein digestion rates into nutrient matrices for least-cost feed formulation. However, this study had some limitations as there were no significant differences in growth performance across the six experimental diets despite quadratic relationships between formulated rate ratios and feed conversion ratio. This suggests the extent of starch and protein digestion is critical and digestive dynamics will further optimise performance. Secondly, there was only one feeding phase from 7-35 days post-hatch and this may have confounded outcomes. Thirdly, the number of feed ingredients tested for establishing matrices for diet formulation was limited and the relationship of digestion rates between feed ingredients may or may not be additive in complete diets. Nevertheless, this study is the only one in the literature which demonstrates the possibility of formulating broiler diets on the basis of starch and protein digestion rates. More research is required to verify current findings and to apply rates of digestion in practical feed formulation.

PROTEIN-BOUND AND NON-BOUND AMINO ACIDS

The balance between protein-bound amino acid and non-bound amino acid (NBAA) has gained more recent attention from the formulation of low protein diets (Liu and Selle, 2017). Macelline *et al.* (2020a) used a triangular response surface design to compare three diets rich in soybean meal, whey protein concentrate or NBAA to determine the optimal level of NBAA inclusion in wheat-based diets. Superior weight gain and FCR was found in broiler chickens offered an equal blend of soybean meal and whey

protein diets. This diet was constituted of 84.3 g/kg whey protein concentrate and 13.4 g/kg NBAA. This finding is curious because the diet containing the highest NBAA inclusions generated relatively inferior growth performance. Liu *et al.* (2013b) reported methionine and lysine had higher rates of digestion in standard broiler diets which contained some synthetic methionine and crystalline lysine (Table 1). Apparent amino acid digestibility coefficients are largely influenced by endogenous flows of amino acids. In Liu *et al.* (2013b), threonine had the lowest ileal digestibility coefficient (0.744) and methionine had the highest (0.947), which consistent with their relative contributions to endogenous protein. Hence, the balance between intestinal uptakes of amino acid and endogenous amino acid flows is a challenges for future research. Matrix values based on amino acid digestion rates, rather than protein, may be more useful for least-cost feed formulation, especially in low protein diets.

Table 1 Diet formulations included starch and protein digestion rates (g/kg) (Liu *et al.*, 2020)

Diet	1	2	3	4	5	6
Wheat	411	262	200	200	200	200
Red sorghum	100	276	385	435	479	510
Canola seed	50.0	50.0	50.0	30.0	30.0	30.0
Soybean meal	243	234	272	257	213	165
Canola Meal	100	100	19	0	0	0
Soybean oil	35.6	27.2	19.2	18.0	11.3	10.0
L-Lys HCl	2.21	2.51	2.81	3.80	5.09	6.54
DL - Met	2.14	2.27	2.78	3.19	3.56	4.01
L-Thr	0.97	0.99	1.17	1.61	2.16	2.81
L-Trp	0.00	0.00	0.00	0.00	0.00	0.01
L-Val	0.10	0.04	0.22	0.73	1.39	2.19
L-Arg	0.00	0.00	0.02	0.92	2.16	3.57
L-Ile	0.05	0.00	0.00	0.40	1.06	1.85
L-His	0.00	0.00	0.00	0.00	0.00	0.32
Salt	1.91	1.61	1.66	0.47	0.00	0.00
Sodium bicarbonate	2.03	2.50	2.68	4.47	5.17	5.19
Potassium bicarbonate	0.00	0.00	0.00	0.00	1.55	3.93
Limestone	11.1	11.2	11.7	12.0	12.1	12.3
Di-calcium phosphate	7.20	7.21	8.19	8.69	9.09	9.57
Xylanase ¹	0.05	0.05	0.05	0.05	0.05	0.05
Phytase ²	0.10	0.10	0.10	0.10	0.10	0.10
Choline chloride	0.80	0.80	0.80	0.80	0.80	0.80
Celite™	20.0	20.0	20.0	20.0	20.0	20.0
Sand	9.89	0.00	0.00	0.00	0.00	9.77
Vit-mineral Premix ³	2.00	2.00	2.00	2.00	2.00	2.00
<i>Calculated nutrient specifications</i>						
Starch digestion rate	3.419	3.129	3.169	3.394	3.590	3.728
Protein digestion rate	2.181	2.107	2.219	2.083	1.817	1.519
Starch:protein digestion rate ratio	1.567	1.485	1.428	1.629	1.976	2.453

¹Danisco 40,000 G⁻²Axtra PHY TPT 10,000

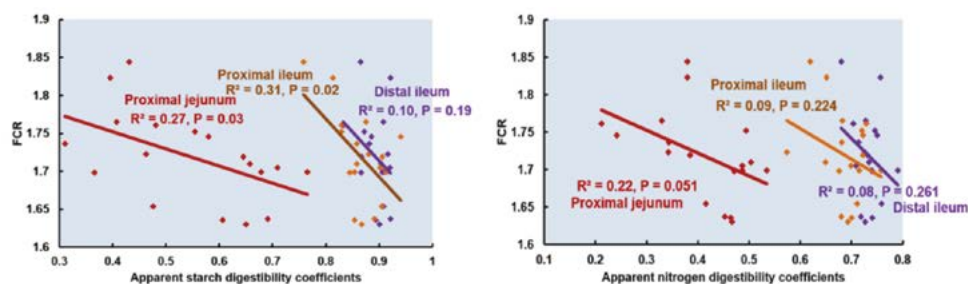
³The vitamin-mineral premix supplied per tonne of feed: [MIU] retinol 12, cholecalciferol 5, [g] tocopherol 50, menadione 3, thiamine 3, riboflavin 9, pyridoxine 5, cobalamin 0.025, niacin 50, pantothenate 18, folate 2, biotin 0.2, copper 20, iron 40, manganese 110, cobalt 0.25, iodine 1, molybdenum 2, zinc 90, selenium 0.3

Table 2 Amino acid digestion rates ($\times 10^{-2} \text{ min}^{-1}$) in typical broiler diets (Liu *et al.*, 2013b)

Amino acid	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Val	Ala	Asp	Glu	Gly	Pro	Ser	Tyr
Rate	3.25	2.57	2.05	2.07	4.14	5.51	2.39	2.58	2.04	2.18	2.52	2.96	2.11	2.28	2.27	1.85

RAPID MEASUREMENT? IS IT POSSIBLE?

The measurement of digestion rate involves determination of apparent digestibility coefficients at various sites of small intestine and estimation of retention time by digesta content and dietary marker concentration (Weurding *et al.*, 2001). This process is expensive and time-consuming. A few studies have reported the potential of *in vitro* assessments (Bryan *et al.*, 2019a, Bryan and Classen, 2020), where they concluded *in vitro* methods do not fully replicate normal *in vivo* digestive conditions and cannot mimic numerous biological factors involved in *in vivo* digestion and the complex interaction between different nutrients. However, in addition to ileal digestible amino acids, it is possible to include jejunal digestibilities as a quick indicator of rate of digestion (Figure 2). Figure 2 shows the more pronounced correlation between FCR and jejunal digestibilities in comparison to ileal digestibilities.

**Fig. 2.** Correlations between FCR and protein (nitrogen) and starch digestibilities in small intestine (Liu *et al.*, 2013a)**Other challenges**

The transfer of amino acids absorbed into enterocytes along the small intestine into the portal and, ultimately, the systemic circulation requires more research. The gastrointestinal tract consumes approximately 20% of all incoming energy (Cant *et al.*, 1996) and both amino acids and glucose are oxidised in the gut mucosa to meet this demand. Moreover, post-enteral amino acid metabolism and deamination of amino acids are reviewed in Selle *et al.* (2022) which could also impact on digestive dynamics.

REFERENCES

1. Aoyagi Y, Tasaki I, Okumura J, Muramatsu T (1988) *Comparative Biochemistry and Physiology* **91A**, 165–168.
2. Bryan D, Abbott DA, Classen HL (2019a) *Animal Feed Science and Technology* **248**, 106–113.
3. Bryan D, Abbott DA, Van Kessel AG, Classen HL (2019b) *Poultry Science* **98**, 3313–3325.
4. Bryan D, Classen HL (2020) *Animals* **10**.
5. Cant JP, McBride BW, Croom WJ (1996) *Journal of Animal Science* **74**, 2541–2553.
6. Giuberti G, Gallo A, Cerioli C, Masoero F (2012) *Animal Feed Science and Technology* **174**, 163–173.

7. Gupta JD, Dakroury AM, Harper AE (1958) *Journal of Nutrition* **64**, 447–456.
8. Hurwitz S, Shamir N, Bar A (1972) *American Journal of Clinical Nutrition* **25**, 311–8.
9. Liu S, Selle P, Gill R, Cowieson A (2013a), In: European Symposium on Poultry Nutrition, Potsdam, Germany.
10. Liu SY, Selle PH, Court SG, Cowieson AJ (2013b) *Animal Feed Science and Technology* **183**, 175–183.
11. Liu SY, Selle PH, Cowieson AJ (2013c) *Animal Feed Science and Technology* **185**, 85–93.
12. Liu SY, Selle PH, Cowieson AJ (2013d) *Animal Production Science* **53**, 1033–1040.
13. Liu SY, Cadogan DJ, Péron A, Truong HH, Selle PH (2014) *Animal Feed Science and Technology* **197**, 164–175.
14. Liu SY, Selle PH (2015) *Worlds Poultry Science Journal* **71**, 297–310.
15. Liu SY, Selle PH (2017) *Animal Production Science* **57**, 2250–2256.
16. Liu SY, Chrystal PV, Selle PH (2020) *Proceedings, Australian Poultry Science Symposium* **31**, 90–94.
17. Macelline SP, Chrystal PV, Toghyani M, Greenhalgh S, Selle PH, Liu SY (2020a) *Proceedings, Australian Poultry Science Symposium* **31**, 95–98.
18. Macelline SP, McQuade L, McInerney BV, Moss AF, Selle PH, Liu SY (2020b) *Animal Nutrition* **6**, 521–528.
19. Melnick D, Oser BL, Weiss S (1946) *Science* **103**, 326–329.
20. Riesenfeld G, Sklan D, Bar A, Eisner U, Hurwitz S (1980) *Journal of Nutrition* **110**, 117–121.
21. Selle PH, Moss AF, Khoddami A, Chrystal PV, Liu SY (2021) *Animal Nutrition* **7**, 450–459.
22. Selle PH, Macelline SP, Chrystal PV, Liu SY (2022) *Frontiers in Bioscience-Landmark* **27**, 126.
23. Sydenham CJ, Truong HH, Moss AF, Selle PH, Liu SY (2017) *Animal Feed Science and Technology* **227**, 32–41.
24. Tasaki I, Takahash N (1966) *Journal of Nutrition* **88**, 359–364.
25. Toghyani M, McQuade LR, McInerney BV, Moss AF, Selle PH, Liu SY (2020) *Plos One* **15**, e0239156.
26. Truong HH, Neilson KA, McInerney BV, Khoddami A, Roberts TH, Liu SY, Selle PH (2015) *Animal Nutrition* **1**, 220–228.
27. Truong HH, Neilson KA, McInerney BV, Khoddami A, Roberts TH, Liu SY, Selle PH (2016) *Animal Feed Science and Technology* **219**, 159–174.
28. Weurding RE, Veldman A, Veen WAG, van der Aar PJ, Verstegen MWA (2001) *Journal of Nutrition* **131**, 2329–2335.

Plenary Session 5:
NON-SOY PROTEIN SOURCES

PERSPECTIVE AND LIMITS IN THE USE OF ALGAE AND FREE AMINO ACIDS IN LOW PROTEIN DIETS

M. T. Kidd and G. J. Mullenix

Center of Excellence for Poultry Science, Division of Agriculture, University of Arkansas, Fayetteville, AR, USA

mkidd@uark.edu

INTRODUCTION

Meeting amino acid needs of commercial broilers relies heavily on the dietary inclusion of soybean meal to supply the major portion of protein needs. Although soybean oil demands in the US are increasing, human protein consumption of poultry products in China, Asia, Africa, and Middle Eastern countries is resulting in substantial growth in broiler production in many countries. Soybean meal and soybean products will continue to meet protein needs of broiler diets in emerging markets, as well as in the Americas, but tight supplies may warrant heightened use of feed grade amino acids and alternative protein meals (e.g., *Arthrospira platensis*).

FEED GRADE AMINO ACID USE IN BROILER DIETS

As amino acids were being discovered in the 1800's it was widely known that protein denaturation through acid boiling provided compounds in crystalline forms. A review has been written on the synergistic use of feed grade amino acids (i.e., methionine) in broiler diets coupled with the adoption of linear programming-least cost diet formulation (Kidd et al., 2013) which began in the 1950's. At this time, it was known that amino acids could be produced through ingredient extraction procedures. However, in the 1950's a group of Japanese researchers of Kyowa Hakko Kogyo derived a fermentation method to yield L-form amino acids by using available sugar sources and ammonia (Kinoshita et al., 1957). The fermentation method encompassed the use of *Corynebacterium glutamicum* beginning with glutamate production (Kinoshita et al., 1957), and led to industrial production of lysine, arginine, histidine, valine, isoleucine, etc. (Ikeda, 2003). It can be argued that commercial production of L-lysine via fermentation revolutionized protein nutrition of poultry (Wittmann and Becker, 2007) and paved the way to the concept of "low protein diets".

The inclusion of each sequential limiting feed grade amino acid in formulation results in a decrease of intact protein contributing ingredients (Table 1). Challenges for nutritionists represent many, of which some include: 1) understanding non-essential amino acid supply as CP decreases; 2) understanding the implications of increased leucine; and 3) understanding nutritional needs of essential, but less defined, amino acids (i.e., arginine, isoleucine, proline, histidine, and phenylalanine). Considering leucine, feed grade amino acid use or L-valine or L-isoleucine may increase if nutrient needs of the former are adjusted upwards to account for a practical antagonism. Further, an arginine to lysine minimum of 1.05 versus 1.10 completely changes diet makeup as satisfying the former necessitates increased soybean meal or L-arginine. Recent work on the branched-chain amino acids and histidine needs of broilers will be presented, in addition to gut health implications of low CP diets, as noted in a subsequent section.

ALGAE USE IN BROILER DIETS

The cost-effective nature and well-balanced amino acid profile of soybean meal dictates that

alternative protein feed sources will be difficult to introduce into practical broiler diets. Many dietary protein alternatives are region specific and often are by-products of another industry (i.e., other oil seed meals from oil extraction, distillers dried grains with solubles from ethanol production, and animal meals from commercial production). More novel dietary animal dietary protein sources, such as single cell proteins, have gained scientific interest because of their nutrient profile, biological activity, and the potential role they could play in sustainable animal production (Suman et al., 2015). Certain single cell proteins, such as microalgae, can be produced with minimal water usage and its production methods have a distinct advantage over terrestrial crops in that they're less impacted by unpredictable weather, diseases, pests, weeds, and variable soil quality (FAO, 2008; Hartman et al., 2011).

Arthrospira platensis, or commonly referred to as *Spirulina*, is a ubiquitous photosynthetic cyanobacteria and is prized as a nutrient dense microalga. *Spirulina* is high in protein (55-70%), minerals, vitamins, pigments, and essential fatty acid content (Henrikson, 1994). Many of these nutrients provide health promoting effects and *Spirulina* has proven to be beneficial in weight loss, diabetes, hypertension, viral protection, anticancer properties, cholesterol management, anemia, cardiovascular health, antioxidation, and anti-inflammation (Bishop and Zubeck, 2012). These health promoting benefits and an amino acid profile that can easily be incorporated in broiler diets make *Spirulina* an appealing alternative dietary protein source. However, *Spirulina*'s limited production, costly mediums, and demand for its byproducts equate to a product that is still well above consideration for use in most commercial broiler diets.

LIMITS IN RESPONSES

Establishment of low crude protein test diets was done so after *Spirulina* analyses (Table 2) with the addition of feed grade Met, Lys, Thr, Arg, Val, Ile, and Trp sources in a diet reduced from 20 to 17% CP (Mullenix et al., 2022). The test diet was then formulated with 10% *Spirulina* resulting in soybean meal inclusion being reduced from 22.2 to 10.5% of diet. Diets reduced in CP resulted in 35-day old female birds (Experiment 1) and 37-day old male birds (Experiment 2) exhibiting significantly increased feed conversion. *Spirulina*, however, restored feed conversion in Experiment 2, but not Experiment 1 (Mullenix et al., 2022). Subsequent research (Mullenix, 2021) revealed that lower additions of *Spirulina*, up to 5%, may prove efficacious in terms of meeting the amino acid needs of broilers.

Additional testing of plasma from broilers fed the former mentioned three test diets revealed that pro-inflammatory circulating cytokines (IL-3,4,6, and 18) were elevating as CP was reduced, but this inflammatory response was reduced equal to the 20% CP control when *Spirulina* was added (Mullenix et al., 2021). Further testing by Mullenix (2021) indicated that the culprit behind increased inflammation as CP is reduced may be leaky gut syndrome. Indeed, the research of Mullenix (2021) revealed numerous benefits from reductions in dietary CP (i.e., reduced water intake and foot pad lesions), but future research addressing diet amino acid supply for optimal gut health in low CP diets is warranted.

CONCLUSIONS

Reductions in dietary CP will continue to be achieved as feed grade amino acids become available. However, balancing diet needs for birds' intestinal health may dictate dietary amino acid supply. As alternative protein sources are commercialized, *Spirulina* has promise as an upcoming feed ingredient for broilers.

REFERENCES

1. Bishop, W.M. and H.M. Zubeck. 2012. Evaluation of Microalgae for use as Nutraceuticals and Nutritional Supplements. Journal of Nutrition and Food Sciences 2:147.

2. FAO. 2008. A review on culture, production, and use of Spirulina as food for humans and feeds for domestic animals and fish. Fisheries and Aquaculture Circular. No. 1034, Food and Agriculture Organization of the United Nations, Rome, Italy.

3. Hartman, G.L., E.D. West, and T.K. Herman. 2011. Crops that feed the World 2. Soybean worldwide production, use, and constraints caused by pathogens and pests. Food. Sec. 3:5-17.

4. Henrikson, R. 1994. "Superfood Spirulina microalgae future", Microalgae Spirulina, superalimento del futuro. 2nd ed. Ronore Enterprises; 222 p

5. Ikeda, M. 2003. The amino acid production process. In: Faurie, R., Thommel, J. (eds.) Adv. Biochem. Eng. Biotech. 79:1-36.

6. Kidd, M. T., P. B. Tillman, P. W. Waldroup, and W. Holder, 2013. Feed-grade amino acid use in the United States: The synergetic inclusion history with linear programming. J. Applied Poul. Res. 22:583-590.

7. Kinoshita, S., S. Udaka, and M. Shimono, 1957. Studies of the amino acid fermentation, part I. Production of L-glutamic acid by various microorganisms. J. Gen. Appl. Microbiol. 3:193-205.

8. Mullenix, G. J. 2021. Efficacy of Spirulina (Arthrospira platensis) Utilization in Broiler Diets. Dissertation, University of Arkansas, Fayetteville.

9. Mullenix, G. J., C. J. Maynard, C. M., Owens, S. J., Rochell, W. G., Bottje, R. D., Brister, M. T., Kidd 2022. Spirulina platensis meal inclusion effects on broilers fed a reduced protein diet. Journal of Applied Poultry Research, 31, 100199.

10. Mullenix, G. J., E. S. Greene, N. K., Emami, G., Tellez-Isaias, W. G., Bottje, G. F., Erf, M. T., Kidd, and S. Dridi. 2021. Spirulina platensis inclusion reverses circulating pro-inflammatory (Chemo)cytokine profiles in broilers fed low-protein diets. Front. Vet. Sci., 8, 640968.

11. Suman, G., M. Nupur, S. Anuradha, and B. Pradeep. 2015. Single Cell Protein Production: A Review. International Journal of Current Microbiology and Applied Sciences, 4(9): 251-262.

12. Wittmann, C. and J. Becker, 2007. The L-lysine story: From metabolic pathways to industrial production. In. Wendisch V. F. (ed.) Amino acid biosynthesis-pathways, regulation and metabolic engineering. 39-70.

Table 1. Broiler diet changes in response to feed grade amino acid source offerings¹

Ingredients	Resultant diet CP level and ingredient inclusions (%)					
	24.7	24.3	22.2	20.0	20.0	17.4
Corn	43.0	44.4	57.7	53.4	61.8	73.1
Soybean meal	38.1	36.9	35.1	28.8	21.2	10.6
Distiller's grains	10.0	10.0	3.6	10.0	10.0	10.0
Methionine	0.23	0.24	0.31	0.30	0.36	0.44
Lysine ²	0.01	0.04	0.15	0.28	0.51	0.83
Threonine	0.03	0.05	0.12	0.15	0.25	0.39
Isoleucine		0.02	0.11	0.13	0.24	0.39
Valine			0.09	0.11	0.22	0.37
Arginine				0.10	0.35	0.59
Tryptophan					0.03	0.08
Histidine ²						0.11

Table 2. Amino acid analyses of soybean meal and Spirulina relative to crude protein (CP)^{1,2}

¹Digestible lysine (1.22% of diet) and subsequent ratios in the formulation exercise were: methionine + cystine 0.75; threonine 0.68; arginine 1.05; valine 0.77; isoleucine 0.66; tryptophan 0.16; and histidine 0.35.

²Sources of Cl salts.

Analysis	Soybean	Spirulina ⁴				Spirulina
	Meal ³	A	B	C	D	SID ⁵
Met	1.4	2.5	2.3	2.3	2.5	86.8
Cys	1.5	0.9	0.9	0.9	1.0	86.5
Lys	6.2	4.5	4.6	4.7	4.3	86.1
Thr	3.9	4.9	4.9	4.9	4.8	85.2
Val	4.7	5.6	5.6	5.3	5.7	83.2
Ile	4.5	5.4	5.4	5.3	5.5	83.9
Arg	7.3	6.3	6.2	6.4	6.0	86.4

¹Amino acids represented total analyzed levels relative to ingredient CP. Adapted from Mullenix (2021).

² Funding for some of the research presented herein was provided by USDA-NIFA SAS (#2019 69012-29905) and the Division of Agriculture, University of Arkansas, Fayetteville AR 72701.

³NRC (1994).

⁴Represents analyses from four separate *Spirulina* batches.

⁵Represents standardized ileal digestibility from batch A.

Plenary Session 5:

NON-SOY PROTEIN SOURCES

NUTRITIONAL CONFLICTS IN USING PROCESSED ANIMAL PROTEINS: NEW PERSPECTIVE ON THEIR USE

D. Józefiak and B. Kierończyk

Department of Animal Nutrition, Poznan University of Life Sciences

damian.jozefiak@up.poznan.pl

The protein supply for European poultry compound feeds is highly dependent on soybean import, which is close to 17 million metric tons per year. Local production of soybean tripled in the last years, while 3 million metric tons were harvested last year. However, it is still far from meeting the market demand. On the other hand, on average 30 to 48% of animal by-products are coming each year from animal industry depending on the animal species and post-slaughter values, generating a source of the protein and fat in recycling. In this scenario PAPs may play an important role while according to the European Fat Processors and Renderers Association (EFPRA) 18.6 MT of different animal origin raw by-products on over 400 production lines are converted into 3 million tons of fat and 4.1 million tons of animal protein classified into 3 different categories. It should be stressed here that in poultry nutrition only category 3 (CAT3) can be used, which originates from different sources such as slaughter animal by-products whether suitable or not for human consumption provided they pose no risk to animals, humans and the environment, as well as domestic catering waste. While the currently binding legislation regulating PAPs in the EU allows to use only porcine proteins in poultry nutrition (cross-feeding), it should be pointed out that out of 2.85 million tons of CAT3 only approximately 0.45 MT is porcine PAPs, including blood meal and its fractions.

In 2022 in the European poultry industrial feed sector production was reduced by 3.4% compared to the previous year. The main reason is connected with the occurrence of avian influenza across Europe as well as increased production costs, resulting from feed, energy, labor and inflation. However, still more than 50 million metric tons of compound feed are produced per year. Assuming that porcine PAPs would be present in only 3% in all poultry feeds produced by the EU feed industry, 1.5 MT is needed only to cover domestic market needs. However, despite the fact that in September 2021 amendments in Annex IV of EU Regulation (EC) No. 999/2001 were passed, allowing the application of PAPs in poultry production, the availability and application of PAPs are limited and consequently few feed producers have started to use PAPs again. While animal by-products are still present, the question arises what has changed in the last 20 years, and who is the main consumer of PAPs in Europe.

The first not only nutritional, but also economic conflict, which should be listed when talking about the use of processed animal proteins is the pet food industry. Dogs (93 million) and cats (113 million) are the pets present in 46% of European homes and consuming annually over 10 million metric tons of various pet food diets. Today companion animals, particularly dogs and cats, are considered family members. The main trend in the recent years in the pet food industry is connected with humanization of companion animals resulting in the growth of premium brands, particularly in the market share of products claimed as natural and organic. Therefore, one of the outcomes of this humanization trend is the greater demand for meat type products and the presence of grain-free, gluten-free and fresh meat based diets. The PAP producers dynamically followed the pet food industry and today according to EFPRA 2.15 MT out of 2.85 MT of PAPs (CAT3) produced in the EU are used in dog and cat nutrition. Moreover, application of different meat and bone meal, feather or blood meals is not as restricted as in poultry nutrition, while no cross-feeding procedure is needed, so different PAPs can be mixed in one formulation, including multispecies meals. Finally the pet food industry is still growing by approximately 3.5% annually,

in terms of willingness to pay more for different types of PAPs than any other feed sector and even buying human grade products, particularly meat and fats. Therefore one of the key factors affecting usage of PAPs in the EU is currently their price and availability driven by pet food. Today, most rendered animal by-products are simply too expensive in the least cost formulation systems used in poultry nutrition. Moreover, the growing usage in the pet food industry will continue and likely PAP prices will also increase. This situation will not change in the coming years, while dogs and particularly cats need animal origin protein, and they owners called today “petsumers” are willing to pay much higher prices for petfood, expecting that it is human grade and based on quality proteins. This is hard competition for the poultry feed industry and we should not expect changes increasing PAP availability for poultry.

Since 2001 PAP usage has been limited and most of the EU raised fowl became vegetarians. Therefore maybe we should post the question if we need PAPs in chicken or turkey diets. Looking at modern poultry meat and egg production it seems that we forgot many evolutionary adaptations present in birds in the natural environment. Chickens, turkeys and quail belong to the Galliformes, but this is a much larger order representing over 200 species, including pheasants, quails, guinea fowl and partridges. In natural conditions all of those species have different nutritional strategies and should be characterized as omnivores rather than granivores. This is not only reflected in the composition of their diets, nutritional requirements, but also anatomy and functions of their gastrointestinal tract. However, one common feature should be indicated here, which is an evolutionary adaptation to flight. Birds tend to choose feed with the highest concentration of digestible nutrients. Therefore even herbivorous birds select plant parts that are relatively high in protein and low in fiber, such as rhizomes, buds, flowers, catkins, very young leaves, and young grasses. Modern broiler chickens originate from the Red Jungle Fowl (*Gallus gallus*), originating in Southeast Asia and in wild populations their diet is in 60% based on invertebrates, mainly termites and their eggs. Studies conducted on turkeys in natural conditions also demonstrate the importance of diet diversification, while in 524 turkey crops and gizzards from Virginia 350 plant species and 300 invertebrate species were identified. Therefore from the evolutionary point of view, in most of the Galliformes animal origin proteins play an important role and were present long before the introduction of selective breeding and compound feed production. In contrast, commercial production of poultry meat demonstrates that usually birds perform very well on vegetarian diets. On the other hand, many metabolic disorders resulting in wet litter as well as higher water consumption are also linked to antinutritional factors found in plant material. Therefore replacing a part of soybean meal with PAPs can improve performance of turkey poult in the first stage of rearing. For years PAPs, particularly meat and bone meals, have been considered not only as a source of protein, but also energy derived from fat, as well as different minerals, particularly organic phosphorus, which is not associated with phytic acid, thus considered as more available than P present in plant origin raw materials. Therefore some research suggests that incorporation of 5% meat and bone meal (MBM) is sufficient to eliminate inorganic P reducing feed costs. In contrast, true ileal P digestibility in broiler chickens fed soybean base diets was estimated at 74-83%, while in the case of MBM true ileal P digestibility ranged from 42 to 69%.

Another potential conflict in the application of PAPs, particularly MBM and fishmeal, is their effect on gastrointestinal microbiota. It is well demonstrated that the dietary protein source (animal vs. plant) play an important role in the development of *Clostridium perfringens* populations. While a significant correlation ($P < 0.05$) between the level of dietary glycine and the numbers of *C. perfringens* in the ileum and cecum, suggesting that animal origin proteins stimulate proliferation of *C. perfringens* mainly due to 2-4 higher levels of glycine in amino acid profiles. Therefore for many years fishmeal was considered as an important factor contributing to the development of necrotic enteritis (NE) in studies on broiler chickens and most of the infection models are based on 2-5% fishmeal inclusion in the diets. Regarding MBM and its possible role in proliferation of *C. perfringens* and/or NE not much data is available. In recent years much attention has been paid to alternative proteins in animal nutrition, in the case of PAPs not many new products have been launched on the market with one exception, i.e. insect biomass. However, we should pose the

question whether this is a real alternative and something totally new or rather a natural choice for birds, applied in their natural nutritional strategies for over 60 million years? In contrast to other PAPs, insects contain two functional fractions such as chitin and antimicrobial peptides (AMPs). According to the Antimicrobial Database (aps.unmc.edu), to date 326 AMPs have been identified from insects. At present two main insect species are produced for animal nutrition: the black soldier fly (*H. illucens*) and mealworms (*T. molitor*), with both containing AMPs. The inhibition activities of AMPs extracted from *H. illucens* have been proven against gram-negative bacteria, *E. coli*, *E. coli* serotype O157:H7, *Salmonella pullorum*, *S. typhimurium*, *S. enteritidis*, *Enterobacter aerogenes*, and *Pseudomonas aeruginosa*; gram-positive bacteria: *Staphylococcus aureus*, methicillin-resistant *S. aureus* (MRSA), *S. epidermidis*, *Streptococcus suis*, *Listeria ivanovii*, *Bacillus subtilis*, and *Micrococcus luteus*; as well as fungi, *Rhizoctonia solani*, *Sclerotinia sclerotiorum*, and *Candida albicans*. Therefore, besides nutritional properties of insect proteins and fats there could be important effects on gut health, which maybe already is used by birds in natural nutritional strategies. However, similarly to other PAPs we observe a conflict in their availability and economy. Insect industrial production is a new branch of agriculture, which is developing dynamically in many EU countries, although the currently produced amounts are limited and mostly used in the pet food and aquaculture sectors.

Finally, one important factor should be mentioned here in connection with all PAPs, i.e. energy. Rendering is a process consuming gas and electricity at many steps of pasteurization, drying and milling, therefore PAP prices are greatly dependent on energy cost and supply. Therefore, in the coming years European poultry companies will be dependent on fluctuations of energy costs not only in terms of animal rearing or feed production, but also indirectly on raw materials. Prospects on the production and usage of new PAPs are improving for instance with every new insect protein factory being opened; however, it will take several years to meet the market demand.

Plenary Session 5: NON-SOY PROTEIN SOURCES

INSECTS IN POULTRY FEEDING: REGULATORY ISSUES AND PRODUCTIVE UPDATES

T. Veldkamp, S. Naser El Deen, and A. Rezaei Far

Wageningen University & Research, Wageningen Livestock Research (WLR), De Elst 1, 6700 AH Wageningen, the Netherlands

teun.veldkamp@wur.nl

POULTRY PRODUCTION AND SUSTAINABILITY

Poultry production, which contributes more than 30% of protein for human consumption globally through meat and eggs due to its high nutritional value and affordability, is expected to grow further. This increased demand for poultry products implies an increase in demand for poultry feed. To improve the sustainability of the poultry value chain, sustainability aspects related to the feed ingredients used in poultry feed must be considered and finding sustainable feed ingredients would be an important step toward more sustainable poultry production. The substitution of soybean meal by locally derived protein sources will most likely result in increased sustainability in terms of land use, energy use, and emissions. Insect farming, as a sustainable, environmentally friendly agricultural practice, can avoid overexploitation of natural resources by converting organic side-streams and biowaste into high-quality insect products. Producing insect protein requires a fraction of the space required to produce the same amount of protein from soybeans. Housefly (HF, *Musca domestica*) and black soldier fly (BSF, *Hermetia illucens*) rearing on 1 hectare of land, for example, could produce at least 150 tons of insect protein per year, compared to less than a ton of soybeans protein for the same area (Dunkel and Payne, 2016). Furthermore, the use of organic side-streams and biowaste from various agricultural processes reduces the amount of land used for insect feed production. Compared to other agricultural activities, insect farming has a low water footprint, with the most footprint attributed to insect feed (Miglietta et al., 2015). Oonincx (2021) reviewed the first studies on the environmental impact of insect farming, which revealed that land use associated with insect production was generally low in comparison to conventional feed ingredients. When insects are reared in temperate climates, which require extensive climate control, the energy use of insect production is often high compared to conventional products. Aside from the energy consumed during the rearing process, the commercial allowed feedstock accounts for a significant portion of the environmental impact. This effect can be mitigated by using low impact feedstock, assuming that feed can be used efficiently, lowering the environmental impact of insect production. As the sector develops, increased efficiency and thus reduced environmental impact are expected. Based on the foregoing, insect farming has the potential to be a sustainable and environmentally friendly agri-food sector producing more sustainable alternative ingredients for the feed sector. Replacing conventional ingredients with insect products in poultry feed could reduce the environmental impact of chicken meat and egg.

INSECT PRODUCTIVE UPDATE

For the implementation of insect products in poultry feed, it is required to deliver large volumes with a consistent nutritional composition and quality. Currently, insect production is taking place at different scales globally. Small-scale farmers can benefit greatly from the production of insects for feed (Barragán-Fonseca et al., 2020). Most producers begin on a small-scale to learn how to optimize conditions for the insects in terms of substrate preparation, handling larvae and

adults, egg production, and harvesting time. After a successful start, they may eventually scale up to moderate or even large-scale production units (van Huis and Tomberlin, 2017). Small-scale producers can form organized cooperatives to centralize processing, reducing the need for higher investment and costs while meeting feed mills' constant, high-volume demand. In addition to small-scale producers, insect products may need to be produced on a large and highly automated scale while adhering to strict quality and safety standards. If these new products are included in feed formulations for various animals, feed manufacturers must ensure that the necessary quantity, quality, and supply are available in the various insect-derived products. Establishing a full-scale insect rearing unit could cost several million dollars. However, these units are adapted to global market needs, dealing with higher production capabilities, product quality demands, and feed safety regulations that small scale producers find more difficult to meet. Currently most of the insect farms are SMEs (e.g. small enterprises, with 10 to 50 employees or medium enterprises, with 50 to 250 employees). Micro enterprises (1 to 10 employees) also represent more than 40% of the companies active in feed production. By the end of the decade, it is expected that almost 1 out of 2 insect farms will be a large enterprise – with over 250 employees (Figure 1). Total production of the European insect sector may reach 1 million tonnes of insect meal by 2030 (IPIFF, 2021).

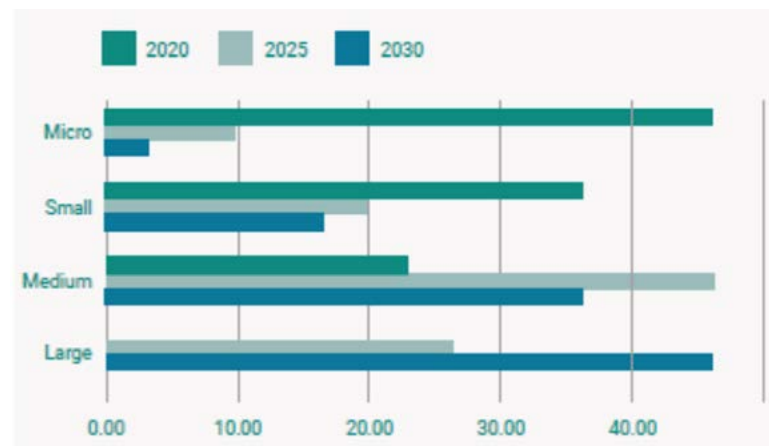


Figure 1. Relative share of insect feed business operators by company size in total production (IPIFF, 2021)

As is currently the case in agriculture and livestock production in general, future insect producers may opt for a decentralized system with many producers specializing in every stage of the insect production chain (e.g., breeding, rearing, and processing). Insect production can benefit from existing knowledge in other livestock sectors, such as breeders, fatteners, and processors.

FACTORS AFFECTING THE NUTRITIONAL COMPOSITION OF INSECTS

The nutrient composition of insects may vary depending on life stage (Kipkoech et al., 2017), sex (Meyer-Rochow et al., 2021), processing methods (Oonincx and Finke, 2021), and substrate, also called feedstock (Naser El Deen et al., 2023). For instance fatty acid and mineral composition of yellow mealworm (YMW, *Tenebrio molitor*), house cricket (HC, *Acheta domesticus*), lesser mealworm (LMW, *Alphitobius diaperinus*), and BSF can be altered by substrate (Dreassi et al.,

2017, Oonincx et al., 2020, Spranghers et al., 2017). Aside from the nutritional properties of insects, the substrate can have a significant impact on their nutraceutical properties, such as the antioxidant activity of the larvae (Andreadis et al., 2022) and antimicrobial peptides (AMPs) in larvae (Vogel et al., 2018). These bioactive compounds could contribute to the immune modulation and the health promoting effects that have been observed by including insect products in poultry (de Souza Vilela et al., 2021, Facey et al., 2023). Including insect products in the diet of broilers can enhance immune response during microbial infections and increase survivability of broilers (Lee et al., 2018). Considering the antimicrobial and antibacterial activity of several insect peptides (Veldkamp et al., 2022), it is clear that there is still much to learn about modulating insect composition via the feeding substrate, not only to produce insects of high nutritional quality, but also insects that could promote animal health when used as feed ingredients. Depending on the producer, insect products can range from fresh and frozen larval biomass as final products to processed products (larval puree, insect meals, and insect oils), or highly purified bio-components. The low consistency of insect products can be attributed to the various substrates used by producers, which are frequently made up of a mixture of several side-streams. Biomass collection, delivery, and processing can have a significant impact on production costs, so producers must ensure its availability and, ideally, stability throughout the year. Research is now focusing on the safety of using substrates that are currently not yet legally allowed to grow insects, which may contribute to increased insect production capabilities. Large quantities of substrates with consistent quality, frequent delivery, and a reasonable price are required for the widespread use of insect products in poultry feed. As a result, further scaling up of the insect chain is required, and a consistent supply of raw materials is critical.

INSECT PRODUCTS IN POULTRY FEED

There are numerous applications for insect products in poultry feed. Whole insects can be processed, and the nutrient composition of the derived products (meals and oils) can change as a result. The insect industry relies on dry fractionation, which produces partially defatted meals with a crude protein (CP) content of 50-65% (DM) and an ether extract (EE) content of 8-10% (DM). The defatting process can be improved further by using solvents, resulting in highly defatted meals containing approximately 58-70% CP and 4-6% EE (DM) (Ravi et al., 2021). Compared to full-fat meals, defatted meals are more digestible by monogastrics (Schiavone et al., 2019), and are also more stable, richer in proteins, and employable at higher rates in diets for poultry. Wet fractionation is also possible by steam-blanching the larvae, which can be chemically or enzymatically pre-treated with protease or chitinase enzymes. They are then processed into a chitin-rich press cake (similar to a partially defatted meal) and a juice that, when centrifuged further, yields four distinct fractions with high CP (aqueous and solid fractions) and EE contents (lipid and cream fractions) (Ravi et al., 2021). This alternative processing method also provides significant benefits to the insect industry, as product diversification allows for increased yields in proteins, lipids, and chitin, as well as providing the market with products that can be easily incorporated into various feed formulations (Ravi et al., 2021). Insects have an excellent nutrient profile, particularly in terms of CP content and amino acid (AA) profile. Insects with the highest potential as poultry feed ingredients, such as BSF, HF, and YMW, contain 35% to 60% CP (as whole and expressed in dry matter, DM), which is typically higher than SBM (DiGiacomo and Leury, 2019, Koutsos et al., 2019). When comparing protein composition data, pay close attention to the nitrogen-to-protein (N-P) conversion factor used to calculate protein content. Indeed, the conventional N-P factor of 6.25 overestimates the true content, and more appropriate N-P factors have been proposed (Janssen et al., 2017). Because of their higher content in some essential AAs (mainly lysine, valine, and – for some insect species – methionine), BSF, HF, and YMW have a better amino acid (AA) profile than SBM (DiGiacomo and Leury, 2019,

Hong et al., 2020). The CP and AA digestibility in insect meals is generally good to high, with apparent digestibility coefficients ranging from 51 to 90% (Lee et al., 2022) and from 42 to 99% (Oonincx and Finke, 2021), respectively. In addition to protein and AAs, insects are a good source of lipids (10-30%), which are also highly digestible by monogastrics, with EE apparent digestibility coefficients ranging from 78 to 99% (Gasco et al., 2022, Lee et al., 2022), and minerals such as calcium (DiGiacomo and Leury, 2019).

EU LEGISLATION AND REGULATION

IPIFF's website (<https://ipiff.org/insects-eu-legislation/>) contains European legislative and regulatory documents. In accordance with EU regulations in the areas of food and feed hygiene, insect producers have to adhere to best hygiene practices, comply with traceability requirements and follow appropriate mitigation and risk management procedures in case of a safety incident. Operators of insect feed businesses must implement a permanent procedure or procedures based on HACCP principles. As a resource for insect producers, IPIFF has created a good practices guide (IPIFF, 2022) with the aim to support the effective implementation of EU food and feed safety legislation. With a few exceptions, farmed insects in the European Union can only be fed vegetal materials (EU, 2011). Research on not yet allowed feed side-streams is ongoing on the bio-conversion properties and safety of insects which can upcycle these otherwise unsuitable materials into suitable feed materials (FEFAC, 2022). Feed safety should be prioritized, so expanding the substrate spectrum should be accompanied by a safety evaluation. The Regulation (EU) 2017/893 authorised the use of PAPs derived from insects and compound feed containing such processed animal protein for feeding aquaculture animals in 2017. The legislative breakthrough of 2017 was followed by a milestone in 2021, when the authorized use of insect processed animal proteins (PAPs) was extended to the pig and poultry sectors (EU, 2021).

REFERENCES

1. ANDREADIS, S. S., PANTELIS, N., MASTORAKI, M., RIZOU, E., STEFANOPOULOS, V., TZENTILASVILI, S., SARROU, E., CHATZIFOTIS, S., KRIGAS, N. and ANTONOPOULOU, E. (2022) Towards functional insect feeds: Agri-food by-products enriched with post-distillation residues of medicinal aromatic plants in *tenebrio molitor* (coleoptera: Tenebrionidae) breeding. *Antioxidants* 11: 68.
2. BARRAGÁN-FONSECA, K. Y., BARRAGÁN-FONSECA, K. B., VERSCHOOR, G., VAN LOON, J. J. A. and DICKE, M. (2020) Insects for peace. *Current Opinion in Insect Science* 40: 85-93.
3. DE SOUZA VILELA, J., ANDRONICOS, N. M., KOLAKSHYAPATI, M., HILLIAR, M., SIBANDA, T. Z., ANDREW, N. R., SWICK, R. A., WILKINSON, S. and RUHNKE, I. (2021) Black soldier fly larvae in broiler diets improve broiler performance and modulate the immune system. *Animal nutrition* 7: 695-706.
4. DIGIACOMO, K. and LEURY, B. J. (2019) Review: Insect meal: A future source of protein feed for pigs? *Animal* 13: 3022-3030.
5. DREASSI, E., CITO, A., ZANFINI, A., MATEROZZI, L., BOTTA, M. and FRANCARDI, V. (2017) Dietary fatty acids influence the growth and fatty acid composition of the yellow mealworm *tenebrio molitor* (coleoptera: Tenebrionidae). *Lipids* 52: 285-294.
6. DUNKEL, F. V. and PAYNE, C. (2016) Chapter 1 - introduction to edible insects, in: DOSSEY, A. T., MORALES-RAMOS, J. A. & ROJAS, M. G. (Eds) *Journal*, pp. 1-27 (San Diego, Academic Press).
7. EU (2011) Regulation (eu) no. 142/2011 of 25 february 2011 implementing regulation (ec) no 1069/2009 of the european parliament and of the council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing council directive 97/78/ec as regards certain samples

and items exempt from veterinary checks at the border under that directive, *Journal*, (Brussels, Belgium).

8. EU (2021) Commission regulation (eu) 2021/1372 of 17 august 2021 amending annex iv to regulation (ec) no 999/2001 of the european parliament and of the council as regards the prohibition to feed non-ruminant farmed animals, other than fur animals, with protein derived from animals., *Journal*, pp. 1-17. (Official Journal).
9. FACEY, H., KITHAMA, M., MOHAMMADIGHEISAR, M., HUBER, L.-A., SHOVELLER, A. K. and KIARIE, E. G. (2023) Complete replacement of soybean meal with black soldier fly larvae meal in feeding program for broiler chickens from placement through to 49 days of age reduced growth performance and altered organs morphology. *Poultry science* 102: 102293.
10. FEFAC (2022) Fefac circular factsheet "circular feed – optimised nutrient recovery through animal nutrition". 21.
11. GASCO, L., CAIMI, C., TROCINO, A., LUSSIANA, C., ODDON, S. B., MALFATTO, V., ANEDDA, R., SERRA, G., BIASATO, I., SCHIAVONE, A., GAI, F. and RENNA, M. (2022) Digestibility of defatted insect meals for rainbow trout aquafeeds. *Journal of Insects as Food and Feed* 8: 1385-1399.
12. HONG, J., HAN, T. and KIM, Y. Y. (2020) Mealworm (*tenebrio molitor* larvae) as an alternative protein source for monogastric animal: A review. *Animals* 10: 2068.
13. IPIFF (2021) Ipiff factsheet "an overview of the european market of insects as feed", *Journal*.
14. IPIFF (2022) Ipiff guide on good hygiene practices for european union producers of insects as food and feed – updated september 2022, *Journal*, (Brussels, Belgium).
15. JANSSEN, R. H., VINCKEN, J.-P., VAN DEN BROEK, L. A. M., FOGLIANO, V. and LAKEMOND, C. M. M. (2017) Nitrogen-to-protein conversion factors for three edible insects: *Tenebrio molitor*, *alphitobius diaperinus*, and *hermetia illucens*. *Journal of Agricultural and Food Chemistry* 65: 2275-2278.
16. KIPKOECH, C., KINYURU, J. N., IMATHIU, S. and ROOS, N. (2017) Use of house cricket to address food security in kenya: Nutrient and chitin composition of farmed crickets as influenced by age. *African Journal of Agricultural Research* 12: 3189-3197.
17. KOUTSOS, L., MCCOMB, A. and FINKE, M. (2019) Insect composition and uses in animal feeding applications: A brief review. *Annals of the Entomological Society of America* 112: 544-551.
18. LEE, J.-H., KIM, T.-K., CHA, J. Y., JANG, H. W., YONG, H. I. and CHOI, Y.-S. (2022) How to develop strategies to use insects as animal feed: Digestibility, functionality, safety, and regulation. *Journal of Animal Science and Technology* 64: 409-431.
19. LEE, J., KIM, Y. M., PARK, Y. K., YANG, Y. C., JUNG, B. G. and LEE, B. J. (2018) Black soldier fly (*hermetia illucens*) larvae enhances immune activities and increases survivability of broiler chicks against experimental infection of salmonella gallinarum. *J Vet Med Sci* 80: 736-740.
20. MEYER-ROCHOW, V. B., GAHUKAR, R. T., GHOSH, S. and JUNG, C. (2021) Chemical composition, nutrient quality and acceptability of edible insects are affected by species, developmental stage, gender, diet, and processing method. *Foods* 10: 1036.
21. MIGLIETTA, P. P., DE LEO, F., RUBERTI, M. and MASSARI, S. (2015) Mealworms for food: A water footprint perspective. *Water* 7: 6190-6203.
22. NASER EL DEEN, S., VAN ROZEN, K., ELISSEN, H., VAN WIKSELAAR, P., FODOR, I., VAN DER WEIDE, R., HOEK-VAN DEN HIL, E. F., REZAEI FAR, A. and VELDKAMP, T. (2023) Bioconversion of different waste streams of animal and vegetal origin and manure by black soldier fly larvae *hermetia illucens* l. (diptera: Stratiomyidae). *Insects* 14: 204.
23. OONINCX, D. G. (2021) Environmental impact of insect rearing (CABI International).

24. OONINCX, D. G. A. B. and FINKE, M. D. (2021) Nutritional value of insects and ways to manipulate their composition. *Journal of Insects as Food and Feed* 7: 639-659.
25. OONINCX, D. G. A. B., LAURENT, S., VEENENBOS, M. E. and VAN LOON, J. J. A. (2020) Dietary enrichment of edible insects with omega 3 fatty acids. *Insect Science* 27: 500-509.
26. RAVI, H. K., GUIDOU, C., COSTIL, J., TRESPEUCH, C., CHEMAT, F. and VIAN, M. A. (2021) Novel insights on the sustainable wet mode fractionation of black soldier fly larvae (*hermetia illucens*) into lipids, proteins and chitin. *Processes* 9: 1888.
27. SCHIAVONE, A., DABBOU, S., PETRACCI, M., ZAMPIGA, M., SIRRI, F., BIASATO, I., GAI, F. and GASCO, L. (2019) Black soldier fly defatted meal as a dietary protein source for broiler chickens: Effects on carcass traits, breast meat quality and safety. *Animal* 13: 2397-2405.
28. SPRANGHERS, T., OTTOBONI, M., KLOOTWIJK, C., OVYN, A., DEBOOSERE, S., DE MEULENAER, B., MICHIELS, J., EECKHOUT, M., DE CLERCQ, P. and DE SMET, S. (2017) Nutritional composition of black soldier fly (*hermetia illucens*) prepupae reared on different organic waste substrates. *Journal of the Science of Food and Agriculture* 97: 2594-2600.
29. VAN HUIS, A. and TOMBERLIN, J. K. (2017) Insects as food and feed: From production to consumption.
30. VELDKAMP, T., DONG, L., PAUL, A. and GOVERS, C. (2022) Bioactive properties of insect products for monogastric animals – a review. *Journal of Insects as Food and Feed* 8: 1027-1040.
31. VOGEL, H., MÜLLER, A., HECKEL, D. G., GUTZEIT, H. and VILCINSKAS, A. (2018) Nutritional immunology: Diversification and diet-dependent expression of antimicrobial peptides in the black soldier fly *hermetia illucens*. *Developmental & Comparative Immunology* 78: 141-148.

Plenary Session 5:

NON-SOY PROTEIN SOURCES

INSECTS IN POULTRY FEEDING: TRANSLATING RESEARCH OUTCOMES INTO PRACTICEAchille Schiavone¹ and Annelisse Castillo²¹Dipartimento di Scienze Veterinarie - University of Turin (Italy). L.go Paolo Braccini 2; 10095 Grugliasco (TO) - University of Turin (Italy)²Dipartimento di Scienze Veterinarie - University of Pisa (Italy). V.le delle Piagge 2; 56124 Pisa (Italy)

achille.schiavone@unito.it

The consumer's demand for animal products still increases, and further increase is expected determined by the global population growth, therefore the food industry and the farmers face a great challenge (Avendaño, Sánchez, and Valenzuela 2020; WHO 2007; Govorushko 2019). Different aspects of the productive chain need to be further optimised and improved, since the consumer becomes more demanding and selective too. The increase production of animal origin foods generates a huge pressure in the environment, the water sources, and the biodiversity, with consequential climate changes (Avendaño, Sánchez, and Valenzuela 2020).

The major cost in a farm production cycle is represented by the feed, for instance in broilers, around 60 % of cost engravement is due to the feed needed to produce 1 kg of meat (Centro Ricerche Produzioni Animali, 2011). Besides, the feed ingredients used and how these are processed engrave not only the monetary aspect, but also the bird's performance (Avendaño, Sánchez, and Valenzuela 2020). High protein components are necessary for the bird's growth and for a high productivity (Sverguzova et al. 2021). Plant proteins represent the main supply source, and soybean meal is the most used in the poultry feed industry, mainly due to a balanced profile in essential amino acids (Beski, Swick, and Iji 2015; Ravindran 2013). However, this is not the rule in other plant sources, which in most cases lack a balanced essential amino acids profile. Contrarily, proteins of animal origin offer a high biological value protein, even if these are often more expensive (Saima et al. 2008; Beski, Swick, and Iji 2015). The resources needed to produce conventional protein feedstuffs are considerable, becoming economically unsustainable (Gasco et al. 2019), therefore new strategies and feedstuffs are being studied and progressively becoming more tested and adopted (Avendaño, Sánchez, and Valenzuela 2020; Bellezza Oddon et al. 2021; Colombino et al. 2021). The use of insects in poultry feed has received huge interest as a potential solution to improve sustainability of poultry diets. Insects are proficient in converting agricultural and biological residues in high qualitative nutrients, reducing drastically gas emissions and waste mass (Avendaño, Sánchez, and Valenzuela 2020; T. Veldkamp et al. 2022). Insects are high in protein and fat content, and provide other nutrients like macro and micro minerals, vitamins, etc. Insects contain bioactive compounds such as antimicrobial peptides, fatty acids, and polysaccharides, which might give protection against oxidative tissue damage and defend against microbial threats (Veldkamp et al. 2022). A wide range of insects are potential candidates as protein source, and the most studied and used insects in poultry feeding are the black soldier fly (*Hermetia illucens*), common housefly (*Musca domestica*) and mealworm (*Tenebrio molitor*) (Avendaño, Sánchez, and Valenzuela 2020). Insects are also versatile, being offered in different forms as meals, oils, dehydrated or live larvae (Veldkamp and van Niekerk 2019; Gasco et al. 2019).

A higher importance should be given to the knowledge of the natural behaviour of birds, to keep farm birds under conditions able to satisfy the animal's welfare. Farming conditions should be able to give birds the possibility to express as much as possible their natural behaviours. Fortunately, an increasing concern on the farm animal's welfare has been developed not only by the farmers, but by the consumers also, and the use of live insects in the bird's diet may highly contribute to this purpose. In this sense, few studies have been focused on testing the bird's response and beneficial effects the dietary inclusion of live insects may produce (Biasato et al. 2022; Tahamtani et al. 2021; Colombino et al. 2021; Bellezza Oddon et al. 2021; Star et al. 2020; Ipema et al. 2020; Veldkamp and van Niekerk 2019; Bongiorno et al. 2022; Ipema et al. 2022). However, scientists have realised the importance of this practice, and most probably in the near future an increasingly number of papers will be published, analysing several aspects which need to be considered, for instance: a) the bird species and their physiological state and age; b) edible insect species used and which developmental stage to use; c) time, amount, frequency and mode of provision of the insects.

Under natural conditions, poultry reveals their feeding behaviour, eating a wide-ranging diet, which includes ingredients differing for their nutritional value, and from which the bird may choose to satisfy its daily nutritional requirements. Throughout the daily routine, the two important meals occur at dawn and at dusk, since the bird needs to refill its crop after depleted overnight, and to refill it for the night (Moreby, Aebischer, and Southway 2006; Mench 2009). However, a great part of the everyday the bird forages for feed. During the foraging, the bird pecks and scratches the ground, and eats. In the case of ducks, they use their bills to sort out food items from the water (Moreby, Aebischer, and Southway 2006; Coppinger 1970; Mench 2009) or when ducks find hard, unusual or an unknown tasty food, they use to soak it into water to render it "eatable". The time dedicated to feeding might be influenced by the type of feed the bird is able to find and consume, to satisfy its needs. In the case of edible invertebrates, some authors associated the availability of this feed source to the bird's preference, however, other elements are determinant in the bird's choice, for instance colour, size, movement, etc. (Green 1984). In grey partridge chicks, observations reported that when dead insects were offered, their preference was for those larger in size and green-yellow coloured (Moreby, Aebischer, and Southway 2006). Between red-black or green-yellow ant pupae, a preference towards the last two colours was observed (Moreby, Aebischer, and Southway 2006; Potts 1986). Quails prevent red coloured insects, choosing green or black arthropods (Moreby, Aebischer, and Southway 2006). Still in grey partridge chicks, certain dead insect species (*Lasius sp.*, *Bembidion lampros*, and *Lema melanophora*) were rejected, while the same living species were quickly eaten. Larger live insects (*Lygus lineolaris*, *Adelphocoris lineolatus*) were preferred by pheasants, rather than small or very large (moths, grasshoppers) ones (Whitmore, Pruess, and Gold 1986). As describe in previous reports, the prey handling may contribute to the bird's choice, for instance chicks to eat a whole mealworm need to accomplish a complex sequence of actions rather than adequate chick-bill-size preys that might be entirely eaten at once (Moreby, Aebischer, and Southway 2006). Studies have shown that novel food items are often aversive, and that the degree of rejection is related to the previous experience of the bird and how the food differs from the one the bird is used to (Coppinger 1970).

Table 1: Live or whole dried larvae inclusion in poultry diets: inclusion modality, quantity, and related effects on bird.

		bird's age (d)	insect inclusion	daily insect distribution	effects on bird	reference
Broiler chicken	<i>Hermetia illucens</i> ¹	1 to 35	8 % TDDM ²	4 times	Increased bird's activity; increased daily body weight gain; higher final body weight and lower total dry matter intake; better litter quality; food pad dermatitis was less severe	(Ipema et al. 2022)
		1 to 42	10 % FEDI ³	4 times	increased bird's activity; improved leg health; no significant effect on performance	(Ipema et al. 2020)
		4 to 38	5 % FEDI ³	once	no effects on growth and health status; improve caecal microbiota; no effect on mucin composition or local immune response	(Colombino et al. 2021; Bellezza Oddon et al. 2021)
		1 to 42	Basal diet <i>ad libitum</i> + 10%, 20% or 30% defrozed larvae	once	increased foraging; birds more active; reduction of behaviours attributable to frustration; no effect on plumage status, leg health, excreta corticosterone metabolites	(Biasato et al. 2022)
	<i>Tenebrio molitor</i> ¹	4 to 38	5 % FEDI ³	once	no adverse effect on growth and feed conversion ratio with up to 20%, higher levels associated with lower protein utilization	(Seyedalmoosavi et al. 2022)
	<i>Alphitobius diaperinus</i> ¹	3 to 8	7 to 13 mm length larvae on litter, <i>ad libitum</i>	only larvae	no effects on growth and health status; improved feed conversion ratio; improve caecal microbiota; no effect on mucin composition or local immune response	(Bellezza Oddon et al. 2021; Colombino et al. 2021)
		2 to 9	7 to 13 mm length larvae on litter, <i>ad libitum</i>	feed + larvae	increased foraging; birds more active; reduction of behaviours attributable to frustration; no effect on plumage status, leg health, excreta corticosterone metabolites	(Biasato et al. 2022)
	dried maggots	1 to 35	5%, 10%, 15% or 20% OFB ⁴	with feed	chicks had no access to feed, eating exclusively larvae, which causes distress and no weight gain	(Despins and Axtell 1995)
Slow growing chickens	<i>Hermetia illucens</i> ¹	28 to 82	10 % FEDI ³	once	less feed consumption, no effect on weight gain, from 10% to 35% of protein intake from larvae	(Hwangbo et al. 2009)
Laying hen	<i>Hermetia illucens</i> ¹	469 to 546	12.5 g/ hen	6 h period	improved feed conversion ratio and live body weight	(Bongiorno et al. 2022)
		126 to 210	ad libitum (aprox. 52 % OEDMI ⁵) ad libitum or 10 % or 20 % FEDI	163 g	positive effects on feather condition; no effect on performance and egg quality	(Star et al. 2020)
Local chickens	<i>Hermetia illucens</i> ¹	14 until first laid egg	30 - 50 g	three times	decrease feed consumption; increased body weight	(Tahamtani et al. 2021)
	dried maggots	126 to 168	30 min each meal	three times	no effect on egg production, egg weight, shell thickness; no effect on hen behaviour towards a novel food	(Dankwa et al. 2004)
Turkey	<i>Hermetia illucens</i> ¹	0 to 35	10 % FEDI ³	once	approx. consumption: 4.68 g (am) 5.23 g (noon) 4.6 g (pm); no effect on egg parameters; maggots seem to be preferred at noon	(Traoré et al. 2020)
Guinea fowl	dried maggots	308 to 357	50 g	three times	increased daily feed intake and body weight gain; lower feed conversion ratio; reduced aggressive pecking; a tendency of lowered incidence of feather and skin damage	(Veldkamp and van Niekerk 2019)
					preference for cereal grains rather than dried maggots	(Traore et al. 2020)

¹Live larvae; ²total dietary dry matter; ³feed estimated daily intake; ⁴on feed bases; ⁵on estimated dry matter intake.

Since insects are already part of the natural diet of poultry and as shown by the numerous papers published in the past ten years regarding the benefits of the use of dietary insect meals (Veldkamp et al. 2022; Gasco et al. 2019; Elahi et al. 2022), the use of live and/or dried whole insects is highly recommended and should be further studied (Table 1).

Apparently, the substitution at different levels of the bird's diet with live larvae of *Hermetia illucens* or *Tenebrio molitor* might bring wellness to the bird; their foraging behaviour is stimulated so birds become more active, the aggressive pecking is reduced, and good feathers condition is preserved. The productivity in broilers, laying hens and turkeys might be improved and no negative effects have been yet reported. At present, dietary live insect employment might be suitable in organic or free-range productive systems, while the feasibility in intensive productive systems, is reasonable difficult to be adopted, mainly for the huge bird numbers managed in these systems, consequently huge economic and logistic efforts are needed. On the other hand, the highest bird's welfare benefit may be obtained in intensive systems. Hence, it is desirable that soon, with an increasingly number of companies producing live insects, such a practice may become more approachable by all productive systems.

Considering what has been studied until now, further research is recommended, in particular on how the dietary live insect inclusion might influence the quality of life as perceived by the bird, keeping in mind that the animal's welfare is related to how the bird is inclined to behave under natural conditions.

REFERENCES

1. Avendaño, C., M. Sánchez, and C. Valenzuela. 2020. "Insectos: Son Realmente Una Alternativa Para La Alimentación de Animales y Humanos." *Revista Chilena de Nutrición* 47 (6). <https://doi.org/10.4067/s0717-75182020000601029>.
2. Bellezza Oddon, S., I. Biasato, A. Imarisio, M. Pipan, D. Dekleva, E. Colombino, M. T. Capucchio, et al. 2021. "Black Soldier Fly and Yellow Mealworm Live Larvae for Broiler Chickens: Effects on Bird Performance and Health Status." *Journal of Animal Physiology and Animal Nutrition* 105 (S1). <https://doi.org/10.1111/jpn.13567>.
3. Biasato, I., S. Bellezza Oddon, G. Chemello, M. Gariglio, E. Fiorilla, S. Dabbou, M. Pipan, et al. 2022. "Welfare Implications for Broiler Chickens Reared in an Insect Larvae-Enriched Environment: Focus on Bird Behaviour, Plumage Status, Leg Health, and Excreta Corticosterone." *Frontiers in Physiology* 13 (August). <https://doi.org/10.3389/fphys.2022.930158>.
4. Bongiorno, V., M. Gariglio, V. Zambotto, E.E. Cappone, I. Biasato, M. Renna, C. Forte, et al. 2022. "Black Soldier Fly Larvae Used for Environmental Enrichment Purposes: Can They Affect the Growth, Slaughter Performance, and Blood Chemistry of Medium-Growing Chickens?" *Frontiers in Veterinary Science* 9 (December). <https://doi.org/10.3389/fvets.2022.1064017>.
5. Centro Ricerche Produzioni Animali. 2011. "Avicoltura Italiana e Costi Di Produzione."
6. Colombino, E., I. Biasato, I. Ferrocino, S. Bellezza Oddon, C. Caimi, M. Gariglio, S. Dabbou, et al. 2021. "Effect of Insect Live Larvae as Environmental Enrichment on Poultry Gut Health: Gut Mucin Composition, Microbiota and Local Immune Response Evaluation." *Animals* 11 (10). <https://doi.org/10.3390/ani11102819>.
7. Copping, R.P. 1970. "The Effect of Experience and Novelty on Avian Feeding Behavior with Reference to the Evolution of Warning Coloration in Butterflies. II. Reactions of Naive Birds to Novel Insects." *The American Naturalist* 104 (938). <https://doi.org/10.1086/282666>.
8. Dankwa, D., F.S. Nelson, E.O.K. Oddoye, and J.L. Duncan. 2004. "Housefly Larvae as a Feed Supplement for Rural Poultry - Research and Development Notes." *Ghana Journal of Agricultural Science* 35 (1). <https://doi.org/10.4314/gjas.v35i1.1859>.
9. Despins, Joseph L., and Richard C. Axtell. 1995. "Feeding Behavior and Growth of Broiler Chicks Fed Larvae of the Darkling Beetle, *Alphitobius diaperinus*." *Poultry Science* 74 (2): 331–36. <https://doi.org/10.3382/ps.0740331>.
10. Elahi, U. C.C. Xu, J. Wang, J. Lin, S.G. Wu, H.J. Zhang, and G.H. Qi. 2022. "Insect Meal as a Feed Ingredient for Poultry." *Animal Bioscience*. <https://doi.org/10.5713/ab.21.0435>.
11. Gasco, L., I. Biasato, S. Dabbou, A. Schiavone, and F. Gai. 2019. "Animals Fed Insect-Based Diets: State-of-the-Art on Digestibility, Performance and Product Quality." *Animals*. <https://doi.org/10.3390/ani9040170>.
12. Govorushko, S. 2019. "Global Status of Insects as Food and Feed Source: A Review." *Trends in Food Science and Technology*. <https://doi.org/10.1016/j.tifs.2019.07.032>.
13. Green, R. E. 1984. "The Feeding Ecology and Survival of Partridge Chicks (*Alectoris rufa* and *Perdix perdix*) on Arable Farmland in East Anglia." *The Journal of Applied Ecology* 21 (3). <https://doi.org/10.2307/2405049>.
14. Hwangbo, J., E. C. Hong, A. Jang, H. K. Kang, J. S. Oh, B. W. Kim, and B. S. Park. 2009. "Utilization of House Fly-Maggots, a Feed Supplement in the Production of Broiler Chickens." *Journal of Environmental Biology* 30 (4).
15. Ipema, A.F., E.A.M. Bokkers, Walter J.J. Gerrits, Bas Kemp, and J. Elizabeth Bolhuis. 2022. "Provision of Black Soldier Fly Larvae (*Hermetia illucens*) in Different Ways Benefits Broiler Welfare and Performance, with Largest Effects of Scattering Live Larvae." *Physiology & Behavior* 257 (December): 113999. <https://doi.org/10.1016/j.physbeh.2022.113999>.
16. Ipema, A. F., W.J.J. Gerrits, E.A.M. Bokkers, B. Kemp, and J. E. Bolhuis. 2020. "Provisioning of Live Black Soldier Fly Larvae (*Hermetia illucens*) Benefits Broiler Activity and Leg Health in a Frequency- and Dose-Dependent Manner." *Applied Animal Behaviour Science* 230. <https://doi.org/10.1016/j.applanim.2020.105082>.
17. Mench, J. A. 2009. "Behaviour of Fowl and Other Domesticated Birds." In *The Ethology of Domestic Animals: An Introductory Text, Modular Texts*. <https://doi.org/10.1079/9781845935368.0121>.
18. Moreby, S. J., N. J. Aebischer, and S. Southway. 2006. "Food Preferences of Grey Partridge Chicks, *Perdix perdix*, in Relation to Size, Colour and Movement of Insect Prey." *Animal Behaviour* 71 (4). <https://doi.org/10.1016/j.anbehav.2005.06.017>.
19. Potts, G. R. 1986. *The Partridge: Pesticides, Predation and Conservation*. Edited by Collins. First edition. London: Sheridan House Inc.
20. Ravindran, V. 2013. "Poultry Development Review: Poultry Feed Availability and Nutrition in Developing Countries - Advances in Poultry Nutrition." *Poultry Development Review*.
21. Saima, M. Akhter, M. Z.U. Khan, M. I. Anjum, S. Ahmed, M. Rizwan, and M. Ijaz. 2008. "Investigation on the Availability of Amino Acids from Different Animal Protein Sources in Golden Cockerels." *Journal of Animal and Plant Sciences* 18 (2–3).
22. Seyedalmoosavi, M. M., M. Mielenz, S. Görs, P. Wolf, G. Daş, and C. C. Metges. 2022. "Effects of Increasing Levels of Whole Black Soldier Fly (*Hermetia illucens*) Larvae in Broiler Rations on Acceptance, Nutrient and Energy Intakes and Utilization, and Growth Performance of Broilers." *Poultry Science* 101 (12): 102202. <https://doi.org/10.1016/J.PSJ.2022.102202>.
23. Star, L., T. Arsiwalla, F. Molist, R. Leushuis, M. Dalim, and A. Paul. 2020. "Gradual Provision of Live Black Soldier Fly (*Hermetia illucens*) Larvae to Older Laying Hens: Effect on Production Performance, Egg Quality, Feather Condition and Behavior." *Animals* 10 (2). <https://doi.org/10.3390/ani10020216>.
24. Sverguzova, S. v., I.H. Shaikhiev, Z.A. Saponova, E.v. Fomina, and Y.L. Makridina. 2021. "Use of Fly Larvae *Hermetia illucens* in Poultry Feeding: A Review Paper." *Journal of Water and Land Development*. <https://doi.org/10.24425/jwld.2021.137101>.
25. Tahamtani, F. M., E. Ivarsson, V. Wiklicky, C. Lalander, H. Wall, T. Bas Rodenburg, F. A.M. Tuytens, and C.E. Hernandez. 2021. "Feeding Live Black Soldier Fly Larvae (*Hermetia illucens*) to Laying Hens: Effects on Feed Consumption, Hen Health, Hen Behavior, and Egg Quality." *Poultry Science* 100 (10). <https://doi.org/10.1016/j.psj.2021.101400>.
26. Traoré, I., S. Pousga, F. Sankara, Z.G. Zongo, K. Coulibaly, J-P. Nacoulma, M. Kenis, and G.A. Ouédraogo. 2020. "Influence Des Larves Séchées de Mouches Domestiques (*Musca domestica*,

- L.) Sur La Prise Alimentaire Du Poulet Local (*Gallus domesticus*, L.) Au Burkina Faso." *Journal of Animal & Plant Sciences* 45 (2). <https://doi.org/10.35759/janmplsci.v45-2.2>.
27. Traoré, I., S. Pousga, F. Sankara, K. Coulibaly, J-P. Nacoulma, M. Kenis, G. A. Mensah, and G. A. Ouédraogo. 2020. "Étude Du Comportement Alimentaire de La Pintade Locale (*Numida meleagris*, L.) à l'Ouest Du Burkina-Faso." *International Journal of Biological and Chemical Sciences* 14 (1). <https://doi.org/10.4314/ijbcs.v14i1.13>.
 28. Veldkamp, T., L. Dong, A. Paul, and C. Govers. 2022. "Bioactive Properties of Insect Products for Monogastric Animals – a Review." *Journal of Insects as Food and Feed* 8 (9). <https://doi.org/10.3920/JIFF2021.0031>.
 29. Veldkamp, T., and T. G.C.M. van Niekerk. 2019. "Live Black Soldier Fly Larvae (*Hermetia illucens*) for Turkey Poults." *Journal of Insects as Food and Feed* 5 (4). <https://doi.org/10.3920/JIFF2018.0031>.
 30. Whitmore, R. W., K. P. Pruess, and R. E. Gold. 1986. "Insect Food Selection by 2-Week-Old Ring-Necked Pheasant Chicks." *The Journal of Wildlife Management* 50 (2). <https://doi.org/10.2307/3801902>.
 31. WHO. 2007. "Protein and Amino Acid Requirements in Human Nutrition. Report of a Joint WHO/FAO/UNU Expert Consultation." *WHO Technical Report Series*.

Plenary Session 6:

UNSOLVED ISSUES IN POULTRY NUTRITION

"OXIDATIVE STRESS IN POULTRY: A HOLISTIC OVERVIEW FROM THE ANIMAL TO THE FINAL CONSUMER"

Mario Estévez

Meat and Meat Products Research Institute, Universidad de Extremadura, 10003, Spain

mariovet@unex.es

INTRODUCTION

Recent history in poultry production illustrates the extent to which decisions made at the farm level have a crucial impact on meat quality. This presentation provides an updated review on the main sources of oxidative stress (OS) to domestic birds, its consequences and the application of innovative means of antioxidant protection. We emphasize strategies and interventions designed to not only improve animal health and meat quality, but also consumers' health and well-being.

ROLE OF CHICKEN MEAT IN HUMAN NUTRITION

Globally, the world faces two major issues in regards to foods and nutrition. One of them is hunger. Limited (or no access) to nutritious foods, which leads to undernutrition, stunting and eventually, death, is suffered by an estimated 8% of world population (more than 600 million people)¹. Globally, one out of three women suffer anemia, and in Spain, 1 out of 3 children are at risk of food poverty². The other issue is the first cause of death caused by a non-communicable disease: cardiovascular diseases typically linked to obesity and Type 2 diabetes mellitus (T2DM). In this case, the driving cause is unlimited access (and sustained consumption) of refined carbs and ultraprocessed foods³. Meat and other animal-based foods are not only responsible of these two situations but they could, in fact, play a major role in the solution. The FAO¹ has recurrently reported by the hunger is to be battled by providing nutrient-dense foods and animal-based foods (meat, dairy, fish...) are particularly lacking in underdeveloped countries and among poor population. On the other hand, it is well-known that T2DM is caused by chronic exposure to sugars and carbs which leads to insulin resistance, chronic hyperglycemia and metabolic syndrome³. Meat, as well as other animal products, lack such nutrients, do not induce insulin secretion and in fact, a low-carb high-quality protein diet is known to reverse T2DM condition in specific patients. Despite the many educational, academic and scientific reports claiming for cuts in meat production and consumption, the truth is that meat remains an essential component of a balanced diet⁴. Chicken in particular, remains as the most consumed type of meat worldwide and its popularity relies on its relatively low price, no religious/moral restrictions, ease to prepare and cook, and its pleasant sensory properties.

ROLE OF ANIMAL BACKGROUND (GENETICS/FEEDING/HANDLING) ON MEAT QUALITY: MYOPATHIES AS EXAMPLE

Designing the composition and quality traits in chicken meat starts at the farm. Decisions made at the farm level have crucial consequences in terms of meat quality and safety. The high incidence of chicken breast myopathies in the last two centuries is an example of such connection between the two extremes of the meat production chain. The priority of the chicken meat sector in producing fast, and efficiently, high-yield broilers may not respond only to economic reasons: the necessity of producing chicken meat for a growing population and hence, satisfy the demand of consumers worldwide, requires intensive production systems. The remarkable progress made in the poultry sector in terms of genetic selection, optimized feed formulations and proper handling led to produce 2 kg live weight broilers in less than 42 days. However, this proficient production system appeared

to have caused certain pathophysiological processes in the animals that led to diverse myopathies, identified as white-stripping (WS), wooden breast (WB) and spaghetti meat (SM)⁵. While the causes and quality features of these abnormal breasts may vary, the underlying mechanisms seems to be related to the onset of OS due to mitochondrial disturbance and generation of reactive-oxygen species that leads to tissue generation⁵. This is just one remarkable example on how the onset of OS is linked to animal performance and health and responsible for the poor quality of the meat. OS is in fact related to many pathophysiological conditions in animals and humans such as inflammatory processes, chronic diseases and aging⁶. Animals suffering from OS may also be more susceptible to suffer infectious diseases. It is hence, important to identify the sources of OS for animals so that we can minimize this condition and hence, avoid its negative consequences in terms of animal performance and meat quality.

OXIDATIVE STRESS (OS) AS A SOURCE OF DECREASED ANIMAL PERFORMANCE AND IMPAIRED MEAT QUALITY

OS can be defined as the imbalance between pro-oxidant factors (mainly ROS and free radicals) and the endogenous antioxidant defenses so that the latter cannot counteract/neutralize the oxidizing potential of the former⁶. Under these circumstances, ROS and radicals oxidize molecules of biological relevance (membrane lipids, proteins, DNA) which is manifested, depending on the severity of the oxidative damage and its duration, to pathological conditions (inflammation, susceptibility to infections, tumors...). Yet, under physiological conditions the endogenous antioxidant defenses is well equipped with molecules (tocopherols, ascorbic acid, carotenoids, glutathione...) and enzymes (catalase, peroxidases, dismutases...) which are able to scavenge the pro-oxidant species⁷. It is worth to highlight that as well as the immune system can be strengthened via vaccination, the endogenous antioxidant system can also be reinforced by dietary means⁸. In fact, most of the elements of such systems are essential nutrients or are synthesis in our tissues using essential nutrients and therefore, an adequate supply of certain nutrients is essential to keep a good redox balance in our cells. As far as domestic birds is concerned, these are particularly susceptible to suffer OS given the high energetic demand in skeletal muscles from animals genetically selected to synthesize large amounts of meat protein in a short period of time⁶. The energy (ATP) required for such accelerated anabolism is preferentially obtained from the degradation of carbohydrates in the presence of oxygen. The final stage of such metabolic route (oxidative phosphorylation) takes place in mitochondrial membranes and the formation of ROS in an unavoidable consequence of such metabolism. While these ROS are neutralized under homeostasis, if the production of ROS is elevated and surpass the endogenous antioxidant defenses, OS may occur. While apparently contradictory, situations of hypoxia/anoxia, such as those occurred in the onset of myopathies, facilitate ROS formation and OS, as mitochondrial activity is not efficient at low oxygen concentrations. The high demand of oxygen to produce ATP may not be fulfilled in cells when energy demand is high and oxygen supply is reduced due to impaired supportive circulatory system (i.e. myopathies) or any other circumstances (respiratory diseases, poor air circulation...)⁹. OS can also be facilitated under conditions of physical stress (cortisol release), heat stress (increased energetic demand) or dietary OS (~ feeding animals with oxidized oils/fats)⁶⁹. The consequences of OS are well known in terms of animal production parameters and meat quality traits⁶. Fortunately, laying hens, chicks and broilers can be protected from OS by fortifying their endogenous antioxidant defenses as explained in the following lines.

NUTRITIONAL INTERVENTIONS TO AVOID OXIDATIVE STRESS

We can modulate the susceptibility of poultry to suffer OS through dietary means. First relevant issue to take into account is the fat quality of the feeds in terms of composition (avoid highly susceptible polyunsaturated fatty acids) and degree of oxidation (as intake of oxidized lipids leads

to OS). Then, we can reinforce the endogenous antioxidant defenses by enriching broiler feeds with tocopherol, ascorbic acid/carotenoids, organic selenium and assorted forms of methionine including selenomethionine⁸. Other elements currently used in animal nutrition such as phytochemicals and probiotics, display, in my opinion, the most remarkable potential, not only for protecting animals (and humans) against OS but also to improve overall well-being. Phytochemicals (used as such or in plant-based materials) are known to display assorted benefits including antioxidant, antimicrobial, anti-inflammatory, anti-proliferative and antidiabetic effects, among others¹⁰. Interestingly, some oxidized forms of such phytochemicals (phenolic/quinone forms) may induce a mild extent of OS in cells from the animal, inducing, as a result, the strengthening of the endogenous antioxidant defenses¹¹. These species may act as “vaccines” for the antioxidant defenses in cells as they would prepare tissues to an upcoming and most severe oxidative insult. Additionally, phytochemicals act as prebiotics, promoting microbiota homeostasis and hence, intestinal health. Yet, current research in human and animal medicine explores the ability of microbiota to modulate function of distant internal organs such as central nervous system (SNC) (Brain-gut axis)¹². It is proven that some microbial metabolites from phytochemicals act as neurotransmitters promoting assorted health benefits, including mental health and overall well-being¹³. While this is much less studies in animals, recent studies emphasize the occurrence of similar mechanisms in farm animals that worth be explored further.

CONCLUSION

This paper provides an updated review on the main sources of OS to domestic birds, its consequences and the application of innovative means of antioxidant protection. The ultimate purpose of this paper is bringing awareness of the role that animal nutritionists and meat producers have in feeding a world suffering from malnutrition and hunger. Producing enough meat to fulfil global demands is as relevant as assuring its nutritional quality, sensory properties and safety, and animal nutritionists play a major role in this relevant mission. While formulations should still be based on optimizing growth and carcass yield, feeds should also include elements that provide benefits to the animal in terms of health and well-being and to the final consumer, as he/she should be offered safe, nutritious and appealing chicken meat.

REFERENCES

1. FAO, (2022). In Brief to The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable. Rome, FAO. <https://doi.org/10.4060/cc0640en>
2. Save the Children (2023). Retrieve from (28/03/2023): <https://www.savethechildren.es/trabajo-ong/pobreza-infantil/pobreza-infantil-en-espana>
3. Willet et al., (2002); <https://doi.org/10.1093/ajcn/76.1.2745>
4. Klurfled (2018); <https://doi.org/10.1093/af/vfy009>
5. Petracci et al. (2019). <https://doi.org/10.1111/1541-4337.12431>
6. Estévez (2015). <https://doi.org/10.3382/ps/pev094>
7. Surai et al. (2019). <https://doi.org/10.3390/antiox8070235>
8. Surai et al. (2020). <https://doi.org/10.3390/antiox9020105>
9. Chen et al. (2022). <https://doi.org/10.5713/ab.22.0019>
10. Abdeli et al. (2021). <https://doi.org/10.3390/ani11123471>
11. Speisky et al. (2022). <https://doi.org/10.3390/antiox11010133>
12. Cao et al. (2021). <https://doi.org/10.3389/fphys.2021.752265>
13. Banc et al. (2023). <https://doi.org/10.3390/foods12020270>

Plenary Session 6:
UNSOLVED ISSUES IN POULTRY NUTRITION

NUTRITION OF LAYING HENS FOR AN EXTENDED LAYING CYCLE

Delezie Evelyne

Flanders Research Institute for Agriculture, Fisheries and Food - ILVO, Belgium

evelyne.delezie@ilvo.vlaanderen.be

INTRODUCTION

Improvements in genetic selection have made it possible to extend the laying cycle of hens from 68 to 80-90 weeks or even to more than 100 weeks since the 1970's. During this period about 500 eggs are produced per laying hen (Van Sambeek, 2011). Extending the laying period has both financial and environmental benefits. In a longer laying cycle, the costs of egg production (e.g.: pullet purchase price, feed) are balanced by the earnings of a longer productivity period and a reduced amount of resources that are needed in the long term, as replacement of hens, depopulation and cleaning of stables would be less often required. In fact, if commercial layer flocks are replaced less often, less pullets would have to be reared, which would also have an impact on the breeder flock size. All in all, the main goal of extended laying cycles is to produce more eggs with less birds.

However, extending the production period of laying hens still faces several bottlenecks, such as the declining laying persistency and egg and bone quality, health and welfare status (Bain et al., 2016). To tackle these problems a multifactorial approach is needed: not only breeding programs have to focus on improving these traits, but also nutrition and management have to be optimized to be able to exploit the genetic potential of highly prolific layer hybrids during extended production cycles. Further, scarce information is available on the nutritional requirements of aged laying hens (>70 weeks). Considering the growing tendency towards the extension of production cycles, gaining insights in these demands is of utmost importance. Feeding laying hens according to their needs is essential to fully exploit their genetic production potential while maintaining a good birds' health status. The role of nutrition to tackle the bottlenecks of extending the laying cycle will be discussed.

SPLIT FEEDING STRATEGY

In general, laying hens are fed one single diet throughout the day, and its composition is adjusted based on the age of the birds: in each consecutive phase energy, protein, Ca and P levels are adjusted towards the end of the laying cycle. The length of each feeding phase should be defined by the performance of each specific flock and cannot be generalized (Leeson and Summers, 2009). Alternative feeding systems for laying hens have been developed to achieve an efficient resource use. In these systems diet formulation is based on (1) birds' specific appetite for certain nutrients throughout the day (Holcombe *et al.*, 1976), (2) their ability to regulate nutrient intake based on the daily egg formation cycle (Chah and Moran, 1985) and (3) their preferences and ability to select feed ingredients according to their particle size (Bennett and Classen, 2003). Different known feeding systems are free-choice feeding, loose-mix feeding, sequential feeding and split feeding, i.e. feeding different diets throughout the day, with different nutritional compositions, matched to the stage of egg formation (Keshavarz, 1998). In this way, during the first half of the day (first 5-6 h after ovulation) the feed will have higher levels of essential amino acids, needed for albumen synthesis and shell membrane formation. As the egg enters the shell gland, where shell formation occurs, Ca requirement increases. A diet richer in Ca is therefore needed during the afternoon and the evening.

Some of the studies focusing on split feeding systems tried to improve egg quality of younger hens by adjusting Ca and P levels in the morning and afternoon diet according to the egg formation cycle (Ahmad and Balandier, 2003). Others focused on reducing the birds' need for specific nutrients by only

supplying these (amino acids, P and Ca) when required for egg formation (De los Mozos, 2012). De los Mozos et al. (2012) found that hens aged 65 to 80 weeks can maintain a similar performance when fed 17.0% protein in the morning and 15.5% in the afternoon compared to hens fed a constant 17.0% protein level. Zhang and Coon (1997) indicated that not only the level of Ca is important in the diet but also the particle size of its source. It has been suggested that incorporation of coarse Ca source particles is beneficial when these particles have low in vitro solubility, suggesting a longer retention time in the gizzard and higher availability for absorption (Zhang and Coon, 1997). Because the eggshell is formed mostly during the dark hours, providing more coarse limestone particles as Ca source during the afternoon could improve the utilization of this mineral and possibly the quality of the eggshell, thus reducing the amount of Ca mobilized from bone reserves. Several trials were performed by Molnar et al. (2016, 2017, 2018 a, b) investigating the effect of different ratios of fine (F) and coarse (C) limestone (L) (0FL:100CL, 30FL:70CL, 50FL:50CL) in conventional and split feeding systems for aged brown and white laying hens (> 70 weeks). Although the positive effects on performance, egg and bone quality were very small and in most cases non-significant there might be a potential for split feeding to reduce the occurrence of cracked eggs in the last phase of the production cycle. For brown laying hens 30 FL in the morning and 70 CL in the afternoon seemed to be the best strategy to maintain egg production and quality. However, for white hen providing constant levels as 50 FL in the first half and 50 CL in the second half of the day proved more beneficial. The different responses in white and brown hens to the same diets suggest that it might be necessary to apply different nutritional strategies for white and brown laying hens.

CALCIUM AND PHOSPHORUS LEVELS FOR SENIOR LAYING HENS

In order to fulfill the Ca and P requirements of several biological processes, these minerals have to be available from the blood plasma. The supply of the minerals into the plasma pools occurs by three controlled systems, i.e., the absorption of dietary Ca and P, mobilization from the medullary bone and resorption in the kidney. Phosphorus requirements are constant throughout the day, leading to small changes in the plasma pool compared to the changes that occur for the Ca plasma pool due to fluctuating Ca requirements throughout the day, mostly linked to the eggshell formation. Changes in the Ca plasma pool are regulated by the Ca regulated hormones parathyroid hormone (PTH), calcitonin and 1,25-dihydroxycholecalciferol (1,25-(OH)₂D₃) (Bar, 2008). While Ca level in layer diets is increased throughout the production period, P level is reduced in each consecutive dietary phase as hens become older (Keshavarz, 2000) 20 to 36 wk of age; Phase 2, 36 to 54 wk of age; and Phase 3, 52 to 64 wk of age. The treatments (T. Although the Ca and P metabolism of laying hens is frequently studied, the nutritional requirements of laying hens past 70 weeks of age are still unknown. Therefore, our research group conducted two experiments to determine the available P (avP) requirement and the effect of additional phytase using diets with different feedstuffs. Wheat-based diets varying from 0.30 avP to 0.11 avP mg/kg diet with a gradually reduction of 0.05, with or without phytase supplementation, were fed to Lohmann Brown hens (90 weeks of age). No effect on performance, egg and bone quality was observed, indicating that avP can be reduced to 0.11. In a second experiment, Isa Brown hens and Dekalb White hens from 70 to 80 weeks of age, were fed a maize- or wheat-based diet with avP levels of 0.45 or 0.11. No phytase was supplemented to the diets. Breed and feed ingredients used significantly affected performance and egg quality, with egg quality of white laying hens being decreased, and this effect being more pronounced for the maize-based diet. From these two experiments, it is clear that P levels can be reduced in diets of laying hens older than 70 weeks, but to what extent this is possible, depends on the breed and feed ingredients used, indicating the importance of the feed ingredient endogenous phytase activity and of the different Ca-P metabolism of white and brown laying hens.

ENERGY/ CRUDE PROTEIN

Determining the energy (E) and crude protein (CP) needs of senior laying hens is of high importance,

as this is linked to feed costs and environmental impact of the production system. It is generally assumed that E and protein demands of aged laying hens decreases, nevertheless specific guidelines are lacking. Our research group conducted another experiment to determine whether there is a need to reduce the feed E and/or protein level for laying hens with 74 to 91 weeks of age. Hens were distributed over 4 dietary treatments: 1) a standard laying hen diet containing 2759 kcal ME/kg and 15.5% CP, 2) a reduced CP-diet, with 10% reduction of levels of essential amino-acids Met, Cys, Lys and Thr, 3) a reduced E-diet by 5%, based on reduction of starch levels and 4) a reduced E and CP-diet, (as well as limiting AA's). In all four diets, crude fat was maintained constant at 5.60%, and all diets were maize-soy based. Both E and CP levels did not significantly influence laying hen performance, egg production or quality. Also, no significant differences were found for liver health associated parameters such as lactate dehydrogenase, aspartate transaminase, liver weight, abdominal fat content, liver hemorrhagic and color scores. Plumage condition was also not affected by the feed E and/or CP level. A follow-up trial was performed to observe if further reductions, namely of 15% for CP and of 20% for E would also be possible. Results indicate that it is possible to reduce E by 1% and CP by 10% in feed of senior laying hens, without compromising performance or egg quality. Reductions of 15% in CP and of 20% for E did affect performance and egg quality: hens receiving the lower E diet showed an increased feed intake and a lower laying percentage, whereas hens receiving the lower CP diet, had a lower egg and yolk weight, and a lower liver health status.

PRE-LAY PERIOD

When laying hens are kept in production for extended periods, the contribution of the rearing and pre-laying period become more important and should not be forgotten. Optimal pullet development and nutrition is a prerequisite for a successful extended production cycle. Growth during rearing and the early laying period determine for a great part, how a flock will perform and how long it can be kept in production. Kwakkel et al. (2017) highlighted that during the relatively short period of rearing - 20 weeks compared to a laying cycle of 80 weeks that follows - young birds face several challenges such as dehydration during the first few days and stressful vaccinations. At the same time, their feed intake capacity has to be increased. With the goal of extending the laying cycle, perhaps not only laying hen nutrition has to be revised, but the feeding system of the rearing period also has to be re-examined.

In an innovative approach in broiler nutrition a wet, porridge-type diet was offered as a choice next to a dry feed. Birds choose consistently the wet diet, and at 21d of age, broilers consuming the wet diet achieved a higher body weight (+10%) compared to broilers eating the dry diet (Kwakkel et al., 2017). This approach could be applicable during pullet rearing to prevent dehydration, ensure a good start and so an optimal growth. It is well known that changes or deviations from the optimal growth curve will have an effect of egg production, egg weight and overall performance of the hen. Indeed, initial pullet weight at the onset of lay is related to total egg output, and the growth during this period determines how egg size will increase during the start of lay.

Another approach to ensure a good onset of lay and a high laying percentage in extended production cycles is to offer the young hen a high energetic feed to optimize nutritional uptake, or feed the laying hens a structure rich-feed to stimulate development of the gut. Both interventions were shown to affect feed intake, development of the gut and egg quality. However, the observed effects were short term, as differences were leveled out by 54 weeks of age. As in extended production cycles hens will maintain peak performance for longer, shifts between diet phases might have been too fast in this trial.

CONCLUSION

Split feeding has proved beneficial for laying hens in extended production cycles, however **further optimization** of this feeding concept is necessary. Nutritional needs for energy, crude protein and

minerals of the senior laying hens (> 70 weeks) are lower compared to their younger counterparts, and diets can be adapted to these different needs without negatively affecting performance, egg- and bone quality. However, **more experiments with aged laying hens** (>70 weeks) should be conducted to gain insights into the true nutritional requirements of these senior hens. In addition, these nutritional requirements should be established also taking into account the breed metabolic differences. Revisiting pullet nutrition in the frame of extended production cycles would also contribute to a more sustainable and economically feasible extension of the production cycle.

REFERENCES

- Ahmad, H. A., and R. J. Balander. 2003. Alternative feed regimen of Calcium Source and Phosphorus Level for Better Eggshell Quality in Commercial Layers. *J. Appl. Poult. Res.* 12 (4): 509-514.
- Bain, M. M., Y. Nys, and I. C. Dunn. 2016. Increasing persistency in lay and stabilising egg quality in longer laying cycles. What are the challenges? *Br. Poult. Sci.* 57:330-338
- Bar, A. 2008. Calcium homeostasis and vitamin D metabolism and expression in strongly calcifying laying birds. *Comp. Biochem. Physiol. A. Mol. Integr. Physiol.* 151:477-90
- Bennett, C. D., and H. L. Classen. 2003. Performance of two strains of laying hens fed ground and whole barley with and without access to insoluble grit. *Poult. Sci.* 82:147-149
- Chah, C. C., and E. T. Moran. 1985. Egg characteristics of high performance of hens at the end of lay hen given cafeteria access to energy, protein and calcium. *Poult. Sci.* 64:1696-1712.
- Dunn, I. C. 2013. Long Life Layer; genetic and physiological limitations to extend the laying period. Pages 124-129 in 19th European Symposium on Poultry Nutrition. Potsdam.
- Holcombe, D. J., D. a Roland, and R. H. Harms. 1976. The ability of hens to regulate protein intake when offered a choice of diets containing different levels of protein. *Poult. Sci.* 55:1731-1737
- Keshavarz, K. 2000. Nonphytate phosphorus requirement of laying hens with and without phytase on a phase feeding program. *Poult. Sci.* 79:748-763.
- Kwakkel, R., M. L. Elling-Staats, and M. M. Van Krimpen. 2017. How to survive a challenging childhood: rearing the laying hen. in XXII European Symposium on Poultry Nutrition. Salou, Spain.
- Leeson, S., and J. D. Summers. 2009. Commercial Poultry Nutrition.
- Mozos de los, J., A. Gutierrez del Alamo, T. v. Gerwe, A. Sacranie and P. Perez de Ayala (2012a). "Oviposition feeding compared to normal feeding: effect on performance and egg shell quality." Proceedings of the 23rd Annual Australian Poultry Science Symposium, Sydney, New South Wales, Australia, 19-22 February 2012, Poultry Research Foundation.
- Sambeek, F. Van. 2011. Breeding for 500 eggs in 100 weeks. *World. Poult.*:14-16.
- Molnar, A., Maertens, L., Ampe, B., Buyse, J., Kempen, I., Zoons, J., Delezie, E. 2016. Changes in egg quality traits during the last phase of production: is there potential for an extended laying cycle? *British Poultry Science*, 57 (6): 842-847.
- Molnár, A., L. Maertens, B. Ampe, J. Buyse, J. Zoons, and E. Delezie. 2017. Supplementation of fine and coarse limestone in different ratios in a split feeding system: effects on performance, egg quality and bone strength in old laying hens. *Poultry Science*, 96 (6): 1659-1671.
- Molnár, A., L. Maertens, B. Ampe, J. Buyse, J. Zoons, and E. Delezie. 2018. Effect of different split-feeding treatments on performance, egg quality, and bone quality of individually housed aged laying hens. *Poultry science*. 97, 1, blz. 88-101
- Molnár, A., I. Kempen, N. Sleetckx, J. Zoons, L. Maertens, B. Ampe, J. Buyse, and E. Delezie. 2018. Effects of Split Feeding on Performance, Egg Quality and Bone Strength in Brown Laying Hens in Aviary System. *Journal of Applied Poultry Research*, 27 (3): 401-415.
- Zhang, B., and C. N. Coon. 1997. The relationship of calcium intake, source, size, solubility in vitro and in vivo, and gizzard limestone retention in laying hens. *Poult. Sci.* 76:1702-1706.

Plenary Session 6:

UNSOLVED ISSUES IN POULTRY NUTRITION

ECONOMICAL EFFICIENCY IN TURKEY NUTRITION

M. Kenny¹, J. Ralph¹ and H. Glawatz²¹Aviagen Turkeys Ltd, Chowley Five, Chowley Oak Lane, Tattenhall, Chester CH3 9GA United Kingdom²Moorgut Kartzfehn von Kameke GmbH & Co KG, Germany

mkenny@aviagen.com

INTRODUCTION

Economical feed efficiency is critical in terms of meeting the financial objectives of the turkey enterprise. This has never been more important given the volatility of the raw material market and lack of consistent supply of materials. In recent years feed cost has increased, as a proportion of total cost to the enterprise, from 65% to 70% of the total cost of turkey production.

In such situations, it is critical that nutritionists can make informed decisions in order to choose the most efficient feeding programme for different economic circumstances. This must be considered within the context of an ever-changing growing environment where the turkey's response to a given feeding regime is influenced by health challenges, environmental constraints, and increased removal of antibiotics and, in some cases, removal of coccidiostats.

REVENUE DRIVERS

Any feeding programme needs to take into account the revenue drivers of the operation. The majority of turkeys grown in Europe are processed into portions. Breast meat, in the majority of countries, is the most valuable part of the turkey carcass (Noll, 2001). While breast meat only contributes 26-28% of the weight of the bird, it represents 60-70% of the income from the carcass in most European countries (Hammond, 2006). There have been significant advances in breast meat development as selection by breeders for this trait has intensified. Typical breast meat improvement over the last 10 years is estimated at 1.6% (Noirault, 2014) and the annual rate of improvement is increasing and now estimated to be approximately +0.2% per annum. It is of economic importance to exploit this genetic potential and maximize the growth of breast meat in terms of the weight of breast meat per bird and the percentage that is taken up in the carcass (Noirault, 2015). An economic feeding programme must minimise feed cost but at the same time maximise output as efficiently as possible for both a farm situation and end processed product perspective.

NUTRIENT DENSITY RESPONSES

Economic assessments have been conducted at varying nutrient levels in different studies. Lemme *et al*, 2005, assessed the impact of different levels of essential amino acids on heavy strain turkeys in different phases of the growing period. Birds fed lower amino acids up to 9 weeks of age had lower bodyweights than those fed higher amino acid levels. Final bodyweights were not as influenced by dietary amino acid levels as much as breast meat yield, which was higher in those birds fed higher amino acid levels. Optimal economic performance (income over feed cost/bird and breast) was achieved in those birds fed higher amino acid density diets in the early phases, control levels of amino acids in the intermediate phase and lower amino acid levels in the later phases. Hammond (2006), fed diets based on breed recommended amino acid levels and lower amino acid levels at different phases through the growing period; 0-6, 6-12 and 12-18 weeks of age. Highest liveweight was achieved in birds fed the breed recommended amino acid levels in the last phase of growth. Highest breast meat yield was achieved at the higher amino acid density levels fed throughout all phases. The most influential phase of growth, in terms of breast meat yield, was the last phase between 12 to 18 weeks of age. In a similarly designed study (Kenny, 2018) diets varying in amino acid density relative to a breed standard, were provided in a continuous or phased regime to heavy strain male turkeys. Birds fed intermediate amino acid density diets showed a trend towards increased

bodyweight relative to those fed lower amino acid density diets while breast meat yield was highest in those birds fed the highest amino acid density diets. Optimal farm margin (income over feed cost/bird) was achieved at lower amino acid densities while optimal processing margin (income over feed cost/breast meat) was achieved at intermediate to higher amino acid levels.

A further evaluation (Aviagen Turkeys Inc. unpublished data) assessed the impact of increased balanced protein (crude protein and amino acid levels) on performance of heavy strain male turkeys relative to a breed standard nutrient recommendation (Aviagen Turkeys Inc.). The evaluation showed that males fed the higher density diet gained a higher bodyweight and higher breast meat yield. Feed cost was higher for those birds fed the high-density diets relative to those fed the lower density feed. However, those birds fed the higher density feed yielded more revenue from meat, consequently those birds fed the higher density diet achieved higher margin.

The above evaluations assessed the impact of varying amino acid densities while energy density levels remained constant between treatments. Amprou (2108) assessed the effect of two digestible lysine levels and two energy levels on heavy strain turkeys fed between 62 to 124 days of age. Reducing the energy content of the diets had no impact on growth but resulted in poorer FCR. Increased digestible lysine improved growth but had no effect on FCR. A financial assessment based on mass production cost showed the lower energy and higher digestible lysine regime resulted in the lowest cost relative to all other treatments. In a series of trials, Kenny (2023) examined the impact of various energy and amino acid density diets on the performance of heavy strain male turkeys. Performance data from these trials were collated to assess the response of turkeys over a range of nutrient densities. Figure 1a,b shows liveweight and feed conversion ratio (FCR) responses to altering nutrient density. Both liveweight and FCR were responsive to amino acid and energy density, both of which were optimised at the highest nutrient densities. The data also suggests that energy density appears to impact positively on the response to increasing amino acid concentration suggesting that diet energy density should be considered when feeding higher amino acid densities.

Figure 1a,b: Liveweight and FCR responses to a range of amino acid and energy densities.

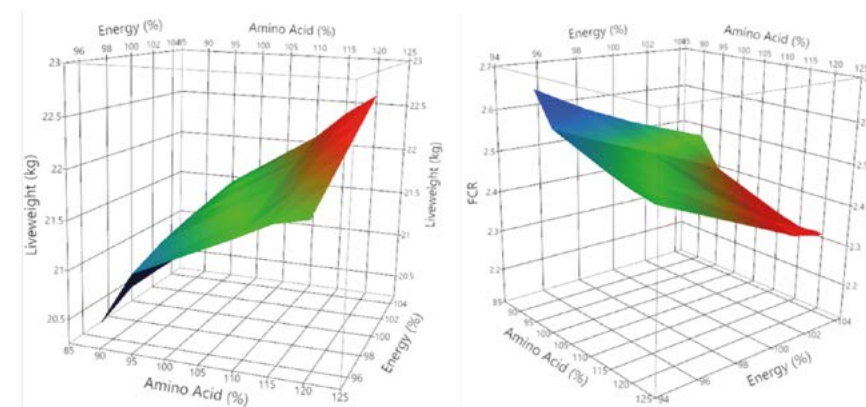


Fig 1a: Liveweight (kg) at 20.5 weeks

Fig 1b: FCR at 20.5 weeks

Processing traits were also assessed, as with liveweight and FCR responses, increasing nutrient density had a positive impact on breast meat yield (see figure 2). At lower energy densities breast meat yield (BMV) showed a curvilinear response to increasing amino acid density. However, BMV continued to respond to increasing amino acid concentration at higher energy densities, this reinforces the

importance of considering both nutrients particularly when optimising processing yield. This is a similar observation to that made by Lemme et al. 2005 who proposed that there are interactions between nutrient and energy intake with respect to their effectiveness of utilisation for meat deposition.

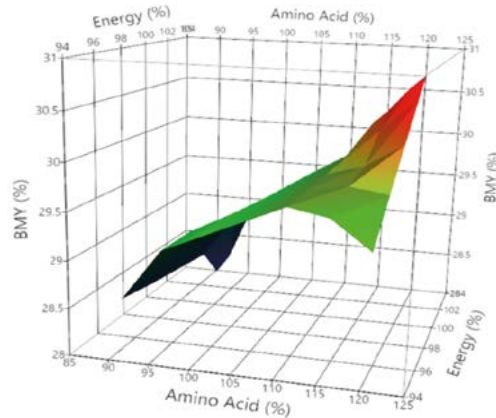


Figure 2: 20.5 week breast meat yield response to a range of amino acid and energy densities (% relative to standard).

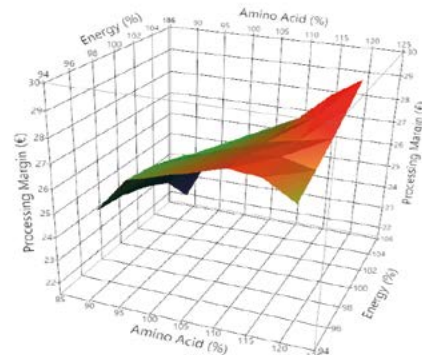
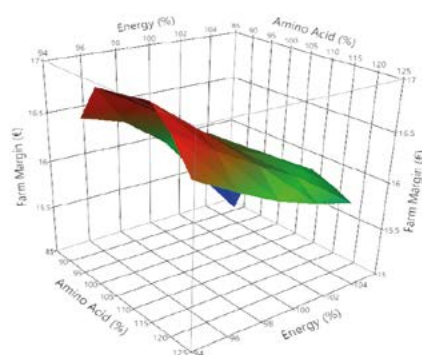
ECONOMIC RESPONSES

The data set derived by Kenny (2023) was used to estimate economic responses, margin (after feed cost) was calculated by estimating the difference between revenue (value of live bird or meat) and feed cost at each nutrient density. Examining the profile of the surface plot graph (figure 3a) the effect of nutrient density on farm margin can be established. The same approach was taken to derive an estimate of margin for processed products, margin was estimated at each nutrient density (figure 3b) based on revenue (the value of breast meat yield) minus feed cost per bird.

Figure 3a,b: Farm and processing margin (Euro/bird) at differing amino acid and energy densities.

3a: Farm margin¹ (Euro/bird) after feed cost

3b: Processing margin² (Euro/bird) after feed cost



¹revenue based on Euro 1.71/kg liveweight

²revenue based on Euro 7.45/kg breast meat

Optimal farm margin was achieved at an amino acid density above the standard (105% of standard) and at the lowest energy density (95% of standard). Energy density has a much greater influence on margin than amino acid density and reflects the impact of the recent increase in the cost of dietary energy. The lowest farm margin was at the highest energy (105%) and lowest amino acid concentration (90%). Based on existing raw material costs, higher margin is achieved at higher amino acid density and lower energy density than the existing standard. Higher energy densities may achieve higher biological performance however this is outweighed by increased feed cost per bird. Contrary to farm margin optimal processing margin was achieved at both the highest amino acid and energy density. This reflected the response of breast meat yield to both nutrients and the higher revenue associated with processed products relative to liveweight. Increasing amino acid density without a concomitant increase in energy results in lower margin, lowest margin was at the lower amino acid densities.

CONCLUSION

The modern turkey responds to a wide variety of nutrient levels and the choice of nutrient density is principally an economic one. The most economically efficient nutrient density is also dependent on the objectives of the enterprise, based on current European raw material costs optimal farm (bird) economic performance is achieved at lower energy densities and higher amino acid concentrations whereas optimal processing (breast meat) is achieved at higher amino acid and energy density.

REFERENCES

1. Amprou, E. 2018. Study of the response of male heavy turkeys to lysine and ideal protein intake from 0 to 48 days and energy and lysine intake from 62 to 124 day. Proc. of the 12th Turkey Science and Production Conference. 64-69.
2. Hammond, L. 2006. The influence of diet on breast meat yield. Proc. of the 29th Technical Turkey Conference: 29-32.
3. Kenny, M., 2018. Nutritional developments in Turkeys. Proc. of the 12th Turkey Science and Production Conference: 70-77.
4. Kenny, M., 2023. Feeding strategies for commercial turkeys. Proc. of the 15th Turkey Science and Production Conference.
5. Lemme, A., Petri, A., Frackenpohl, U. and Meyer, H. 2005. Response of male BUT Big 6 turkeys to varying amino acid feeding programs.
6. Noirault, J. 2014. CP01 Factors Affecting Breast Meat Yield in Turkeys. Aviagen Management Article.
7. Noirault, J. 2015. Turkey breast meat development and maximizing the genetic potential. Proc. of the 9th Turkey Science and Production Conference: 25-28.
8. Noll, S. 2001. Nutrition and management effects on growth and breast meat yield. Proc. of the 24th Technical Turkey Conference: 47-51.



ORAL PRESENTATIONS



CONTENT

OS1 - Nutrition for sustainability in broiler, layer and turkey production	88
OS1-1 Feeding male broilers without the use of an inorganic phosphorus source is possible	88
OS1-2 Towards a better prediction of phosphorus digestibility in broilers	89
OS1-3 Effect of substituting peptide-bound with free amino acids in broiler feeding on acid-base balance depends on asparagine and glutamine supply	90
OS1-4 Effect of pellet diameter and length on performance and particle preference of broilers fed diets based on coarsely ground wheat and maize	91
OS1-5 Comparison of in vitro bioaccessibility and in vivo bioavailability of carotenoids in hens	92
OS2 - Nutritional intervention for climate changes	93
OS2-1 Effect of n-acetyl-l-cysteine in drinking water of heat stressed finisher broilers on performance and redox status	93
OS2-2 The effect of reducing dietary crude protein and energy as well as the amino acid origin on the reduction of global warming potential of broilers using the latest carbon footprint public databases	94
OS2-3 Effects of different arginine to lysine ratios on growth performance, metabolism, and intestinal microbiome of broiler chickens exposed to cyclic heat stress	95
OS2-4 Using a proprietary broiler growth model to optimize the body weight (BW) or feed conversion ratio (FCR) of broilers reared under thermoneutral or heat stress condition	96
OS2-5 Formulation of eco-friendly feeds for conventional and organic poultry to reduce feed-food competition, greenhouse gas emissions, and land use	97
OS3 - Nutrition and microbiome under challenging conditions	98
OS3-1 Culture of avian caecum organoids to study the effect of functional amino acids and polyphenols supplementation	98
OS3-2 Effect of dietary treatments on performance, oocysts shedding and lesion scores in broiler chickens challenged with Eimeria infection	99
OS3-3 Effects of commercial processing conditions of extruded soybean on ileal and cecal microbiota of broiler chickens	100
OS3-4 Systematic review on microbiome-related interventions to enhance broiler productivity and safety of poultry meat	101
OS3-5 Ex vivo assessment of the direct and indirect antimicrobial capacities of glycerides of lauric acid using gastrointestinal fluids	102

OS4 - Solution to improve the nutritional value of feed	103
OS4-1 The net energy system predicts more accurately broiler feed energy than the metabolisable energy system regardless of the crude protein content	103
OS4-2 Effects of limestone source and increasing levels of a novel 6-phytase on growth performance of conventional and slow growing broiler breeds	104
OS4-3 Effects of maize moisture at harvest and drying temperature on starch content and particle size of corn ground in a roller mill	105
OS4-5 Prediction of feeds net energy for broilers	107
OS5 - Non-soy protein sources	108
OS5-1 The nutritional value of porcine blood proteins: AMEn and apparent total tract digestibility of blood meal, haemoglobin powder and plasma powder in young broilers of different ages	108
OS5-2 Determination of nutritional value of seeds from different cultivars of pea, yellow lupine, and faba bean for laying hens	109
OS5-3 Effects of the partial replacement of dietary soybean with insect meal on growth performance, meat quality and ceca metabolome and microbiota composition of female turkeys	110
OS5-4 Comparative Assessment of Digestion of Protein-Rich Feed Ingredients in Broiler Diets Using a Dynamic and a Static In Vitro Model of the Avian Foregut	111
OS5-5 Effect of single cell protein incorporated diets on growth performance, carcass characteristics, serum biochemistry and gut health of broilers based on total and standardised ileal digestible amino acids	112

OS1 - Nutrition for sustainability in broiler, layer and turkey production**OS1-1 Feeding male broilers without the use of an inorganic phosphorus source is possible**S. Leleu¹, A. De Grande¹, E. Delezie¹, B. Ampe¹, D. Feuerstein²¹ILVO (Institute for Agricultural, Fisheries and Food Research), Melle, Belgium, ²BASF SE, Ludwigshafen am Rhein, Germany

From both ecological and economical perspectives, a reduced phosphorus use is becoming increasingly interesting. To evaluate the feasibility of feeding poultry completely without inorganic phosphate, a trial was performed in a 2x2x2 full-factorial design: phosphorus source (purely monocalcium phosphate (MCP) or purely a phytase), Ca level (normal/low vs high), and absence or presence of a formic acid (FA; improving phytate solubility and digestibility; except in finisher diet); resulting in 8 treatment groups. The normal/low Ca category had a normal Ca level when only MCP was added and a lower Ca level when only phytase was added. Each treatment consisted of 6 pens or replicates of 30 male Ross 308 broilers. The diets were applied in a 4-phase feeding scheme (starter d0-10, grower I d10-18, grower II d18-25, finisher d28-36) as wheat-soybean meal based, pelleted diets. At the end of the trial (d36), body weight was significantly lower (2.2%) for the high-level Ca treatments. The feed conversion ratio of the overall period was not significantly influenced by one of the three factors. The overall mortality was influenced by the Ca level, resulting in the highest-level treatment groups having the lowest mortality (1.9% vs 3.8%). This could not be attributed to health problems. Tibia breaking strength at d36 was influenced by both the Ca level and the presence of FA: when the normal/low level of Ca was fed, the addition of FA had no effect, while when the high Ca level was fed, the addition of FA lowered the breaking strength. Tibia ash (%) was not significantly influenced by the treatment groups. Therefore, based on the performances and tibia quality parameters in this trial, it can be concluded that there is no significant difference between the use of MCP or the sole use of the phytase tested without inorganic phosphate. Furthermore, a normal/low Ca level should be used to maximize growth performance, and the addition of FA for a better solubility and digestibility is not needed.

OS1 - Nutrition for sustainability in broiler, layer and turkey production**OS1-2 Towards a better prediction of phosphorus digestibility in broilers**A. Narcy¹, V. Khaksar¹, A. Preynat², M. Jlali², M. Létourneau Montminy³¹INRAE UMR BOA, Nouzilly, France, ²Adisseo France S.A.S., Commentry, France, ³Laval University, Quebec, Canada

Predicting the digestive use of dietary phosphorus (P) considering its main factors of variation remains crucial from an environmental and economic point of view. In this regard, a meta-analysis was conducted to develop a predictive model of digestible P (digP) for broilers as a function of calcium (Ca), phytic P (PP), non-phytic P (NPP) and microbial phytase (PhytM) and their interactions. An exhaustive database was built based on publications from 2010 to 2021 having measured P digestibility at the prececal level using an indigestible marker, reporting the diet composition and using fast growing broilers. The final database included 292 and 333 treatments for periods from 1 to 21 and 22 to 42 days of age, respectively. The digestibility coefficient was multiplied by the total P concentration in the diet to obtain the digP in g/kg diet. Digestible P responded linearly to PhytM and this relation was affected by PP level showing higher impact of PhytM with more PP ($PP \times PhytM$, $P < 0.05$) in 1-21-day-old chickens. In older birds, the impact of PhytM in relation to PP level depends on Ca ($Ca \times PP \times PhytM$, $P < 0.05$). At both ages, digP was optimized with lower Ca levels. In older chickens, the negative effect of Ca is more pronounced for higher PP levels. Furthermore, the impact of phytase is maximized in low NPP and high Ca diets ($Ca \times NPP \times PhytM$, $P < 0.01$) at both ages. To validate the model, a total of 8 dietary treatments with increasing levels of digP were formulated using the prediction equation for the period 1-21 days. Different combinations of Ca, NPP and microbial phytase were used to obtain the following levels: 2.1, 2.5, 3.1, 3.6, 3.9, 4.2, 4.5 and 4.9 g digP/kg diet. Chicks were raised in pens from 1 to 21 days of age (6 pens of 8 broilers per treatment) and weighed at the beginning and the end of the experiment. They were fed the experimental diets from 1 to 21 days and feed intake was determined. Results showed a quadratic relationship between growth performance and the predicted digP with a R² of 92, 91 and 64 for average daily gain, feed intake and feed conversion ratio, respectively. The maximal response of the quadratic model is obtained at 4.2 g digP/kg diet. Further analyses ongoing (bone mineralization and measured prececal digestibility of P) will allow to compare the reliability of the digestible phosphorus prediction equation and to model requirements based on digestible P.

*OS1 - Nutrition for sustainability in broiler, layer and turkey production***OS1-3** Effect of substituting peptide-bound with free amino acids in broiler feeding on acid-base balance depends on asparagine and glutamine supplyA. Ibrahim¹, M. Rodehutscord¹, W. Siegert¹¹University of Hohenheim, Stuttgart, Germany

Using free amino acids (FAA) enables to adjust dietary amino acid (AA) concentrations in low protein diets to the requirement of broilers. Different absorption rates between peptide-bound AA and FAA led to the suggestion of an upper limit of FAA inclusion in broiler feed. The acid-base status of broilers may be affected by high dietary FAA inclusion, but this was not investigated to date. The acid-base status may depend on the asparagine (Asn) and glutamine (Gln) supply. Therefore, this study investigated whether substitution of peptide-bound with FAA affects the acid-base balance of broilers and whether this depends on the Asn and Gln supply. Nine diets with about 184 g crude protein (CP)/kg dry matter were mixed. One diet contained 80 g soy protein isolate (SPI)/kg, which provided about 38% of dietary CP. In the other diets, 25, 50, 75 and 100% of the digestible AA from SPI were substituted with FAA. Analysed aspartic acid (Asp) and glutamic acid (Glu) of SPI were substituted with Asp and Glu or 50/50 mixes of Asp/Asn and Glu/Gln, respectively. Precaecal AA digestibility of SPI had been determined in a previous trial. Each diet was provided to 7 metabolism units of 10 broilers and was fed from 7-21 days (d) of age. Total excreta were collected on d 18-21 to measure ammonia (A) and uric acid (U) excretion in addition to total N. The acid-base status was analysed in blood samples from one bird per unit on d 21 using the i-Stat®Alinity system. Bicarbonate (HCO₃), base excess (BE), total carbon dioxide (TCO₂), and chloride (Cl) were unaffected up to 50% and 75% AA substitution without and with addition of Asn and Gln, respectively. Above such levels, HCO₃, BE, and TCO₂ decreased, and Cl increased, respectively (P<0.012). Other blood traits related to the acid-base status including pH, sodium, potassium, and the anion gap were not significantly affected by treatment. The A/(A+U) ratio in excreta was unaffected up to 50% AA substitution and increased at higher AA substitution with a bigger effect when only Asp and Glu were added instead of Asp/Asn and Glu/Gln (P<0.014). The blood data indicate that the acid-base balance was influenced by AA substitution. Considering Asn and Gln enabled to increase FAA inclusion without affecting the acid-base balance. Effects on acid-base balance apparently were compensated as blood pH was unaffected, possibly by increasing urinary A excretion (indicated by A/(A+U) ratio) because this is a mechanism to excrete acid.

*OS1 - Nutrition for sustainability in broiler, layer and turkey production***OS1-4** Effect of pellet diameter and length on performance and particle preference of broilers fed diets based on coarsely ground wheat and maizeM. Neteland¹, B. Svihus¹, C. Gundersen Storkås¹, S.E. Ording Reierstad¹¹Norwegian University of Life Sciences, Aas, Norway

Processing of diets for broiler chickens result in high energy use due to the fine grinding and the small diameter (D) of the holes in the pellet die. An earlier experiment showed that 3 mm D diets with coarsely ground cereals did not affect performance negatively. Thus, an experiment was carried out where diets based on coarsely ground wheat- and maize were pelleted to the same physical quality but with either a 3 or a 5 mm D die. The effect of a large length (L) of the 5 mm D pellets was also studied by adjusting the knife such that the average L was either approx. 6, 8 or 10 mm. Each diet was fed to 8 pens with 40 male Ross 308 broiler chickens from 10 to 34 days of age (DOA). A commercial crumbled starter diet was used. Post-pellet temperature was around 83 °C for all diets and durability varied between 87 and 89. Wet sieving revealed that much more of the coarse particles were preserved during pelleting when a 5 mm D die was used, approaching 20 % particles > 2 mm, and 40 % > 1 mm. Increasing pellet D had no effect on weight gain from 10-16, 17-28 or 29-34 DOA, but feed/gain increased (P<0.05) from 1.44 to 1.46 for the whole period, which appeared to be due to feed spillage 10-16 DOA for the 5 mm D diet as indicated by an unusual high feed intake. The 3 mm D pellets resulted in a higher feed intake during 1 h feeding preceded by 2 h starvation than the 5 mm D diet at 15 and 22 DOA, and no clear particle preferences were observed. At 29 DOA, no differences were seen in feed intake, and particles > 2.8 mm were preferred. Interestingly, birds given the 5 mm D/6 mm L pellets did not seem to avoid particles > 4.75 mm at 15 and 22 DOA and had a strong (P<0.05) preference for these particles at 29 DOA. No differences in ileal digestibility of starch or N were observed, which concurs with the lack of differences in particle size distribution of ileum contents. Gizzard size and pH of contents was not significantly affected, but thickness of the large gizzard muscle increased (P<0.05) with the 5 mm D diet. Individual weights of all birds within pen demonstrated that none of the diets affected weight variability. Increasing the length of the 5 mm pellets had no effect on any performance parameters, indicating that broiler chickens are able to handle good durability pellets as large as 5 mm diameter and 10 mm average length. In conclusion, it appears that a more energy efficient pelleting process resulting in larger micro- and macrostructure can be applied without negative effects on broiler performance.

OS1 - Nutrition for sustainability in broiler, layer and turkey production**OS1-5 Comparison of in vitro bioaccessibility and in vivo bioavailability of carotenoids in hens**

D. Zurak¹, V. Gunjević¹, Z. Svečnjak¹, M. Duvnjak¹, G. Kiš¹, D. Bedeković¹, Z. Janječić¹, V. Pirgozliev², Z. Kralik³, D. Grbeša¹, K. Kljak¹

¹University of Zagreb Faculty of Agriculture, Zagreb, Croatia (Hrvatska), ²National Institute of Poultry Husbandry, Harper Adams University, Shropshire, United Kingdom, ³Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia (Hrvatska)

Yellow maize carotenoids positively affect poultry health, while their deposition into yolk and pigmentation improve egg quality. When evaluating pigmentation efficiency and final content in the yolk, it is important to consider not only the carotenoid content in the grain, but also its digestion. Although in vivo digestion methods are most useful to obtain relevant physiological results, in vitro assays can serve as practical tools for general prediction of carotenoid bioavailability. The aim of this study was to compare the in vitro bioaccessibility of carotenoids from 15 commercial maize hybrids with their content in yolks obtained in in vivo trial with hens fed diets differing in these hybrids. The INFOGEST in vitro method, adapted to the starch matrix and digestive tract of poultry, was used to evaluate the bioaccessibility of total (TC) and individual maize carotenoids (zeaxanthin, Z; lutein, L; α - and β -cryptoxanthin, α CX and β CX; β -carotene, β C). The in vivo trial was conducted with 225 Lohmann Brown hens randomly allocated to 15 dietary treatments (15 treatments $\times$ 5 cages). Hens were fed treatment diets containing 60% of grain and without added pigment for 8 weeks. Eggs were collected once a week from week 4 until the end of the experiment. The carotenoid profile in grain, digesta and yolks was determined using HPLC method. The TC content in maize hybrids ranged from 6.45 to 20.64 μ g/g DM. The average amount of micellar Z, L, β CX, α CX and β C was 5.00, 4.44, 0.34, 0.25 and 0.18 μ g/g DM, respectively. The yolk content of carotenoids increased with their increased bioaccessibility ($P < 0.0001$), with the highest contents of L and Z, followed by β CX, α CX, and β C (on average 15.98, 12.68, 0.54, 0.50 and 0.48 μ g/g, respectively), indicating that hybrids with higher levels of micellar carotenoids also had higher absorption and incorporation into the yolks. The obtained results indicate that the applied in vitro protocol is suitable to determine the efficiency of carotenoid micellization in a model mimicking the poultry digestive tract. The method can be used to predict the amount of carotenoids that will be incorporated into the yolk of maize grain-fed hens. Funding: This work has been fully supported by Croatian Science Foundation under the project ColourMaize (IP-2019-04-9063). The work of doctoral student Dora Zurak has been fully supported by the "Young researchers' career development project - training of doctoral students" of the Croatian Science Foundation.

OS2 - Nutritional intervention for climate changes**OS2-1 Effect of n-acetyl-L-cysteine in drinking water of heat stressed finisher broilers on performance and redox status**

H. Pertiwi¹, H. Zhang¹, M. Majdeldin¹, J. Degroote¹, J. Michiels¹

¹Laboratory for Animal Nutrition and Animal Product Quality, Department of Animal Sciences and Aquatic Ecology, Ghent University, Ghent, Belgium

Heat exposure is one of many environmental stressors that severely affects growth performance, well-being, and productivity of broiler chickens. One negative effect of thermal stress is as a trigger of oxidative stress that can result in the development of several metabolic dysfunctions, which might be reversed by the endogenous antioxidant tripeptide glutathione. Based on the fact that L-cysteine is the rate limiting amino acid for the intracellular synthesis of glutathione, it was hypothesized that supplementation of N-acetyl-L-cysteine (NAC), as a stable form of L-cysteine, in drinking water could increase the productivity of finisher broilers under heat stress (HS) by supporting antioxidant defences. A total of 288 15-day-old Ross 308 broilers with 480 ± 3.0 g body weight (BW) were allocated to 3 treatments with 8 replicates of 12 birds per replicate to 39 days; thermoneutral (TN), HS, and HS + 1000 mg/L NAC in the drinking water (HS+NAC). All birds accessed to drinking and the same corn soybean meal diet ad libitum. A chronic cyclic HS model (temperature was increased to 34 °C for 7 h, daily, rest of day 26 °C) was initiated at 21 days of age. Birds were sampled during the heat episode on day 39 for redox status parameters. Result showed that HS notably decreased weight gain and feed intake during 22 to 39 d ($P < 0.05$) but it did not affect feed efficiency compared with TN group. NAC failed to reverse the negative impact of HS. Further, HS significantly increased intestinal permeability evidenced by higher serum fluorescein isothiocyanate dextran (FITC-d) content and lower villus height ($P < 0.05$) than TN group. Supplementation with NAC in drinking water slightly decreased serum FITC-d level and increased intestinal villus height and this was not different from TN. Regarding to redox status, malondialdehyde content in the ileal mucosa was higher in birds subjected to HS as compared with TN birds ($P < 0.05$), while the group with NAC was intermediate. However, the highest malondialdehyde level in plasma was found in HS+NAC group ($P < 0.05$ as compared to TN), whereas HS was not different from TN. Treatment had no effect on malondialdehyde and glutathione peroxidase activity and antioxidant enzymes in liver and breast meat. In conclusion, drinking water with 1000 mg/L NAC could not improve performance and showed some benefits in intestinal structure and intestinal redox status by decreasing malondialdehyde production of heat stressed finisher broilers.

OS2 - Nutritional intervention for climate changes

OS2-2 The effect of reducing dietary crude protein and energy as well as the amino acid origin on the reduction of global warming potential of broilers using the latest carbon footprint public databasesE. Gonzalo¹, W. Lambert¹¹METEX Animal Nutrition, Paris, France

Lowering dietary crude protein (CP) allows to reduce the environmental impact associated to broiler production systems, however new nutritional strategies are still required to minimize manure emissions. The aim of this trial was to study the effect of a reduction of CP and energy (E) as a possible strategy to reduce the global warming potential (GWP) in broilers. For this purpose, 936 Ross 308 male broilers from 21-35 days old received 12 dietary treatments (6 replicates of 13 birds per treatment) in a factorial design of 3 levels of CP (CP-19, CP-18 and CP-17, in %) and 4 levels of energy (E-3200, E-3100, E-3000 and E-2900, in kcal AMEn/kg). The new data bases of GFLI 2022 and Agribalyse 3.1 were used to identify the GWP (expressed as kgCO₂eq/kg) of each ingredient of the diet. The following environmental parameters were calculated: N intake, retention, excretion and efficiency, volatilization of N and NH₃ and N₂O emissions, soybean meal (SBM) intake and CO₂eq/kg BWG. Moreover, two different amino acid (AA) sources (EU AA vs non-EU AA) were tested for CO₂ calculations, which included values for free Lysine (Lys), Methionine (Meth), Threonine (Thr), Valine (Val), Tryptophan (Trp), Isoleucine (Ile) and Arginine (Arg). The interactions CP*E, CP*AA-source and E*AA-source were tested by a 2-way ANOVA, and the main effects were reported when the interactions were not significant. Results showed that broilers growth performance was negatively affected by the reduction of dietary E, however no effect was found by the reduction of dietary CP. Results of the environmental parameters showed a significant ($P < 0.001$) interaction CP*E for NH₃ and N₂O volatilization, where CP-17 vs CP-19 presented a higher reduction of both emissions with E-3200 (-48%) vs E-2900 (-44%). Regarding the GWP results, a significant interaction ($P < 0.001$) was observed between CP*AA, where EU AA presented a higher beneficial effect compared to non-EU AA. In fact, GWP was reduced by 14% when compared CP-17 vs CP-19 with EU AA (1.45 vs 1.68 CO₂eq/kg BWG, respectively), while non-EU AA presented a reduction of 1% CO₂ (1.66 vs 1.71 CO₂eq/kg BWG, respectively). A significant interaction ($P < 0.001$) was also observed between CP*E, where CO₂eq/kg BWG for CP-17 vs CP-19 was more reduced with E-2900 (-16%) than E-3200 (-11%). In conclusion, EU AA sources with LCP diets seem to maintain broilers growth performance and present a higher beneficial effect on GWP than non-EU AA sources.

OS2 - Nutritional intervention for climate changes

OS2-3 Effects of different arginine to lysine ratios on growth performance, metabolism, and intestinal microbiome of broiler chickens exposed to cyclic heat stressG. Brugaletta¹, L. Laghi¹, A. De Cesare², M. Zampiga¹, C. Oliveri³, V. Indio², R. Piscitelli¹, M. Petracci¹, F. Sirri¹¹Department of Agricultural and Food Sciences, Alma Mater Studiorum - University of Bologna, Bologna, Italy,²Department of Veterinary Medical Sciences, Alma Mater Studiorum - University of Bologna, Bologna, Italy,³Department of Physics and Astronomy, Alma Mater Studiorum - University of Bologna, Bologna, Italy

Feeding broilers arginine (Arg) beyond the recommended dosages has been shown to be beneficial for their health and growth performance. Little attention, however, has been paid to Arg supplementation in heat-stressed broilers. Therefore, the aims of this study were to evaluate the effects of supplementing feed-grade Arg on growth performance, hepatic, muscular, and blood metabolic profiles, and intestinal microbiome of broilers exposed to heat stress (HS). In a 2x2 design with 24 pens, set to test the effect of diet, environmental temperature, and their interaction, 240 male Ross 308 broilers were fed a commercial mash diet (CON) or the same diet supplemented with crystalline L-Arg (ARG; totArg:Lys of 1.02-1.07 and 1.20, respectively) from D0 to D44 and were reared in a thermoneutral (TN) ambient throughout the trial or subjected to cyclic HS from D35 onwards (34°C, 9:00 AM-6:00 PM). Growth performance data were collected on a pen basis. Rectal temperature was measured on 3 labeled birds/pen at D35 and D42, while liver, Pectoralis major, blood, and caecal content were collected from 2 of them (12 birds/diet/temperature) at D44. Samples were analyzed with 1H-NMR and shotgun metagenomic sequencing. Before HS was applied, ARG birds showed a greater body weight and better feed efficiency than CON birds ($P < 0.05$). Regardless of diet, however, the exposure to HS decreased feed intake and growth rate, while increased mortality ($P \leq 0.01$). No significant interaction between diet and environmental temperature was found for performance traits. Rectal temperature at 6:00 PM was higher than that at 9:00 AM ($P < 0.001$) in either environment, on both the measurement days, and irrespective of diet. Diet and temperature had an effect on the concentration of numerous metabolites (e.g., ARG diet increased Arg and creatine, while HS reduced glycine). ARG birds showed less Proteobacteria and more Bacteroidetes, less Firmicutes only under TN, and a reduced observed diversity. HS reduced Bacteroidetes and increased Firmicutes, increased Proteobacteria only for CON birds, and increased Shannon index. Diet and temperature also affected beta diversity. Despite its exploratory nature, this study offers useful molecular insights to determine whether dietary Arg supplementation is worth investigating further as a potential strategy to mitigate the impacts of HS on broilers. Funding: Italian Ministry of University and Research with "PRIN National Grant 2017 - Prot. 2017S229WC".

OS2 - Nutritional intervention for climate changes

OS2-4 Using a proprietary broiler growth model to optimize the body weight (BW) or feed conversion ratio (FCR) of broilers reared under thermoneutral or heat stress conditionN. T. Ferreira¹, W. D. Mansilla², R. Koedijk³, A.I. García-Ruiz²¹TN Innovation, Trouw Nutrition, Puslinch, Canada, ²Poultry R&D, Trouw Nutrition, El Viso de San Juan, Spain,³TN Innovation, Trouw Nutrition, Amersfoort, Netherlands

Nutritional table guidelines from genetic companies provide a general description of the nutrient requirements of modern broilers. However, precise tuning of these recommendations to optimize specific performance parameters under diverse environmental conditions is of interest to better meet the demands of different markets. Trouw Nutrition has developed a proprietary Broiler Model (BM) that can optimize bird performance parameters differently. The present study's objective was to improve the BW or FCR of broiler chickens reared under thermoneutral (room A) or heat-stress (room B) conditions using nutrient recommendations optimized by the Trouw Nutrition BM. In total, 2640 one-day-old male Ross 308 broiler chickens were distributed to 60-floor pens (30 per room) with 44 birds each. Heat stress conditions started from day 9 onwards (high temperature of 32 °C for 8 h; min temperature was 26 °C for 16 h). A control feeding program was formulated based on 3 feeding phases and following the genetic guidelines (Ross, 2019). The control diet was optimized using Trouw Nutrition BM considering the ingredient composition of the control diet, nutrient content, feeding phase, and expected environmental conditions. The optimized apparent metabolizable energy and standardized ileal digestible Lys contents targeted improvements of either BW or FCR in thermoneutral or heat stress conditions. In thermoneutral conditions, BW was improved with BW optimization by 44 ±24g on day 39 (P =0.080), while the BW in the FCR-optimized treatment was not different (P =0.48). The FCR in the BW-optimized treatment was increased by 0.017 ±0.0049 (P =0.002), but the FCR in the FCR-optimized treatment was reduced by 0.050 ±0.0049 (P <0.001) compared with the control. In heat stress conditions and compared with the control, BW was improved with BW optimization by +147 ±26 g on day 39 (P <0.001), while the FCR-optimized treatment in heat stress conditions was +57.6 ±26 g (P =0.064). The FCR when optimizing for BW was not different compared with the control (P =0.40), but the FCR optimization in heat stress reduced FCR by 0.049 ±0.0050 (P <0.001). The BM accuracy between the predicted and observed performance was 99% for BW and FCR in thermoneutral conditions. In heat-stress conditions, the accuracy was 100% for BW and 95% for FCR. In conclusion, the Trouw Nutrition BM is suitable for optimizing dietary nutrient recommendations differently to improve desired performance parameters.

OS2 - Nutritional intervention for climate changes

OS2-5 Formulation of eco-friendly feeds for conventional and organic poultry to reduce feed-food competition, greenhouse gas emissions, and land useB. Méda¹, L. Jessus¹, P. Denoual², F. Garcia-Launay²¹INRAE, Université de Tours, UMR Biologie des Oiseaux et Aviculture (BOA), 37380 Nouzilly, France, ²PEGASE, INRAE, Institut Agro, UMR Physiologie, Environnement et Génétique pour l'Animal et les Systèmes d'Élevage (PEGASE), 35590 Saint-Gilles, France

While the global demand for animal protein is still increasing, the livestock sector is facing many sustainability challenges. In the poultry sector, feed production contributes to 60-70% of total greenhouse gas (GHG) emissions and consumes large amounts of human-edible feedstuffs (i.e. feed-food competition, FF). In this context, least-cost feed formulation (LCF) is no longer relevant to tackle these challenges whereas multiobjective formulation (MOF) considers simultaneously economic and environmental criteria. Therefore, our objective was to estimate the potential of MOF to reduce GHG emissions, FF and land use (LU) in feeds used in conventional and organic poultry production. Using LCF, we formulated "reference" feeds (Ref), representative of current practices in the feed industry. Using MOF, we quantified i) the maximal reduction in GHG emissions, land use and feed-food competition (MinGHG, MinLU, and MinFF, respectively), and ii) the best compromise between feed cost and either GHG emissions, land use or feed-food competition (OptGHG, OptLU, and OptFF, respectively). Prices of feedstuffs were taken over the 2018-2021 period. GHG and LU values of feedstuffs came from the French Agribalyse® database. Finally, FF coefficients for energy (FFe) and protein (FFp) were taken after Laisse et al. (2018). In the Min approach vs. Ref feeds, significant decreases were observed in GHG (-29 to -38%), LU (-30 to -60%), FFe (-22 to -56%), and FFp (-48 to -68%), for organic broiler and conventional broiler/layer feeds, at the expense of feed cost (+85 to +129%). Surprisingly, in organic layers, the increase in feed cost was more limited (+17 to +33%), for decreases in GHG, LU and FF consistent with those previously mentioned. In the Opt approach, the increase in feed cost (vs. Ref) was more limited (up to +16%), still with decreases in GHG (-17 to -26%), LU (-1 to -36%), FFe (-6 to -34%), and FFp (-15 to -40%). Depending on the criteria considered in formulation (GHG, LU, or FF), substitutions between types of feedstuffs were observed. Corn was relevant to decrease FF, while protein crops and cereal by-products were more relevant to reduce GHG and LU, respectively. Finally, with our approach, the simultaneous decrease in FF, GHG and LU was difficult to achieve and possible trade-offs can occur (i.e. increase in FF when decreasing GHG). Therefore, further work should be carried out to find optimal feed formulas simultaneously compromising cost, GHG, LU, and FF.

OS3 - Nutrition and microbiome under challenging conditions

OS3-1 Culture of avian caecum organoids to study the effect of functional amino acids and polyphenols supplementation

J. De Oliveira¹, T. Pezier¹, T. Chalvon-Demersay², S. Fontaine², W. Lambert², S. Tesseraud³, F. Bussi  re¹

¹INRAE, Universit   de Tours, UMR ISP, Nouzilly, France, ²METEX ANIMAL NUTRITION, Paris, France, ³INRAE, Universit   de Tours, UMR BOA, Nouzilly, France

Intestinal organoids culture models have the advantages of reproducing the composition and architecture of an intestinal epithelium in vitro. The aim of this study was to analyze the impact of various functional amino acids and polyphenols supplementation on intestinal digestive physiology and immune system using this type of model. Caecal crypts from 7 chickens of 14 day-old were purified and cultured in specialized medium embedded in Matrigel matrix. Organoids were grown for 7 days to obtain mature organoids with amino acids (AA) (mix of glutamine, arginine and threonine) with or without polyphenols (P) supplemented media. Viability of cultured organoids was estimated by measuring ATP release and transcriptomic responses were analyzed by medium-throughput BioMark technology. The gene expression related to immune responses, signalling pathways, amino-acid transporters and metabolism was investigated. The nonparametric Kruskal-Wallis statistical test was used to compare the data obtained in the different culture conditions: non-supplemented medium, medium with AA alone, P alone or AA+P and performed using R (version 3.5.1). The supplementations did not impact organoid viability and on the other hand, did not increase their growth. The transcriptomic analysis revealed that numerous gene expressions were not modulated, and among them, the tight junction genes involved in epithelial barrier, which confirms the homeostatic state of cultured organoids. In contrast, gene expressions of specific amino-acid transporters (SLC7A5 [AA : x5,2 p=0,0006; P: x2,1 p=0,0379 ; AA+P : x4,96 p=0,0012] SLC1A4 [AA : x5,4 p=0,0006; P: x2,8 p=0,0023 ; AA+P : x6,4 p=0,0006]) and genes involved in the arginine metabolism such as the ornithine decarboxylase (ODC) [AA : x1,4 p=0,0111; P: x1,3 p=0,0041 ; AA+P : x1,3 p=0,0175] and ornithine aminotransferase (AOT) [AA : x1,5 p=0,0012; AA+P : x1,3 p=0,0111], and in the glutamine metabolism with the Glutamate-cysteine ligase (GCL) [AA : x1,7 p=0,0041; AA+P : x2,3 p=0,0041] were significantly increased. Moreover, c-Myc recently described to play a key role in rebuilding the intestinal epithelium, was also significantly increased [AA : x1,9 p=0,0006; P: x1,5 p=0,0023 ; AA+P : x1,8 p=0,0070]. Caecal chicken organoids are a good tool for modelling nutrient impact on the intestinal epithelium and could therefore be used to evaluate the ability of amino acids supplementation to support gut health in the context of enteric infections.

OS3 - Nutrition and microbiome under challenging conditions

OS3-2 Effect of dietary treatments on performance, oocysts shedding and lesion scores in broiler chickens challenged with Eimeria infection

R.R. Santos¹, L. Star^{1,2}, F.F.C. Velkers³, J.C.M. Vernooij³, J. Heerkens², J. van Harn⁴, I.C. de Jong⁴

¹Schothorst Feed Research, Lelystad, Netherlands, ²University of Applied Sciences Dronten, Dronten, Netherlands, ³Utrecht University, Utrecht, Netherlands, ⁴Wageningen Livestock Research, Wageningen, Netherlands

For coccidiosis control, anticoccidial feed additives are often applied in broilers. However, as legislative restrictions and consumer demands urge replacement of in-feed antimicrobials, dietary interventions are suggested to be used as alternatives to support the birds during infection. The present trial aimed to test different dietary treatments to counteract the negative impact of coccidiosis on health and performance. One-day-old male Ross 308 broilers (n = 960) were randomly assigned to one of 8 dietary treatments, with 6 pens per treatment and 20 birds per pen. At 7 days (d) of age, birds from treatments (Trt) 1-7 were inoculated with sporulated oocysts of *E. acervulina*, *E. maxima*, and *E. tenella*. The positive control group (Trt6) was fed the standard diet supplemented with an anticoccidial (Decoquinat) and the control infected (Trt7) group was fed a diet without anticoccidial or any other alternative during the complete experimental period. A negative control (Trt8) was inoculated with phosphate buffer saline and fed the same diet as Trt7. From d0-10, birds from Trt1-5 received a synbiotic (probiotics combined with fructo oligosaccharides). From d10-28, Trt1 and 2 received synbiotics, whereas Trt3 received glutamine, and Trt4 and 5 received a combination of beta-glucans and betaine. From d28-35 onwards, Trt1 received synbiotics, Trt2-4 received glutamine, and the diet from Trt5 was not supplemented with any test compound. Performance was assessed for each feeding phase (d0-10, d10-28 and d28-35). Oocyst shedding, Eimeria lesion scores, caecal length and relative weight were assessed at d13, d22, d28, and d35. During the starter and finisher periods, performance did not differ between the treatments. During the grower period (d10-28), Trt6 (positive control) and Trt8 (non-challenged) broiler chickens had the best body weight gain of all treatments (P < 0.001). The Trt6 showed the lowest output of *E. acervulina*, *E. tenella* and *E. maxima* and had the lowest number of lesions. When comparing the treatments with the challenged group (Trt7), a beneficial effect of betaine combined with beta-glucans (Trt4) was observed, with a decrease in oocyst output (P < 0.05) and decrease in lesion scores, especially those caused by *E. tenella* (P < 0.05). Although this combination did not improve bird performance, the severity of Eimeria infection was reduced, making these additives relevant to consider in follow-up studies.

OS3 - Nutrition and microbiome under challenging conditions**OS3-3 Effects of commercial processing conditions of extruded soybean on ileal and cecal microbiota of broiler chickens**A.M. Villegas^{1,2}, N. Yacoubi³, M. Klunemann³, A. Menconi², T. Applegate¹¹Department of Poultry Science, University of Georgia, Athens, United States, ²Evonik Corporation / Nutrition & Care, Kennesaw, United States, ³Evonik Operations GmbH, Hanau- Wolfgang, Germany

Expeller Soybean (SB) is commonly used as the main protein source in broiler diets due to its high amino acid digestibility. Optimal SB processing is required to ensure that antinutritional components are deactivated. However, differences in processing can also impact the nutrient quality and digestibility. In this study, we investigated the effect of 3 commercial expeller SB batches processed at different temperatures, on microbiota composition. The 3 expeller SB batches were processed with different extruder temperatures of 182, 199, and 154 °C for normal-control (NC), overcooked (OC), and undercooked (UC) SB, respectively. A total of 1,860 male Cobb 500 broiler chicks were randomly allocated to the 3 different treatments with 10 replicate floor pens (62 birds/pen) from 0 to 35 day of age. At day 7, 14, and 28 one bird/pen was sacrificed and ileal and cecal content were sampled for 16s sequencing. Sequences were processed with DADA2 and diversity analysis was focused on the genus level. For both ileal and cecal samples alpha diversity measured as Shannon index increased significantly with time. Additionally, PERMANOVA of Bray-Curtis distance showed that also beta diversity differed significantly between all-time points. For ileum samples, alpha diversity of NC samples was higher than OC or UC samples at day 28 only. Treatment affected ileal beta diversity at day 14 and day 28 separating all treatments from each other. We found a cluster of OC samples away from NC or UC samples in PCA. In ileum OC samples have a significantly higher abundance of two Lactobacillaceae genera. In cecum, alpha diversity measured with Shannon index was not affected by treatment. Treatment affected also cecal beta diversity at day 14 and day 28 separating all treatments from each other. Similarly, to ileum OC samples were most different. Also in cecum, OC samples had higher abundance of several Lactobacillaceae genera at day 14. At day 28, OC samples showed higher levels of Akkermansia, Lactobacillus and Bacteroides, but also Streptococcus and Staphylococcus. In conclusion, inappropriate SB processing can impact the microbiota in the ileum and caecum, particularly nearer to processing age. In both compartments OC has a stronger effect than UC one.

OS3 - Nutrition and microbiome under challenging conditions**OS3-4 Systematic review on microbiome-related interventions to enhance broiler productivity and safety of poultry meat**Y. Mekonnen¹, V. Indio¹, F. Savini¹, F. Giacometti¹, A. Serraino¹, M. Candela², G. Manfreda³, A. De Cesare¹¹Department of Veterinary Medical Sciences, University of Bologna, Bologna, Italy, ²Department of Pharmacy and Biotechnology, University of Bologna, Bologna, Italy, ³Department of Agricultural and Food Science, University of Bologna, Bologna, Italy

Broiler productions are facing huge challenges due to the increase of feed costs, circulation of traditional and emerging pathogens and managing of antimicrobial resistance. The control of pathogens circulating in the broiler food system is the primary goal to improve broiler production and health, thus contributing to the achievement of at least some of the Sustainable Development Goals of the United Nations. This systematic literature search addresses different microbiome-related nutritional strategies based on supplementation of microbiomes or targeting the microbiomes which are, and have been used, to improve broiler productivity and control pathogens in the poultry value chain. Original research articles describing microbiome-related interventions in the last 10 years were searched in Scopus and PubMed and screened based on specific inclusion and exclusion criteria. A total of 518 articles were retrieved; 145 fulfilled the inclusion criteria and were therefore reviewed for data collection. Overall, 213 microbiome-related interventions were identified in the selected papers and categorized as probiotics (n=93), prebiotics (n=45), phytobiotics (n=30), synbiotics (n=20), organic acids (n=4), enzymes (n=5), short-chain fatty acids (n=2), essential oils (n=5) and combination of those (n=9). The supplementation of microbiome-related interventions in the basal diet of broilers were reported to have different impacts. In particular, in 128 papers the interventions improved weight gain or feed digestibility; in 126 they were aimed at protecting broilers against pathogens, especially foodborne pathogens, or ameliorating their negative consequences; in 91 they played a role in modulating the gut microbiome; in 76 improved meat quality or carcass yield; finally, in 51 they were used as alternatives to antibiotics or anticoccidial. This systematic review discloses the microbiome-related interventions able to improve the economic and social sustainability of poultry food systems.

OS3 - Nutrition and microbiome under challenging conditions

OS3-5 Ex vivo assessment of the direct and indirect antimicrobial capacities of glycerides of lauric acid using gastrointestinal fluids

N. Vieco-Saiz¹, V. Michel¹, A. Mellouk¹, O. Lemâle², T. Goossens³, J. Consuegra¹

¹R&I Nutrition Adisseo France SAS, Lyon, France, ²Adisseo NL B.V., Health by Nutrition, Raamsdonksveer, Netherlands, ³Adisseo, Health by Nutrition, Dendermonde, Belgium

Alpha-monolaurin is an antimicrobial agent with a potent in vitro activity against gram-positive (G+) but less against gram-negative (G-) bacteria. To this reason, glycerides of lauric acid (C12G) are used as a feed additive to prevent intestinal infections, thereby enhancing animal resilience against pathogen challenges, and improving animal performance. Here, we aimed to evaluate the ex vivo antimicrobial activity of C12G using gastrointestinal (GIT) fluids from animals receiving a C12G-supplemented feed. A total of 100 chicks were divided in two experimental groups, both receiving the same standard diet supplemented or not with C12G at 3 kg/ton. Contents from crop, ileum and caeca were sampled at day 28 and GIT fluids were extracted and filter sterilized. Their antimicrobial capacity was assessed using Minimal Inhibitory Concentration (MIC) assays against *Enterococcus faecalis* and *Escherichia coli* APEC. MIC analyses showed that GIT fluids from animals receiving C12G have an antimicrobial activity against G+ and G- bacteria. Specifically, *E. faecalis* growth was significantly reduced by the GIT fluids from crop, ileum, and caeca. This ex vivo antimicrobial activity shows that supplemented C12G conserve their antimicrobial effect all along the GIT which ensures animal protection against pathogen challenges. Interestingly, only cecal fluids presented an antimicrobial activity against *E. coli* APEC. Since C12G are less active in vitro against G- bacteria, we hypothesize that this antimicrobial activity may be explained by a microbial shift on cecal microbiota exerted by C12G towards a microbial profile of metabolite producers that may inhibit G- bacteria. To test this hypothesis, we are currently performing microbiota analyses on ileal and cecal samples. Altogether, using GIT fluids and the ex vivo assessment of its antimicrobial activities, our study suggests that C12G have a dual mode of action to inhibit pathogenic bacteria. First, they can act directly against G+ bacteria all along the GIT. Second, they can indirectly inhibit G- in the ceca, possibly by inducing a microbiota shift towards the production of antimicrobial metabolites. Further studies will be needed to characterize and identify the specific molecules produced by the microbiota explaining this G- antimicrobial effect.

OS4 - Solution to improve the nutritional value of feed

OS4-1 The net energy system predicts more accurately broiler feed energy than the metabolisable energy system regardless of the crude protein content

S. Musigwa¹, P. Cozannet², C.A. Asiamah¹, S. Wu¹

¹Animal Science, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia, ²Adisseo SAS, Antony, 92160, France

Metabolisable energy (ME) is a preferred system used in feed formulation to evaluate the available energy in poultry feeds. However, an accurate prediction of energy intake is provided by the net energy (NE) system, as this takes account of post-absorptive metabolism. This is paramount given the sensitivity of broiler economics to small changes in the efficiency of cost and feed formulation. The aim of this study was to determine if using the NE system in formulation improves performance in birds fed low crude protein (CP) diets, and if so to what extent. The study used a 2x4 factorial arrangement of treatments. Factors included CP: 18% and 16%, and energy combination: normal NE (10.40 MJ/kg) with low apparent ME corrected of nitrogen (AMEn, 12.85 MJ/kg) - NL, normal NE with normal AMEn (12.97 MJ/kg) - NN, low NE (10.30 MJ/kg) with normal AMEn - LN, and high NE (10.50 MJ/kg) with normal AMEn - HN. Eight finisher dietary treatments were formulated to meet Cobb 500 requirements (2018), and they were replicated 8 times using 16 mixed-sex birds/replica. All treatment diets were formulated to contain a similar essential amino acids (AA)-to-true protein ratio of 0.60, with 254 mEq/kg dietary electrolyte balance. Birds were fed a common starter diet (d0-8), a common grower diet (d9-18) and test finisher diets (d19-35). Birds and feeds were weighed on d19, 28 and 35 to evaluate weight gain (WG) and feed conversion ratio (FCR). On d35, 4 birds (2 males and 2 females) per pen were sampled to evaluate carcass quality. All data were analysed using JMP software, with gender as a covariate for the performance data. The results showed no interaction between CP levels and the energy combination ($P>0.05$) for any of the measured parameters. Compared with the HN-fed birds, birds offered NN diets increased WG on d28 ($P=0.01$) and d35 ($P<0.05$), and reduced ($P<0.05$) FCR on d28. The LN-fed birds reduced ($P<0.05$) fat pad weight compared with the NL-fed birds, indicating that energy densities were lower in the LN than in NL diets. Birds fed 16% CP diets had a higher ($P<0.001$) fat pad than 18% CP-fed birds, regardless of energy combination. However, this increase in fat deposition did not affect ($P>0.05$) WG nor FCR on d35. This restored performance was due to well-balanced AA in reduced CP diets. Results from this study demonstrate the advantage of the NE system over the ME system for predicting broiler performance and that balancing AA in reduced CP diets restores bird performance.

OS4 - Solution to improve the nutritional value of feed**OS4-2 Effects of limestone source and increasing levels of a novel 6-phytase on growth performance of conventional and slow growing broiler breeds**V. Lagos¹, C. Walk², C. Kwakernaak¹, L. Levrouw³, A. Smith²¹Schothorst Feed Research, Lelystad, Netherlands, ²DSM Nutritional Products Ltd, Heanor, United Kingdom, ³DSM Nutritional Products N.V., Deinze, Belgium

A study was conducted to evaluate the effect of increasing phytase levels (PL) on growth performance of conventional (Ross 308; RB) or slow growing (Hubbard JA757; HB) broilers fed diets with 2 limestone sources (LS1 or LS2). For each breed (BR) and LS, a starter (5-14d), grower (14-20d), and finisher (20-35d) negative control (NC) diet was formulated based on wheat-corn-soybean meal and including an NSP enzyme. For HB, also a 35-50d NC was used. The RB diet contained: AME = 2900 kcal/kg, dLys = 11.5, Ca = 6.8, rP = 1.9 g/kg in starter; AME = 2975 kcal/kg, dLys = 10.9, Ca = 6.3, rP = 1.8 g/kg in grower; AME = 3050 kcal/kg; dLys = 9.7, Ca = 5.2, rP = 1.5 g/kg in finisher. The HB diets contained 20-25 kcal/kg AME, 0.4-0.8 g/kg dLys, and 0.1 g/kg rP less than the RB diets. The 35-50d HB diet had 3050 kcal/kg AME, 8.3 dLys, 5.0 Ca, and 1.25 g/kg rP. The NC diets were supplemented with 0, 300, 900, or 2700 phytase units/kg (FYT), resulting in 16 dietary treatments. A common diet was fed from 0-5d. Diets were fed as pellets to 6 pens/treatment (34 RB or 36 HB birds). Data were analyzed by ANOVA with BR × LS × PL in the model. No 3-way interactions were observed. Body weight gain (BWG) 5-14d of RB increased with each PL from 424 to 467g, whereas in HB, BWG only increased from 0 to 300 FYT to 900 or 2700 FYT (BR × PL, P<0.05). Feed conversion ratio (FCR) was lower (P<0.05) in RB vs. HB, and overall was reduced (P<0.05) by increasing PL by -4% at 2700 FYT. In the grower phase, the positive effect of PL (up to 900 FYT) on BWG was greater in RB than HB (+20 vs. +16%; BR × PL, P<0.05). BWG was improved +22% at 2,700 FYT with LS1, but +20% at 900 FYT with LS2 (LS × PL, P<0.05). FCR was influenced (P<0.05) by BR and PL as in starter. In the finisher phase, BWG was influenced (P<0.05) by BR (lower in HB vs. RB) and PL (increased by 14% as PL increased). FCR improved with phytase inclusion in HB but was not affected in RB (BR × PL, P<0.05). Performance from 5-35d was not affected by LS, but improvement in BWG and FCR by PL was greater in HB than RB (+3% and -2% at 2700 FYT, respectively; BR × PL; P<0.05). For HB 35-50d, phytase inclusion increased (P<0.05) BWG by 8% with no differences among PL, and FCR was better (P<0.05) in LS1 compared with LS2. In conclusion, increasing PL improved broiler performance and, the degree of such effect was influenced by feeding phase, BR, and LS source. Further research is needed to understand interactions between BR or LS and PL.

OS4 - Solution to improve the nutritional value of feed**OS4-3 Effects of maize moisture at harvest and drying temperature on starch content and particle size of corn ground in a roller mill**J. Cabanas-Ojeda¹, N. Mejia-Abaunza¹, P.A. Lozano-Cruz¹, M. Ali¹, G.A. Gomes², E.O. Oviedo-Rondón¹¹Prestage Department of Poultry Science, North Carolina State University, Raleigh, NC, United States, ²AB Vista, Plantation, FL, United States

Maize moisture at harvest (MH) and post-harvest drying temperatures (DT) may modify starch properties in corn kernels. These interaction effects on grain starch profile and particle size (PS) post-grinding have not been evaluated. However, they can significantly impact feed manufacturing and poultry energy utilization. The objective of this study was to evaluate the effects of MH on starch composition and the resulting PS of four corn varieties (CV) differing in vitreousness (A: 59.7, B: 60.1, C: 58.3, D: 61.7%) and dried at two temperatures. Four yellow dent CVs were planted under similar agronomic conditions. They were harvested with 34, 28, 22, and 16% grain MH. The kernels were dried in an air-forced oven at 35 or 120oC (DT) to obtain corn grain with moisture near 13% for storage. Kernel moisture was measured before and after drying using a portable moisture tester. Pre- and the post-drying kernel were analyzed for starch content, damaged starch, resistant starch (RS), and vitreousness. Samples of each corn type were ground in a roller mill with a 25-25 percent gap between the two sets of rolls. Five samples per corn treatment were evaluated for PS by the sieving method ASAE S319.3. Data were analyzed in a 4x4x2 factorial arrangement of treatments in a completely randomized design using a three-way ANOVA, and the means were separated by Tukey's HSD test. Three-way interaction effects were observed (P<0.001) for vitreousness, starch traits evaluated, PS, and its distribution. Corn with 16% MH and dried at 120oC presented the highest total and RS content for all CVs, except for CV D with 22% MH. Damaged starch was greater in all CVs at any DT when MH was 16%, except for CV D with 28% MH and dried at 35oC. In general, geometric mean PS (d_{gw}) decreased (P<0.001) from 986 to 844 um, and standard deviation (S_{gw}) increased from 4.25 to 5.16 um with higher MH for all CVs. A correlation (P<0.001) between total starch content with d_{gw} (r = 0.38) and S_{gw} (r = -0.33) was identified. Additionally, a correlation (P<0.01) between MH with d_{gw} (r = -0.52) and S_{gw} (r = 0.59) was also detected. In conclusion, corn MH and DT affected the total starch content of almost all CVs, which increased on average by 3.3% points at the lower MH (16 and 22%). Drying at 120oC increased RS for all CVs compared to 35oC, except for CV C. Furthermore, 16% MH presented the highest RS values. Damaged starch and d_{gw} were increased, while S_{gw} was decreased as corn MH reduced and DT increased.

OS4 - Solution to improve the nutritional value of feed**OS4-4 Improvement of protein digestibility by changing digesta passage kinetics in broilers**A. Jansman¹, A. Mens¹, E. Willems², M. van Krimpen¹¹Wageningen Livestock Research, Wageningen, Netherlands, ²Agrifirm, Apeldoorn, Netherlands

We studied the effects of dietary fibre supplementation on the kinetics of crude protein (CP) digestion in broilers using diets with ingredients with a variable fraction of protein (N) entrapped in fibre (NDF). The digestibility study (d 17 - 24 of age) comprised eight dietary treatments and six replicates (12 birds per pen) per treatment. The treatments included (1) a basal diet with potato protein (10%) and egg albumin (10%) as main protein sources or diets in which part of the basal diet was replaced proportionally by wheat (41%), rapeseed expeller meal (25%) or soybean meal (25%) and (2) supplementation of either 5% purified cellulose (Arbocel) or 5% oat hulls (OH). Titanium dioxide (0.5%) and cobalt-EDTA (0.1%) were used as markers. All birds were sacrificed at d 24 for digesta collection and measurement of digestibility and digesta mean retention time (MRT) in various segments of the GIT. Including OH prolonged MRT of both the solid and liquid phase in the gizzard but shortened the MRT in the duodenum and jejunum ($P < 0.05$). In the gizzard, both ingredient composition and fibre source affected the MRT. Supplementation with OH resulted in a higher gizzard weight, an improved development of the gizzard and lower digesta pH ($P < 0.001$). The CP digestibility in the gizzard was highest for the wheat-based diets, followed by the basal diets and lowest for the rapeseed expeller and soybean meal-based diets. The differences were enlarged by including OH in the diets. Furthermore, ingredient composition affected the CP digestibility in the jejunum, proximal ileum and distal ileum. The partial protein digestibility in the jejunum and proximal ileum were 5 till 12% and 2 till 6% higher when OH were supplemented to the diets. The distal ileal protein digestibility was increased by 1 to 3 % by supplementing the diets with OH, the effect varying between diets. The estimated digestibility of the N in NDF was increased by OH supplementation from 83 to 84% in the basal diets, from 16 to 21% in the RSE diet, from 76 to 80% in the SBM diet and from 54 to 63% in the wheat-based diet. In conclusion, inclusion of 5% coarse oat hulls in broiler diets increases digesta retention time in the proximal part of the digestive tract and increases ileal protein digestibility by at least 1 to 3%. Part of the improvement might be related to the release of a potentially digestible protein linked to the fibre fraction in feed ingredients.

OS4 - Solution to improve the nutritional value of feed**OS4-5 Prediction of feeds net energy for broilers**T.Z. Aye Cho¹, M. Wongphatcharachai¹, P. Srichana¹, P. Geraert², J. Noblet³¹Feed Technology Office, Charoen Pokphand Foods Public Company Limited (CPF), Bangkok, Thailand, ²Adisseo France S.A.S., 10 Place du Général de Gaulle, 92160, Antony, France, ³INRAE (retired), 35590 Saint-Gilles, France

Net energy (NE) in poultry is regarded as a more precise energy system compared to conventional apparent metabolizable energy (AME) due to its ability to consider the energy lost as heat increment from nutrient metabolism that averages 25% of AME and is variable with feed characteristics. However, unlike pigs, NE is not yet implemented in poultry nutrition. This study aimed to measure the NE value of 23 diets highly variable in terms of chemical composition (% of dry matter; 33.6 to 55.3% for starch; 20.8 to 28.4% for crude protein (CP), 2.7 to 10.6% for fat (EE) and 7.0 to 17.2% for NDF) in order to establish NE prediction equations for broiler feeds. Diets were prepared with 13 major ingredients (wheat, corn, paddy rice, broken rice, cassava, full-fat soybean, soybean meal, canola meal, animal protein, rice bran, wheat bran, palm kernel meal, palm kernel oil) at various and independent inclusion levels in order to calculate robust prediction equations between NE content and chemical constituents or levels of ingredients. All diets met the amino acid requirements of the birds. The diets were fed to male Ross 308 broilers kept in 12 open-circuit respiratory chambers from 17 to 22 days of age (4 birds per cage) after 5 days of adaptation for measurement of growth performance, diet AME content and heat production and calculation of diet NE value. The trial was planned on a weekly basis with 12 diets measured each week (one per chamber), one of the 23 diets (reference) being measured each week. Each diet was tested in 10 replicates (20 for reference diet) and never measured more than once in each chamber (except the reference diet). In total, 235 energy balance data were available for the final calculations. Performance of birds (89 g/d BW gain on average), diet AME (3644 kcal/kg dry matter on average; range: 3356 to 4003) and AME/GE (79.4% on average) were as expected. The NE/AME ratio averaged 76.6% (range: 74.7 to 78.7%) and increased with EE and decreased with CP in the feed. Accordingly, diet NE value was positively related to AME and EE contents and negatively to CP level; NDF had also a significant negative contribution to NE content. Starch had no significant impact on NE prediction. The NE equations generated in the current study show a good agreement with previous studies on poultry and pigs and were also able to predict the NE value of the ingredients of our trial. This study further highlights the importance of NE approach in broilers.

OS5 - Non-soy protein sources

OS5-1 The nutritional value of porcine blood proteins: AMEn and apparent total tract digestibility of blood meal, haemoglobin powder and plasma powder in young broilers of different agesL. Stokvis¹, C. van Vuure², R. Davin¹¹Schothorst Feed Research, Lelystad, Netherlands, ²Darling Ingredients International Rendering and Specialties B.V., Son, Netherlands

To implement a more circular and safer bioeconomy the use of porcine blood proteins in poultry diets could be especially suitable for young broilers, due to their expected high digestibility. Moreover, information on the effect of age on the nutritional value of these products is lacking. The objective of this study was to obtain AMEn and apparent total tract digestibility (ATTD) of the main nutrients and amino acids (AAs) of porcine blood meal, porcine haemoglobin and porcine plasma protein compared to SBM in young broilers at 3, 7, 14 and 21-23 days of age. In total, 640-day-old female Ross 308 broilers were housed in 32 digestibility cages (2 m²) with 20 birds per pen and 8 replicates for the basal diet and 6 replicates for the other treatments. The basal diet (174 g/kg CP) was diluted to produce the experimental diets containing either 22.3% SBM, 10% blood meal, 10% haemoglobin powder or 9% plasma protein and TiO₂ at 0.35% as undigestible marker. Feed and water were available ad libitum. Excreta was collected quantitatively per pen for 24h on d3, 7 and 14 and semi-quantitatively per pen (7h on 3 consecutive days) from d21-23. All samples were analysed for nutrients to calculate AMEn (based on CVB equation) and digestibility of the diets (including uric acid for correction in the ATTD CP digestibility) and test feedstuffs applying the difference method, and excreta samples from d7 and d21-23 were analysed for AAs. Data were analysed using ANOVA with pen as experimental unit and significance stated at P=0.05. At day 3 all blood proteins showed a higher OM digestibility compared to SBM and plasma showed the highest CP digestibility (P <0.001). The highest CP digestibility was observed for haemoglobin (d7 and d21-23) and plasma (d7, d14 and d21-23), whereas blood meal showed an equal digestibility compared to SBM at d7, 14 and 21-23 (P <0.001). At d7 haemoglobin showed the highest ATTD of AAs (P <0.003), and at d14 both haemoglobin and plasma showed the highest ATTD of most AAs (P <0.010). At days 7, 14 and 21-23, AMEn was highest for haemoglobin and blood meal, followed by plasma and AMEn was lowest for SBM (P <0.001). In conclusion, plasma, haemoglobin and blood meal have a high OM, CP and AA digestibility and AMEn values, higher than SBM, and seem to be suitable dietary ingredients for young broilers. Differences in the ranking of the test feedstuffs over time should be regarded when formulating the diets for different feeding phases.

OS5 - Non-soy protein sources

OS5-2 Determination of nutritional value of seeds from different cultivars of pea, yellow lupine, and faba bean for laying hensM. Hejdysz¹, K. Perz¹, S. Nowaczewski¹, S. Kaczmarek²¹Department of Animal Breeding and Product Quality Assessment, Poznan, Poland, ²Department of Animal Nutrition, Poznan, Poland

The study aimed to determine the value of nitrogen-corrected apparent metabolizable energy (AMEN), apparent ileal digestibility (AID) of dry matter, crude protein, and amino acids of different sources of protein for laying hens. A total of 182 Hy-Line Brown layers with 18 weeks of age were randomly divided into 13 groups, with 14 replications (one bird per replication). The experiment lasted for 12 days and was divided into two periods: from the 1st to 5th day when all birds were fed the reference diet (group 1), and from 6th to 12th day, when 50% of the reference diet was replaced with the tested raw material: groups 2-5 were fed different seeds of peas, groups 6-9 were fed different seeds of yellow lupine, and groups 10-13 were fed different seeds of faba bean. Various Polish cultivars (cv.) of pea (cv. Mecenaz; Mentor; Medyk; Starski), yellow lupine (cv. Lord; Puma; Perkoz; Baryt), and faba bean (cv. Amulet; Fernando; Olga; Amigo) were used. On the 9th, 10th, and 11th day of the experiment excreta collection was done and on the 12th day the birds were sacrificed for the collection of ileal digesta. There were no differences between pea cultivars in AMEN value and AID of crude protein. However, the pea cultivar affected the AID of dry matter and some amino acids. The cv. Mentor was characterized by significantly lower dry matter, cystine, and lysine digestibility coefficients compared to the other cultivars. The yellow lupine cultivars affected AMEN, as well as AID of dry matter, crude protein, and some amino acids; the cv. Puma was characterized by a higher AMEN value, whereas the cv. Lord led to higher AID of dry matter, although statistically similar to the cv. Puma. Lower digestibility of threonine, tyrosine, and lysine was also noted for the cv. Baryt. The faba bean cultivars influenced AMEN and AID of dry matter, crude protein, and some amino acids, as the lowest and highest AMEN values were determined for the cv. Olga and cv. Fernando, respectively. The cv. Amulet and cv. Fernando varieties were characterized by a higher AID of dry matter, whereas cv. Olga had showed lower AID of crude protein and lysine. The experiment shows that the cultivars from different seeds of pea, yellow lupine, and faba bean affect their nutritional value, denoting distinct suitabilities for their use as protein sources for laying hens nutrition.

OS5 - Non-soy protein sources**OS5-3 Effects of the partial replacement of dietary soybean with insect meal on growth performance, meat quality and ceca metabolome and microbiota composition of female turkeys**

M. Zampiga¹, F. Soglia¹, L. Laghi¹, A. De Cesare², G. Brugaletta¹, C. Oliveri³, V. Indio², M. Petracci¹, F. Sirri¹

¹Department of Agricultural and Food Sciences, Alma Mater Studiorum - University of Bologna, Bologna, Italy,

²Department of Veterinary Medical Sciences, Alma Mater Studiorum - University of Bologna, Bologna, Italy,

³Department of Physics and Astronomy "Augusto Righi", Bologna, Italy

The use of non-soybean protein sources can improve the environmental sustainability of poultry production, even if the animal response to this nutritional strategy needs to be evaluated. The present study was performed to investigate the effects of the partial replacement of dietary soybean with insect meal (*Hermetia illucens*) on growth performance, meat quality and ceca metabolome and microbiota in heavy female turkeys. A total of 1,512 one-day-old female poults (BUT Big 6) was divided into two experimental groups (9 replicates of 84 birds/each): CON, fed a conventional soybean-based diet in all feeding phases, and INS, which received CON diet up to 64 d and then CON diet with 5% of insect meal as a substitution for soybean until slaughter (105 d). All diets were isoenergetic and isonitrogenous and supplied in pelleted form. Body weight (BW), daily weight gain (DWG), daily feed intake (DFI) and feed conversion ratio (FCR) were determined on a pen basis in each feeding phase, while mortality was daily recorded. At slaughtering, ceca content was obtained from 15 birds per group and then subjected to microbiota (16S Amplicon Sequencing) and metabolome (1H-Nuclear Magnetic Resonance) analysis. Moreover, 12 breasts/group were collected for the evaluation of the main meat technological properties (pH, color profile, water holding capacity and shear-force). As expected, CON and INS turkeys performed similarly up to 64 d. At market age (105 d), INS turkeys presented greater BW than CON (10,173 vs. 10,057 g/bird, respectively; $P < 0.05$) as well as higher DWG and lower FCR in the overall trial (0-105 d; 96.2 vs. 95.2 g/bird/d, and 2.127 vs. 2.141, respectively; $P < 0.05$). Mortality and DFI were similar between experimental groups. Analogously, the use of insect meal did not substantially modify meat technological properties. Metabolome analysis revealed that some metabolites, including glucose, malonate, isoleucine, betaine and butyrate, exhibited higher concentrations in the ceca content of INS birds and the explanation of these results might come out from the ongoing microbiota analysis. Overall, the partial replacement of dietary soybean with insect meal from 64 d onwards improved the productive performance of female turkeys without considerably affecting breast meat quality. Metabolome and microbiota insights carried out in this study can help to shed light on the factors involved in the performance improvements observed in response to insect meal administration.

OS5 - Non-soy protein sources**OS5-4 Comparative Assessment of Digestion of Protein-Rich Feed Ingredients in Broiler Diets Using a Dynamic and a Static In Vitro Model of the Avian Foregut**

T. Vingerhoets^{2,1}, J. van den Borne¹, K. Venema³, W. Pellikaan², R. Kwakkel²

¹HAS green academy, Research Group 'Healthy Farming', 's-Hertogenbosch, Netherlands, ²Wageningen University, Department of Animal Sciences, Animal Nutrition Group, Wageningen, Netherlands, ³Maastricht University, Centre for Healthy Eating and Food Innovation, Venlo, Netherlands

Soy cultivation and usage of related coproducts in broiler diets is related to global warming and biodiversity loss due to deforestation of the Amazon rainforest. Sustainable broiler nutrition requires (partial) substitution of soybean meal (SBM) by alternative protein sources (APS). Simultaneously, competition over nutritive resources for implementation in either feed or food should be avoided. A large variety of APS qualifies and an inventory study over more than eighty potential ingredients resulted in a selection of eight APS. These APS are considered to benefit sustainable production, since they are either cultivated locally, fit within circular agricultural concepts and limit the feed-food-competition, or are considered 'novel' sources with potency for more intensive or highly efficient production in the near future. The selected APS include: lupins, field beans, rapeseed meal, potato protein, porcine blood meal, black soldier fly (*Hermetia illucens*) larvae meal, micro algae (*Chlorella sorokiniana*) and single cell protein. As a reference, also Brazilian (GMO) SBM was included. In order to stimulate correct inclusion in broiler diets, nutritive properties of the selected APS must further be evaluated. Pre-cecal protein digestibility gives an indication of the potential availability and subsequent inclusion levels in broiler diets. In this study a static and dynamic in vitro model, both simulating enzymatic digestion in the broiler's foregut at an age of approximately 30 days, were applied. Models used were: an adaptation of a model developed by Moquet (2016) (static) and the 'Chicken Alimentary Tract In vitro Model' (CALIMERO®) (dynamic), an adaptation to 'TNO Intestinal Model' (TIM). Alpha amino nitrogen analysis and Dumas' nitrogen detection were applied on samples collected from substrates, digesta and residues at set times during and at the end of each run. Analytical results were used to calculate protein digestibility. Preliminary results show protein digestibility of selected APS varying between 77% and 85%. In vitro models contribute to the further development of animal-free test methods. Combining these results with parameters concerning the impact of APS usage on animal performance-, health- and welfare status, as well environmental impact of related production systems, from later phases of this project, will provide an interdisciplinary focus on new sustainable strategies in broiler nutrition.

OSS - Non-soy protein sources**OSS-5 Effect of single cell protein incorporated diets on growth performance, carcass characteristics, serum biochemistry and gut health of broilers based on total and standardised ileal digestible amino acids**

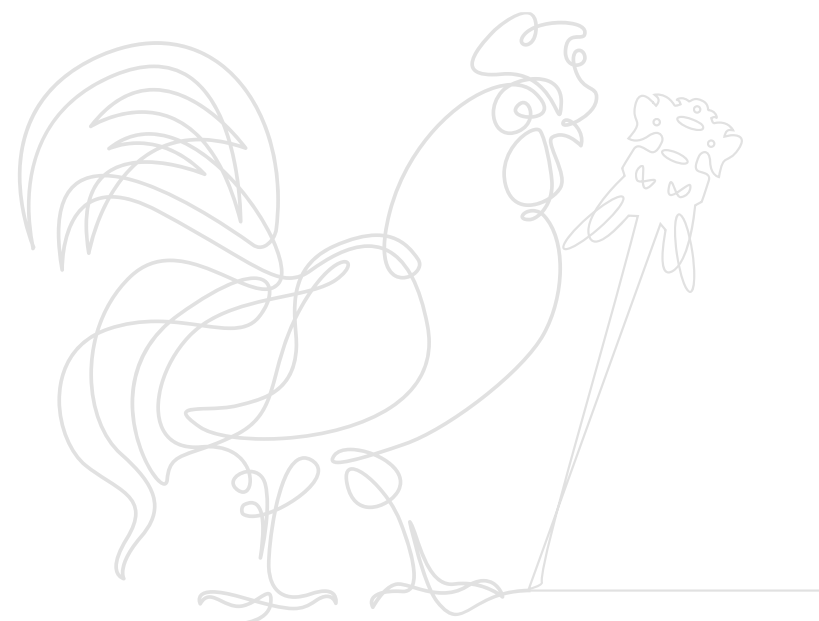
R. Chikkanna¹, S. Bypanahalli², J. Narasimhappa¹, R. Doreswamy¹, N. G S¹, M. Honnenahalli¹

¹Veterinary College, Karnataka Veterinary Animal and Fisheries Sciences University, Hassan, Karnataka State, India, ²Veterinary College, Karnataka Veterinary Animal and Fisheries Sciences University, Bengaluru, India

Single cell protein (SCP), produced produced from *Methylococcus* spp. was evaluated as a protein source in broiler diets formulated on total amino acids (TAA) and standardized ileal digestible amino acids (SIDAA). 320 one-day broiler chicks were allocated to eight treatments, each containing five replicate groups of eight chicks each. A corn-soy based control diet and three test diets incorporating SCP (677 g TAA/kg) at 5, 10 and 15% replacing soybean meal (445 g TAA/kg) in control were formulated on TAA basis. Another four diets containing 0, 5, 10 and 15% SCP were formulated on SIDAA basis. All diets in crumble form were made iso-nitrogenous and iso-caloric for starter (0-8 days), grower (9-18 days), finisher 1 (19-28 days) and finisher 2 (29-42 days) phases. SCP incorporation up to 5% in the diets resulted in similar feed intake and body weight gain as that of control, whereas feed intake and body weight gain reduced significantly ($p < 0.01$) in 10 and 15% SCP diets fed broilers during all the phases and cumulatively. However, the feed conversion ratio and livability remained unaffected by SCP levels. SCP up to 15% in diets has no effects ($p > 0.05$) on abdominal fat percentage, relative weights of spleen, heart, serum enzymes (SGPT, SGOT, ALP), protein fractions (total protein, albumin, globulin), uric acid, mineral profile (Ca, Na, K and Cl) and intestinal morphometry (villi length of duodenum, villi length and crypt depth of jejunum and ileum). However, inclusion of SCP at 10 and 15% showed significantly ($p < 0.01$) lower dressing percentage, breast and thigh yield, relative weight of liver, gizzard, bursa and crypt depth of duodenum while significantly ($p < 0.01$) higher relative length and weight of small intestinal segments than that of control. The performance of broilers fed diets formulated on TAA were comparable with SIDAA diets except higher feed intake and poor feed conversion ratio in starter phase, higher serum total protein and globulin, crypt depth of duodenum and relative weight of ileum and lower relative weight of liver and heart in SIDAA diets. SCP can be incorporated at 5% without affecting the performance, carcass quality, serum biochemistry and gut health of broilers and higher level of SCP (10 and 15 %) in broiler diets affects several parameters including decreased feed intake and body weight gain. Further, no significant difference in broiler performance was observed between SIDAA and TAA diets.



POSTER PRESENTATIONS



CONTENT

PS1 - Nutrition for sustainability in broiler, layer and turkey production 129

PS1-001 A microencapsulated feed additive containing organic acids and botanicals has a distinct effect on proliferative and metabolic related signaling in the jejunum and ileum of broiler chickens	129
PS1-002 A multi-enzymatic complex with high doses of phytase improves environmental and economical sustainability of broiler production.....	130
PS1-003 A novel consensus bacterial 6-phytase variant improves ileal amino acid digestibility independent of dietary phytate content and the age of broilers	131
PS1-004 A novel protease improves apparent nitrogen retention in excreta and reduces ammonia emission from litters in poultry houses.....	132
PS1-005 A triple-strain probiotic approach in laying hens	133
PS1-006 Are digestible calcium values formulated in broiler diets with existing digestible calcium values for individual feed ingredients similar to the digestible calcium values determine in-vivo?	134
PS1-007 Bakery by-products in poultry diet: effects on performance, blood parameters and fatty acid profile of meat	135
PS1-008 Can modulating egg weight by dietary amino acids improve the eggshell quality in old laying hens?.....	136
PS1-009 Carvacrol diffuses from amnion to yolk where it remains stable in pre-hatch chicks	137
PS1-010 Comparative efficacy of dietary IntelliBond copper, manganese, and zinc with organic minerals on egg production and quality in broiler breeders from 42 to 63 weeks of age.....	138
PS1-011 Comparison of feed and water supplementation of <i>Saccharomyces cerevisiae</i> boulardii on gut morphology and microbiota in broilers.....	139
PS1-012 Complete Life-Cycle Assessment of a low dietary crude protein strategy in broiler production system from England	140
PS1-013 Cosabody and Narasin synergistically improve broiler performance in enteritis challenged birds.....	141
PS1-014 Cosabody cooperatively enhances the effect of ionophores on broiler performance in Coccidiosis control model.....	142
PS1-015 Degradation kinetics of maize tocots during storage of grain and complete feeds of differing in commercial hybrids	143
PS1-016 Determining a methionine matrix value for added betaine without and with added choline in broiler diets	144
PS1-017 Dietary addition of quercetin or 1,25-dihydroxyvitamin D3 improves eggshell and bone qualities of aged laying hens by regulating calcium transport in uterus and bones.....	145
PS1-018 Dietary hydrolyzed yeast improved intestinal morphology and immune response of broilers under stress challenge	146
PS1-019 Dietary xylo-oligosaccharides result in decreased abundance of epithelial healing and cell motility proteins indicating improved gut integrity in broiler chickens.....	147

PS1-020 Digestibility of standard and low-input diets in chicken commercial hybrids, local breeds, and crossbreds	148
PS1-021 Distribution of intestinal intraepithelial and lamina propria lymphocytes influenced by feed additives and host-related factors of broilers.....	149
PS1-022 Effect of a monoglyceride blend alone and in combination with butyric acid esters on the performance and gut response regarding stress homeostasis in broilers.....	150
PS1-023 Effect of dietary methylsulfonylmethane supplementation during 1-42 day of age on growth performance and carcass characteristics of broilers.....	151
PS1-024 Effect of dietary Phytase and NSP'ase on performance and egg quality of Lohmann white-classics	152
PS1-025 Effect of Feeding Different Dietary Concentrations of Zinc and Copper on Haematological and Bone Morphometric Parameter of Growing Turkey Chicks (Poults)	153
PS1-026 Effect of the rearing system on calcium, phosphorus and cholecalciferol vitamin intake, productive performance, egg quality traits and keel bone damage in laying hens	154
PS1-027 Effect of varying levels of amaranth leaf meal on performance, meat, and bone characteristics of Ross 308 broiler chickens	155
PS1-028 Effectiveness of starch digestion using different starch sources: Are broiler chickens and pigs different?.....	156
PS1-029 Effects of a commercial triple-strain <i>Bacillus</i> -based probiotic on broiler performance and welfare	157
PS1-030 Effects of butyrate or butyric glycerides in combination with different selenium sources as strategies to improve performance of the aged laying hens.....	158
PS1-031 Effects of combination of butyrins/valerins and butyrins alone on growth performances and carcass quality of broiler chicken	159
PS1-032 Effects of dietary amino acid supply on amino acid metabolism in broilers	160
PS1-033 Effects of novel docosahexaenoic acid (DHA) sources on egg production, egg quality and enrichment of eggs and tissues in Lohmann LSL lite hens	161
PS1-034 Effects of stepwise matrix application of a novel consensus bacterial 6-phytase variant on growth performance, bone quality, economic and sustainability benefits in broilers	162
PS1-035 Effects of varying dietary calcium levels on broiler performance, litter quality, and pododermatitis	163
PS1-036 Egg production parameters, microbiome modulation and environmental benefits of using a precision biotic in laying hens	164
PS1-037 Evaluating the effects of diet type, diet non-phytate phosphorus level, and storage length on egg quality of white egg laying hens	165
PS1-038 Evaluating the link between microbial biomarkers and performance in broiler field trials evaluating gut health additives	166
PS1-039 Evaluation of the dietary administration of a thermo-mechanical and enzyme-facilitated processed soybean meal on growth performance and ceca microbiota of broiler chickens	167
PS1-040 Evaluation of the effect of a natural antimicrobial in feed for laying hens on the productive performance and egg quality	168

PS1-041 Expression of glucose transporters in the jejunum of free-range chickens fed cupuassu seed meal in the diet.....	169
PS1-042 Feeding low protein diets with reduced soybean meal inclusion in laying hens.....	170
PS1-043 Global warming potential of broiler diets with strongly reduced crude protein, soybean meal and energy levels	171
PS1-044 Hydroxy trace minerals with an increased bioavailability as a more sustainable broiler production strategy	172
PS1-045 Impact of crude protein reduction in broiler feed on sustainability impact factors.....	173
PS1-046 Impact of dietary phosphorus supply on laying hen performance and on body, bone and eggshell mineral density.....	174
PS1-047 Impact of dietary sodium diformate on broiler performance - a meta-analysis	175
PS1-048 Impact of different feed vitamin levels on broiler health and performance	176
PS1-049 Impact of graded levels of exogenous xylanase in wheat-soy diet on growth performance, energy utilisation and nutrient digestibility of young broilers	177
PS1-050 Impact of low phosphorus levels on broiler chickens' growth performance and bone mineralization at two calcium to phosphorus ratios	178
PS1-051 Impact of trace element source and level on growth performance and phytase efficacy	179
PS1-052 Impact of Zn source and dietary level on prececal P digestibility, InsP6 disappearance and ileal myo-inositol concentration in broiler chickens.....	180
PS1-053 In ovo injection of twenty essential oils: hatchability and organ weights at hatch in broiler chickens	181
PS1-054 In vivo performance and carcass traits of Japanese quail (<i>Coturnix japonica</i>) fed diets supplemented with <i>Hermetia illucens</i> oil.....	182
PS1-055 Influence of phytase dosage and dietary phytate concentration on prececal phytate disappearance and amino acid digestibility in broilers	183
PS1-056 Influence of use of organic minerals in laying hen diets on productive performance, egg quality and bone strength	184
PS1-057 Interaction of wheat bran particle size and stimbiotic supplementation on growth performance and ceca pH of broilers fed corn-based diets	185
PS1-058 Intestinal health and selenium: effect of selenomethionine on epithelial barrier function in Caco-2 cells.....	186
PS1-059 Intestine morphology and performance of free-range chickens fed different levels of cupuassu seed meal	187
PS1-060 Kernel physical properties affect the carotenoid profile of yolks from hens fed diets differing in maize hybrid.....	188
PS1-061 Lysozyme, essential oils and vitamins' mixture of additive supports respiratory health and improves antibody titres after viral vaccinations in hens	189

PS1-062 Marigold (<i>Calendula officinalis</i>) extract supplementation may improve the oxidative status of broilers fed with high level of n-3 or n-6 PUFA	190
PS1-063 Methionine source and level modulate gut pH, amino acid transporters and metabolism related genes in broiler chickens.....	191
PS1-064 Methionine to sulfur amino acids ratio is not a limiting factor for broiler performance fed with low protein diets	192
PS1-065 Microbial phytase inclusion improves dietary Ca and P digestibility but cannot fully restore the compromised growth performance in broilers fed a Ca-deficient diet	193
PS1-066 Modified wheat bran as feed ingredient and its impact on egg quality of laying hens ..	194
PS1-067 New feeding strategies for organic egg production with reduced dietary phosphorus ..	195
PS1-068 Nitrogen recycling effect of OH-Methionine: a simple action to reduce nitrogen excretion in broiler chickens	196
PS1-069 Novel product with combination of <i>Saccharomyces cerevisiae</i> fermentation product and essential oil compounds improved broiler performance: a metanalysis	197
PS1-070 Nutrient digestibility and digesta mean retention time in laying hens of two different breeds fed with fine vs coarse oat hulls	198
PS1-071 On farm report of <i>Pediococcus acidilactici</i> cncm 4622 supplementation in pullets' production with new criteria for the evaluation of pullet's quality.....	199
PS1-072 Phase dependent reduction of dietary protein levels has no negative impact on performance parameters while low or zero soybean meal (SBM) diets perform better compared to SBM fed broilers	200
PS1-073 Phosphorus and calcium requirements for bone mineralization of growing broilers predicted by mechanistic modelling	201
PS1-074 Phosphorus requirements and phytase activity in wheat- and maize-based diets for two strains of senior laying hens	202
PS1-075 Protein-rich circular ingredients can partly replace soybean meal in broiler diets	203
PS1-076 Raw materials non-digestible nitrogen compounds (NDNC) as formulation predictor of nitrogen excretion in broiler chickens	204
PS1-077 Reduce, recycle and reuse: tomato and pepper from food waste for diets of end-of-lay hens in a sustainable egg production system. Egg quality traits	205
PS1-078 Reducing protein content increases metabolizable energy in broilers.....	206
PS1-079 Reduction of protein content and electrolyte balance to reduce nitrogen losses through volatilization in broilers	207
PS1-080 Relationship of electrolyte balance and dietary calcium and phosphorus content to chicken performance.....	208
PS1-081 Spicy based additives as alternatives to Vitamin E supplementation as antioxidant in broiler chicken feeds	209

PS1-082 Stretching boundaries on sustainable broiler feeding: Moist brewers' spent grains and European inclusive diets.....	210
PS1-083 Sustainable broiler production: total removal of added inorganic phosphate in commercial diets with or without by-products and containing phytase	211
PS1-084 The apparent metabolizable energy value of black soldier fly larvae fat used in broiler chicken diets	212
PS1-085 The association of different feed additives prevents the negative effects of necrotic enteritis on broilers	213
PS1-086 The CEER project - Development of sustainable poultry production based on a circular economy for feeding resources.....	214
PS1-087 The effect of commercial feed additives aiming at reducing antibiotic usage under commercial field conditions of intensive broiler farming in Greece and Cyprus.....	215
PS1-088 The effect of grinding method and extent of pelleting of broiler diets on performance, feeding behavior, and digestive tract functionality	216
PS1-089 The effect of oat hull inclusion level and extent of grinding of main ingredients on the performance and gizzard characteristics of broiler chickens fed oat-based pelleted diets.....	217
PS1-090 The effect of selenium sources on antioxidant status and performance of aging laying hens ..	218
PS1-091 The effects of carrier and production technology of phytobiotic on gastrointestinal tract development in broiler chickens	219
PS1-092 The effects of guanidinoacetic acid supplementation in a low AMEn diet on growth performances and mortality of broilers farmed under Indian conditions.....	220
PS1-093 The effects of sources of manganese, zinc, and copper during the rearing phase on growth performance, tibia traits, egg production and eggshell quality in Lohmann Brown birds	221
PS1-094 The fate of different concentrations of dietary oat hulls with varying grinding levels in broilers	222
PS1-095 The impact of dietary supplementation with an <i>Aspergillus Oryzae</i> -derived postbiotic on productive performance of laying hens under commercial conditions.....	223
PS1-096 The influence of dietary cinnamaldehyde in combination with carvacrol or thymol on the mechanical properties of tibia in post-peak laying hens	224
PS1-097 The influence of varying inclusion levels of whole grain sorghum on performance and gut morphology of indigenous Boschveld chickens.....	225
PS1-098 The maternal effect of dietary mulberry-leaf flavonoids supplementation on the development of skeletal muscle in broiler offspring	226
PS1-099 The potentiality of using high crude protein sorghums in diets for broiler chickens	227
PS1-100 The supplementation of Glycine with a constant methionine-to-sulfur amino acids ratio improves performance of broiler chickens fed with low protein diets.....	228
PS1-101 Total Replacement Technology™ (TRT) reduces mineral excretion, while improving eggshell strength and preserving bone health	229

PS1-102 Use of high-lauric oils in broiler starter diets and their influence on growth performance and fatty acid digestibility.....	230
PS1-103 Using vitamin B2 sourced from non-GMOs to determine the requirements in two breeds of laying hens	231
PS1-104 Utilising a strain of probiotic <i>Bacillus licheniformis</i> to support high-producing layers....	232
PS1-105 Zinc sources provide different effects on performance and on bacteria count in broiler...	233

PS2 - Nutritional intervention for climate changes 234

PS2-01 Determination of the digestibility coefficient of canthaxanthin and apo-ester in broilers and layers	234
PS2-02 Does a curcumin-based feed additive in broiler counteract heat stress consequences ? .	235
PS2-03 Effect of a precision biotic on the growth performance, welfare indicators, and environmental footprint in broiler chickens	236
PS2-04 Effect of different energy levels of low protein diets on the nitrogen retention and excretion of broiler chickens	237
PS2-05 Effect of temperature and feeding time on shell thickness.....	238
PS2-06 Effects of dietary amino acid density on amino acid digestibility, performance, and breast meat composition in broilers reared under thermoneutral, heat stress, and pair-feeding conditions.....	239
PS2-07 Effects of dietary supplementation with a plant extract combination in laying hens raised in hot conditions at the peak production phase	240
PS2-08 Effects of dietary supplementation with a plant extract combination on broiler performance and stress tolerance under hot ambient conditions	241
PS2-09 Effects of dietary α -tocopherol and ascorbic acid on growth performance and breast meat quality parameters in broiler chickens exposed to high ambient temperatures.....	242
PS2-10 Environmental implications of using β -mannanase in broiler feeding programs.....	243
PS2-011 Growth and slaughtering performance of a local chicken breed fed dried and live Black soldier fly larvae as environmental enrichment	244
PS2-012 Plant-derived isoquinoline alkaloids enhance growth performance, gut integrity, and the gut microbiome in broiler chickens reared in summer of tropical climates area	245
PS2-013 Supplemental methyl sulphonyl methane improves performance in grower phase and enhances tolerance to heat stress in the finisher phase of male broilers.....	246
PS2-014 Supplementation of a lignan-rich feed supplement derived from wood alleviates heat stress in fast-growing broilers.....	247
PS2-015 The effects of different feed compositions on reducing the negative effects of heat stress in broilers on performance and meat quality.....	248
PS2-016 The role of a natural antioxidant as a feed supplement in broilers	249

PS3 - Nutrition and microbiome under challenging conditions.....250

PS3-01 A microencapsulated blend of thymol and organic acids can support broilers during a necrotic enteritis challenge with <i>Clostridium perfringens</i>	250
PS3-02 A microencapsulated thymol-based blend of botanicals can clear <i>Salmonella</i> Enteritidis in contrast to common in-feed antibiotics in broilers	251
PS3-03 A qPCR study of APEC and <i>C. perfringens</i> virulence gene prevalence in South African Poultry farms	252
PS3-04 Amino acid digestibility and tissue protein synthesis and degradation in broiler chickens on low protein diets during infection with <i>Eimeria</i> spp.	253
PS3-05 <i>Bacillus</i> sp. PB6 improves performance and alters the microbiome of breeding pheasants under commercial conditions in Poland.....	254
PS3-06 Butyric glycerides act directly and indirectly on chicken enterocytes to enhance resistance to pathogen colonization.....	255
PS3-07 Changes in the gut microbial composition of broiler chicks fed non-antibiotic feed additives	256
PS3-08 Dietary supplementation with 3 strains of <i>Bacillus velezensis</i> improved performance and gut integrity in commercial broilers in Belgium	257
PS3-09 Double <i>Lactobacilli</i> strain-based pro- and post-biotic influenced broiler caecal microbiota mainly under dietary challenging conditions	258
PS3-010 Effect of a precision biotic in broiler chickens fed corn or wheat-based diets	259
PS3-011 Effect of a probiotic solution on intestinal health of broiler chickens co-challenged with salmonella and mycotoxins	260
PS3-012 Effect of a stimbiotic and nutrient density in induced dysbacteriosis broiler chickens on performance, gut health, immune and microbiome modulation	261
PS3-013 Effect of a triple-strain <i>Bacillus</i> -based probiotic on in vitro inhibition of <i>Enterococcus cecorum</i> isolated from broilers	262
PS3-014 Effect of feeding diet containing coccidiostat and administration of antibiotics to turkeys in the first days after hatching on yolk sac resorption and maternal antibody levels	263
PS3-015 Effect of low-oil distillers dried grains with solubles on broilers challenged with <i>C. perfringens</i> and <i>Eimeria</i> spp.	264
PS3-016 Effect of muramidase in combination with different fiber type diets and different anticoccidial programs on broiler performance	265
PS3-017 Effects of the dietary inclusion of insect meal and live larvae on microbiota modulation in Muscovy duck	266
PS3-018 Encapsulated branched-chain amino acids: a novel strategy to mitigate the effects of coccidiosis in chickens	267
PS3-019 Evaluation of formic and propionic acid blends supplemented via feed or drinking water for control of colonization of <i>C. jejuni</i> in broiler chickens	268
PS3-020 Evaluation of monoglycerides of short and medium chain fatty acids on performance of broiler chickens in a bacterial enteritis challenge model	269

PS3-021 How a novel probiotic affects the gut microbiome - Initial insights	270
PS3-022 Impact of a blend of microencapsulated organic acids and botanicals on the microbiota of commercial broilers under clinical necrotic enteritis	271
PS3-023 Phytogetic feed additive ameliorates carcass traits, cecal pathogen load and blood markers of broilers kept under challenging conditions	272
PS3-024 Positive impact of early-probiotic administration on performance parameters and gut microbiota composition in chickens	273
PS3-025 Probiotic supplementation influences performance and apparent ileal digestibility in male and female broilers fed with different protein levels under necrotic enteritis challenge condition	274
PS3-026 Provision of a synergetic solution of functional amino acids and polyphenols improves performance of broilers facing mild coccidiosis challenge under commercial conditions	275
PS3-027 Real-time energy metabolism evaluation of growing broiler chickens under health challenge	276
PS3-028 Reduction of chondronecrosis with osteomyelitis lameness in broilers fed metal amino acid complexes using two challenge models.....	277
PS3-029 Screening and Characterization of <i>Pediococcus acidilactici</i> LC-9-1 Toward the Selection as a Potential Probiotic for Poultry with Antibacterial and Antioxidative Properties	278
PS3-030 Soybean bioactive compounds improve the intestinal and reproductive tract microbiomes of broiler breeders.....	279
PS3-031 Supplementation with a probiotic mixture in the diet of Guinea fowls (<i>Numida meleagris</i>) may introduce beneficial changes in gut microbiota.....	280
PS3-032 The effect of a postbiotic on the growth performance and gastrointestinal microbiota of broilers infected with subacute necrotic enteritis.....	281
PS3-033 The effect of <i>Bacillus amyloliquefaciens</i> CECT 5940 on animal performance and microbiota maturation of broilers fed alternative ingredients	282
PS3-034 The effects of amino acid supplementation of low protein diet on the immune responses and short chain fatty acid profile in broiler chickens challenged with <i>Eimeria</i> spp.....	283
PS3-035 The laying hen's age impact on cholecalciferol (vitamin D3) level of enriched or per se eggs ..	284
PS3-036 The potential of a pre-starter feeding strategy to ameliorate the adverse impact of health challenges on growth performance in broilers.....	285
PS3-037 Unraveling the probiotic potential of two novel <i>Bacillus</i> spp.	286
PS3-038 Yeast cell wall improves immune modulation response in aflatoxin challenge broilers..	287
PS3-039 Yolk color assessment of eggs obtained under heat stress conditions using different dietary phyto-additives.....	288
PS3-040 <i>Yucca schidigera</i> improves performance and lowers oocyst counts in eimeria challenged broilers	289
PS3-041 Zn acid complex reduces salmonella typhimurium shedding and prevalence by inducing the immune response of Cobb500 broilers.....	290

PS4 - Solution to improve the nutritional value of feed 291

PS4-001 A bacterial xylanase improves growth performance and intestinal integrity in broiler chickens.....	291
PS4-002 A bacterial xylanase improves nutrient digestibility and growth performance of pullets	292
PS4-003 Addition of nutritional emulsifiers in decreased nutrient diets	293
PS4-004 Apparent metabolizable energy and soluble fibre utilisation in broiler chickens fed wheat diets with supplemental carbohydrases and organic acid.....	294
PS4-005 Application of methionine source concept in commercial broiler production.....	295
PS4-006 Bacillus licheniformis and phytase mixture affect growth performance, nutrient digestibility, and cecal microbiome of broiler chickens	296
PS4-007 Benefit of full matrix application for a novel consensus bacterial 6-phytase variant alone or in combination with xylanase and beta-glucanase	297
PS4-008 Corn nutrient composition, energy value, and digestibility of amino acids according to the country of origin and year of harvest: The value of Near-Infrared Reflectance Spectroscopy.....	298
PS4-009 Determination of the standardized ileal digestible calcium requirement of fast-growing male broilers from day 29 to 44 post-hatch	299
PS4-010 Dietary supplementation of lysolecithin compared to a combination of lysolecithin, synthetic emulsifier and monoglycerides, on laying performance and egg quality of laying hens	300
PS4-011 Dietary α -galactosidase and xylanase preparation to improve the nutritional value of corn-soybean meal diets of broiler chickens	301
PS4-012 Double Lactobacilli strain-based pro- and post-biotic improved broiler performance and affected minerals metabolism diet-dependently	302
PS4-013 Effect of 1-monoglycerides on performance, ileal mucosa morphometry and footpad dermatitis in broilers	303
PS4-014 Effect of a “structured” micro pellet feed during the first five weeks of live of laying hens. 304	
PS4-015 Effect of a dietary NSPase and grinding method at two nutrient densities on nutrient digestibility & growth performance of Ross 308 broilers	305
PS4-016 Effect of a dietary supply of double-buffered sodium butyrate on performance of layers in a context of reduction of energy and protein in the diet	306
PS4-017 Effect of chestnut tannins and vitamin E supplementation to linseed oil-enriched diets on performance and meat quality of broiler chickens	307
PS4-018 Effect of coated calcium butyrate, monobutylin, and a combination thereof on growth performance and mRNA abundance of genes related to tight junction proteins in broilers	308
PS4-019 Effect of encapsulated lysine on growth performance and carcass quality in broilers....	309
PS4-020 Effect of low-level calcium and phosphorus diets supplemented with calcium pidolate on broiler body weight and rate of culled birds	310
PS4-021 Effect of lysophospholipids and xylanase supplementation on growth performance in turkeys.....	311

PS4-022 Effect of oil quality and supplemental vitamin E source on the performance and vitamin E retention in the liver and breast meat of 21-day-old broiler chickens	312
PS4-023 Effect of phytase and limestone particle size on performance, eggshell quality, bone mineralization and mineral digestibility in laying hens.....	313
PS4-024 Effect of wheat, maize, rice or pea in combination with rapeseed meal or soybean concentrate and sunflower meal on broiler chickens’ growth	314
PS4-025 Effects of 2 limestone solubilities and 3 calcium levels in diets with a phytase on performance, mineral digestibility, and tibia ash of broilers	315
PS4-026 Effects of a synergistic blend of trace minerals on the performance and economics of broilers	316
PS4-027 Effects of an encapsulated phytogenic and phycogenic solution when used in a diet formulated with or without matrix value on growth performance, intestinal functions, and plasma biomarkers of broiler chickens	317
PS4-028 Effects of dietary microalgae (Chlorella vulgaris and Spirulina platensis) on eggs' carotenoid content and yolk color intensity	318
PS4-029 Effects of dietary sugar beet pulp incorporation along with AMEn reduction in broilers at two levels of crude protein content	319
PS4-030 Effects of limestone origin and a new phytase on performance, nutrient digestibility and tibia ash of conventional and slow growing broiler breeds.....	320
PS4-031 Effects of replacing inorganic trace minerals with glycinate on production parameters of older broiler breeder hens during a heat stress period	321
PS4-032 Efficacy of a biosynthetic bacterial 6-phytase on performance, bone mineralization and prececal digestibility of phosphorus in broilers fed normal- or high-phytate diets	322
PS4-033 Efficacy of a new biosynthetic 6-phytase added at 500 FTU/kg diet in broilers from 1 to 35 days of age: data from four independent performance trials	323
PS4-034 Efficacy of a total substitution of synthetic choline chloride by a natural polyherbal-based product in broilers feeds	324
PS4-035 Efficacy of some herbal methionine formulations on nutrient metabolizability and gut health status of broilers.....	325
PS4-036 Emulsifier effect on performance of broilers fed diets with different metabolizable energy levels.....	326
PS4-037 Evaluation of pellet microstructure particle size as consequence of secondary grinding on pellet quality and gizzard development in broilers	327
PS4-038 Evaluation the nutrient composition and protein quality of different soybean varieties	328
PS4-039 Feed cost optimization and gut health improvement by dietary incorporation of multi-enzyme product in commercial broilers.....	329
PS4-040 Grain moisture at harvest and drying temperature impact the non-starch polysaccharides content of four corn varieties	330

PS4-041 Grape polyphenols can replace synthetic vitamin E under standard and challenging formulations	331
PS4-042 Growth performance and gut response of broiler chickens fed diets supplemented with a grape pomace extract	332
PS4-043 Gut health improvements with dietary β -mannanase in meat producing broiler chickens ...	333
PS4-044 Impact of lowering the levels of Ca and P in feed on broiler performance, Ca and P digestibility, bone strength and bone ash	334
PS4-045 Impact of lysolecithin, monoglyceride and emulsifier combinations on emulsion stability and rate of lipid hydrolysis	335
PS4-046 Improvement of intestinal health in broiler chickens fed diets supplemented with β -mannanase: updated meta-analysis study.....	336
PS4-047 Inclusion of a Bacillus-based probiotic in the diets of nutritionally challenged broilers	337
PS4-048 Influence of feeding whole wheat on gut development, energy digestion and hygienic aspects in growing broiler chicken	338
PS4-049 Interaction between feeding regimen, NSPase enzyme and particle size of barley in pelleted diets on the performance of broiler chickens	339
PS4-050 Interactive effect of xylanase or stimbiotic with dietary grain source on growth performance and digesta viscosity of broiler chicks	340
PS4-051 Modelling tool to fine-tune the nutrients requirements for laying hens in cage and cage-free	341
PS4-052 Multi-component protease modulates the gut microbiome and enhances performance in broiler birds partially fed with an unconventional protein source	342
PS4-053 Novel β -mannanase improves dietary nutrient digestibility in fattening poultry	343
PS4-054 Reduction of anti-nutritional effects of β -mannan and energy sparing with addition of dietary β -mannanase in meat turkeys	344
PS4-055 Revealing the physical restrictions of caecal influx to improve caecal fibre fermentation in broilers: effect of insoluble fibre particle size and age	345
PS4-056 Serum biochemical profile of laying hens fed diets with functional fibers and xylanase	346
PS4-058 Supplementation of a combination of lysophospholipids, a synthetic emulsifier and monoglycerides improves the performance and welfare of broilers	348
PS4-059 Supplementation of hydroxy trace minerals improves growth performance, health and oxidative status in broilers	349
PS4-060 Synergistic effect of a novel bacterial phytase and endogenous phosphatases for myo-inositol release evaluated in-vitro	350
PS4-061 Synergy between dietary xylooligosaccharides (XOS) and xylanase supplementation in broiler chickens	351

PS4-062 The benefits of a higher dose of phytase in the pre-starter phase in broilers up to day 42 of age	352
PS4-063 The changing role of endoxylanases in wheat-based broiler diets: from mitigating the anti-nutritive effect towards feeding the microbiome	353
PS4-064 The effect of amylase in the diet with pea and faba bean on growth performance, nutrient utilization, and sialic acid excretion in broiler chicken	354
PS4-065 The use of phytogenic feed additives with nutritional matrix values can decrease feed costs and maintain the production performance of laying hens.....	355
PS4-066 Verification of the claimed P and Ca matrix values of an intrinsic heat stable granular phytase dosed at 500 FTU/kg.....	356
PS4-067 Xylanase can release energy of broiler diets with different wheat cultivars before and after post-harvest storage of wheat.....	357
PS4-068 β -mannanase as an effective tool to increase intestinal health and uniformity of broilers.....	358

PS5 - Non-soy protein sources 359

PS5-001 Apparent ileal protein digestibility in broilers of Black Soldier Fly Larvae (<i>Hermetia illucens</i>) raised on differing substrates	359
PS5-002 Black soldier fly larvae meal as an alternative protein source in broiler chicken's diet ..	360
PS5-003 Comparative use of several microalgae in broiler feeds.....	361
PS5-004 Effect of cereal and protein sources on broilers performance and feed digestibility.....	362
PS5-005 Effect of microwaves on the metabolizable energy of green pea (<i>Pisum sativum</i>)	363
PS5-006 Effects of feeding graded levels of sunflower meal on the apparent ileal amino acid digestion of pullets and laying hens	364
PS5-007 Effects of partial replacement of soybean meal with defatted black soldier fly (<i>Hermetia illucens</i>) meal in the diet of laying hens on performance, egg quality, and serum biochemical indices	365
PS5-008 Influence of partial dietary replacement of soybean with different levels of <i>Hermetia illucens</i> meal during grower and finisher phases on live performances and meat quality in broilers.....	366
PS5-009 Innovative laying hens feed: black soldier fly live larvae supplementation. Effects on production performance, plumage status, and egg quality	367
PS5-010 Microbiological shelf life of <i>Hermetia illucens</i> meal.....	368
PS5-011 Standardized ileal digestible amino acids of single sell protein in broilers	369
PS5-012 The impact of replacement of soya bean meal with three rapeseed cake varieties on broiler performance and nutrient digestibility	370

PS6 - Unsolved issues in poultry nutrition 371

- PS6-001** Assessment of two dietary models for investigation of the effects of amino acids supplementation into low-protein diets for broiler chickens 371
- PS6-002** Dietary supplementation with sodium butyrate: live performances, carcass traits and myopathy occurrence in female and male broilers 372
- PS6-003** Effect of 125% and 135% arginine diets on growth performance and immunological response to necrotic enteritis in broilers.....373
- PS6-004** Effect of corn particle size and pellet diameter on the particle size in the microstructure of pelleted diets.....374
- PS6-005** Effects of eggshell translucency and coloration lightness on eggshell thickness, hatchability and chick weight in broiler breeders 375
- PS6-006** Evaluation of conditioning temperature and retention time in the hygieniser on *Enterococcus faecium*, true amino acid digestibility, and metabolizable energy 376
- PS6-007** Feeding pullets in stressful conditions: does mash size matter?.....377
- PS6-008** Investigation into the potential of superdosing phytase to release plant derived phosphorus for broilers from hatch 378
- PS6-009** Mycotoxin deactivator promotes the intestinal health of broiler chickens co-challenged with salmonella and mycotoxins 379
- PS6-010** Potential influence of methionine source and level on appetite regulation in broiler chickens 380
- PS6-011** Pre-hatch feeding of broiler embryos with calcium salt of OH-Methionine: A study of feasibility 381
- PS6-012** Tailor-made probiotic as alternative to increase intestinal and respiratory integrity of broilers under field conditions 382
- PS6-013** The effects of methionine and threonine supplementation in low protein diets on the performance of broiler chickens challenged with *Eimeria* 383
- PS6-014** Variability in the nutrient composition and standardized ileal amino acid digestibility of dried grains with solubles in broilers.....384
- PS6-015** β -mannanase as an alternative to increasing the layer hen's productivity 385

PS7 -Other topics 371

- PS7-001** 1,25(OH)2D3-glycosides from the plant *Solanum glaucophyllum* alter gene expression in broiler at 21 and 42 days of age 386
- PS7-002** A review: beneficial effects of saponins and polyphenols in *Quillaja saponaria* and *Yucca schidigera* combination product 387
- PS7-003** A scoring system to measure biosecurity compliance in commercial indoor and free-range poultry production 388

- PS7-004** An Algae-Clay based Mycotoxin detoxifier reduces the bioavailability of a mix of Mycotoxins in broiler chickens in a toxicokinetic study 389
- PS7-005** Analysis of egg productivity, blood parameters and pre-laying behavioral characteristics of good layers and poor layers.....390
- PS7-006** Basal energy requirement and partitioning according to the visceral mass tissues in laying pullets.....391
- PS7-007** Changes in the expression of selected peptides regulating the metabolism of depending on birds breed 392
- PS7-008** Competitive exclusion to secure pullets' production: impact on microbiota establishment, relative abundance of *Enterobacteriaceae* and *Enterococcus* sp. in a large field trial 393
- PS7-009** Deposit of Fumonisin in broiler tissues and reduction with an algae-clay based mycotoxin detoxifier 394
- PS7-010** Determination of protein and amino acid composition of poultry ileal digesta by near-infrared spectroscopy.....395
- PS7-011** Dietary organic acids ameliorate high stocking density stress-induced intestinal inflammation through the restoration of intestinal microbiota in broilers 396
- PS7-012** Digesta phase divergently separated in foregut of laying hens fed with fine or coarse oat hulls 397
- PS7-013** Effect of an innovative precision biotic on laying hens' welfare.....398
- PS7-014** Effect of feed deprivation on intestinal integrity.....399
- PS7-015** Effect of monovalent and glycoside ionophore-nicarbazin combination products at typical and 35% increased dose in control of coccidiosis 400
- PS7-016** Effect of the addition of crude fibre concentrate in the feed on the number of colony-forming units of selected cecal bacteria and pH of broiler chicken faeces and litter 401
- PS7-017** Effects of a blend of fatty acids esters on health status, microbiota and broiler performance.....402
- PS7-018** Effects of an antioxidant containing phenolic compounds from olive on oxidative state in broilers and efficacy against feed rancidity 403
- PS7-019** Efficacy of different ionophore-nicarbazin combination products in coccidiosis challenge model 404
- PS7-020** Energy utilization in broiler breeders during the laying phase through a multivariate approach 405
- PS7-021** Evaluation of the effect of MCFA on the expression of avian beta-defensin genes during a *Salmonella* infection in broiler chickens 406
- PS7-022** Growth and slaughter performance of four slower growing hybrids 407
- PS7-023** How chestnut tannins have the potential to influence performance and metabolism of broiler chickens 408

PS7-024 Improvement of broilers uniformity through the use of a led light on feeders	409
PS7-025 Incremental dietary Ca content downregulates intestinal expression of Ca transporters and claudins in a microbial phytase-independent manner	410
PS7-026 Intestinal morphology and performance of European quails submitted to post-hatch fasting for different periods.....	411
PS7-028 Investigation of the active metabolites of <i>Bacillus subtilis</i> DSM 29784 and their effects in broiler chickens	413
PS7-029 Microbiota modulation with <i>Pediococcus acidilactici</i> CNCM I-4622 supplementation in laying hens during the late phase of the production cycle.....	414
PS7-030 Modern laying hens: has the deposition rate of carotenoids in egg yolk changed?	415
PS7-031 Near-infrared spectroscopy to predict the carbohydrate and lignin contents of a variety of feedstuffs included in poultry diets	416
PS7-032 Post-hatch fasting effects on performance and digestive organs of Japanese quails	417
PS7-033 Protective effect of a yeast β -glucan on broiler chickens exposed to a diet naturally contaminated with deoxynivalenol	418
PS7-034 Recent European trends of intestinal health in broilers	419
PS7-035 Setting foundations: Manganese amino acid complex supports eggshell membrane architecture and eggshell quality	420
PS7-036 Short chain fatty acids and their impact on gut health parameters	421
PS7-037 Supplementation with <i>Saccharina latissima</i> extract affects early growth rate and antibody levels, but not microbial composition in broiler chicks	422
PS7-038 The effect of water-soluble probiotics during feed transition period on animal performance of broiler under commercial conditions	423
PS7-039 The influence of the addition of various cereal on the metabolic and hormonal profile of broilers - the role of SPX and LEAP2	424
PS7-040 The role of hatching systems and biological factors on broiler flock homogeneity	425
PS7-041 Visualisation of essential trace element incorporation in laying hen tibia by correlative elemental imaging	426

PS1 - Nutrition for sustainability in broiler, layer and turkey production

PS1-001 A microencapsulated feed additive containing organic acids and botanicals has a distinct effect on proliferative and metabolic related signaling in the jejunum and ileum of broiler chickens

C. Johnson¹, R. Arsenault², E. Grilli^{3,4}, A. Piva^{3,5}, C. Swaggerty¹

¹U.S. Department of Agriculture, Agricultural Research Service, Southern Plains Agricultural Research Center, College Station, TX, United States, ²Department of Animal and Food Sciences, University of Delaware, Newark, DE, United States, ³DIMEVET, University of Bologna, Bologna, Italy, ⁴Vetagro Inc., Chicago, IL, Italy, ⁵Vetagro S.p.A., Reggio Emilia, Italy

Well designed and formulated natural feed additives have the potential to provide many of the growth promoting and disease mitigating characteristics of in-feed antibiotics. Here, we describe the mechanism of action of a microencapsulated feed additive containing organic acids and botanicals on the jejunum and ileum of broiler chickens. Male by-product chicks were obtained from a commercial hatchery (Timpson, TX). Chicks were placed in 3m x 3m floor pens containing pine shavings and provided ad libitum access to feed and water throughout the study. Chicks were fed a corn and soybean meal starter diet base which was either non-supplemented (control birds) or supplemented (treatment birds) with 500 g/metric ton (MT) of a microencapsulated blend of citric (25%) and sorbic (16.7%) acids, thymol (1.7%), and vanillin (1.0%). From each of 2 replicate trials, control (n=10) and treatment (n=10) birds were euthanized by cervical dislocation and necropsied at 15 days post hatch. Chicken-specific kinome peptide array analysis was conducted on jejunum and ileum tissue samples from broiler chickens fed either a diet containing a microencapsulated blend of organic acids and botanicals or a non-supplemented diet (control). Detailed analysis of peptides representing individual kinase target sites revealed that in the ileum there was a broad increase in the signal transduction pathways centering on activation of HIF-1 α , AMPK, mTOR, PI3K-Akt and NF κ B. These signaling responses were largely decreased in the jejunum relative to control birds. Gene expression analysis is in agreement with the kinome data showing strong immune gene expression in the ileum and reduced expression in the jejunum. Fold-change (FC, 40-CT) for IFN γ , IL-4, and HIF-1 α in jejunum were 0.57, 0.59 and 0.69 and 1.61, 0.45, and 1.23 in ileum. P-values (student's t-test) for IFN γ , IL-4, and HIF-1 α for jejunum were 0.12, 0.57, 0.15 and 0.78, 0.09, and 0.92 in ileum. The microencapsulated blend of organic acids and botanicals elicit a more anti-inflammatory phenotype and reduced signaling in the jejunum while resulting in enhanced immunometabolic responses in the ileum. Funding: This research was supported, in part, by Vetagro ([CLS] Agreement number 58-3091-8-005; <https://www.vetagro.com>) and the USDA/ARS (3091-32000-035-00D; <https://www.ars.usda.gov/research/project/?accnNo=430283>). There was no additional external funding received for this study.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-002 A multi-enzymatic complex with high doses of phytase improves environmental and economical sustainability of broiler production**

G. Godoy¹, V. Biselo¹, J.A. Alencar¹, A. Toscan², N. Fagundes², G. Vasconcellos², D. Militello², C. Stefanello¹

¹Department of Animal Science, Federal University of Santa Maria, Santa Maria, RS, Brazil, ²Adisseo Latin America, São Paulo, SP, Brazil

The objective was to evaluate the effect of a multi-carbohydrase complex with a high dose of phytase on environmental and economic sustainability of broilers. A total of 1,200 Cobb 500 one-d-old male chicks were distributed to 4 treatments with 10 replicates of 30 birds each, in a completely randomized design and raised until 43 d-old. Treatments: PC: standard corn-soybean meal diet used by Brazilian integrators without enzymes; NC: PC diet reduced in formulated AME (-5%), digestible amino acids (dig. AAs, -5%), Ca (-0.16%), Av.P (-0.18%), and Na (-0.03%) without enzymes; PC+MCPC: PC supplemented with 100 mg/kg of multi-carbohydrase complex with 1000 FTUs of phytase (MCPC; Rovabio® Advance Phy T, Adisseo) on top; NC+MCPC: NC with MCPC on top. The relative impact of greenhouse gasses emissions including CO₂, CH₄ and N₂O were converted to kg CO₂-eq according to IPPC 2014. CO₂-eq emissions were evaluated with Life Cycle Assessment methodology, according to PEFCR and JRC approaches, having kg of chicken as functional unit. The databases used for the carbon footprint calculation were Agri-footprint 6.3 and GFLI, using ReCiPe method. Feed conversion ratio (FCR) was analyzed with ANOVA and Tukey test (P<0.05; Proc GLM of SAS). The carbon footprint (kg CO₂-eq) per kg of chicken decreased 4.9% in animals fed NC compared to PC (2,001 vs 2,105 kg CO₂-eq/kg of chicken), mainly explained by soybean meal and soybean oil reduction in NC diet. However, animals fed NC diet presented higher FCR compared to PC, as expected due to nutrient reduction (P<0.001). MCPC supplementation improved FCR of broilers fed both diets (PC and NC, P<0.001). Broilers fed NC+MCPC diet presented the lowest environmental carbon footprint - 6.5% reduction compared to PC (1.968 vs 2.105 kg CO₂-eq per kg of chicken, respectively). From an economic sustainability point of view, NC+MCPC diet was USD\$ 79,29 cheaper/MT feed than PC (USD\$ 440,19 vs 519,48), while animals presented the same FCR between treatments (P>0.05). The presented results confirm that decreasing EMA, AAs, Ca, P and Na can be an interesting strategy to be more sustainable and reduce feed costs, but the consequence will be an impairment of FCR. To overcome this challenge, adopting a multi-enzymatic complex strategy in feed can properly recover FCR and guarantee the environmental and economic sustainability of broiler operations, since it reduces carbon footprint per kg of chicken, reduces feed costs and maintains animal performance.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-003 A novel consensus bacterial 6-phytase variant improves ileal amino acid digestibility independent of dietary phytate content and the age of broilers**

W.H.D.S.P. Macelline^{2,1}, M. Tongyani^{2,1}, Y. Dersjant-Li³, A. Bello³, L. Marchal³, P. Selle^{1,4}, S. Liu^{1,2}

¹Poultry Research Foundation, The University of Sydney, Camden, Australia, ²School of Life and Environmental Sciences, Faculty of Science, The University of Sydney, Sydney, Australia, ³Danisco Animal Nutrition & Health, IFF, Oegstgeest, Netherlands, ⁴Sydney School of Veterinary Science, Faculty of Science, The University of Sydney, Camden, Australia

The objective of this study was to investigate the collaborative effect of a novel consensus bacterial 6-phytase variant (PhyG), dietary phytic acid concentrations and bird's age on amino acid (AA) digestibility in broiler chickens. The experimental design comprised a 2 × 3 × 5 factorial arrangement including two ages (day 21 and 35 post-hatch), three phytate phosphorus levels (0.245, 0.295, 0.345%, with analysed across 3 phases 0.285, 0.343, 0.387%) and five doses of PhyG (0, 500, 1000, 2000, 4000 FTU/kg). A total of 1800 (Ross 308) day-old male chicks were randomly allocated to 90 battery cages with 6 replicate cages of 20 birds per treatment. The negative control diets (NC, 0 FTU/kg phytase) were formulated with reduced dig P and Ca (based on the expected contribution of 1000 FTU/kg PhyG) compared to breeder's recommendation. Birds were offered starter diets (dig. P: 0.26% and Ca: 0.76%) for the first 10 days and then offered the grower diets (dig. P: 0.21% and Ca: 0.64%) until day 21 and finisher diets (dig. 0.16% and Ca: 0.55%) from day 21 to 35. At 21 and 35-days post-hatch, 6 and 4 birds per replicate cage were euthanised, respectively and the digesta content of distal half of the ileum was gently expressed and pooled by cage to determine the apparent digestibility of AA. There was no 3-way interactive effect of age, phytate and phytase on AA digestibility (P > 0.05). As the main effect, digestibility coefficients of all tested AA were higher at day 21 than 35 (P < 0.001) where digestibility coefficients of total AA were higher at day 21 than day 35 by 8.82% (0.827 versus 0.760; P < 0.001). Increasing dietary phytate decreased digestibility coefficients of 15 AA (P < 0.05), except tyrosine (P = 0.085). Increasing PhyG doses from 0 to 4000 FTU/kg improved digestibility coefficients of all 15 tested AA (P < 0.001) in a stepwise manner regardless of age and dietary phytate concentrations. In comparison to the NC, total AA digestibility coefficients in phytase-supplemented diets improved by 2.86% with 500 FTU, 2.61% with 1000 FTU, 5.33% with 2000 FTU and 5.46% with 4000 FTU. The improvement in AA digestibility in response to 4000 FTU phytase compared to 0 FTU diets ranged from 8.55% for threonine to 2.79% for glutamic acid. In conclusion, dietary phytate negatively impacted AA digestibility, and PhyG improved AA digestibility in a dose-dependent manner, irrespective of age and dietary phytate concentrations.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-004 A novel protease improves apparent nitrogen retention in excreta and reduces ammonia emission from litters in poultry houses**A. Seon¹, C. Walk², Q. Zhang³, J. Zhang³, J. Berti Sorbara², M. Umar Faruk²¹DSM Nutritional Products France; Research Center for Animal Nutrition & Health, Village Neuf, France, ²DSM Nutritional Products, Kaiseraugst, Switzerland, ³DSM China Animal Nutrition Research Center, Bazhou, China

Two studies were conducted to investigate if supplementation of protease improved nitrogen (N) retention in excreta and reduced ammonia (NH₃) emissions. In both studies, birds were randomly assigned to one of 2 treatments with or without addition of 50mg/kg feed of a novel protease (ProAct 360TM). In the first study, male broiler chickens (Ross 308) were housed in battery cages. Pelleted basal diet was a corn/soybean meal diet formulated to contain 22.5% and 21.0% crude protein (CP) during the starter (D0-14) and grower (D14-28) periods, respectively. Each treatment was replicated with 8 pens of 6 birds each. Apparent N retention was measured per pen, in excreta, at the end of the study. In the second study, male Cobb 500 were raised in floor pens. The pelleted basal diet was a corn/soybean meal diet formulated to contain 22.5, 21.3 and 19.4% CP during starter (D0-14), grower (D14-28), and finisher (D28-42) periods, respectively. Each treatment was replicated with 12 pens of 40 birds each. Birds were placed on clean wood shavings. At the end of the trial, NH₃ emissions were measured at the surface of the litters using Dräger X8000 device. Collected data was subjected to ANOVA and significant differences separated using Student-Newmann-Keuls test. Over whole period it was observed numerical improvement of FCR by 2% and 0.7% respectively in study 1 and 2. It was also shown numerical improvement of body weight gain by 1.9% in the first study, where an improvement (P<0.05) from 63.4% to 67.5% of apparent N retention in excreta, was observed in broilers fed protease compared to the control group. In the second study, the litters from the protease fed group had a decrease (P<0.05) of litter NH₃ emissions (29 ppm) compared to the control group (43 ppm). Data from this study were used to calculate the environmental benefit using SustellTM; the Animal Production System tool according to the methodology of 2018 FAO LEAP. The impact assessment focused on categories relating to climate change, respiratory inorganics, eutrophication marine, and freshwater. Nitrogen excretion was reduced by 2.3%, CH₄ emissions by 1%, NH₃ emissions by 2.3%, N₂O emissions by 2.4% and climate change by 0.8% with the supplementation of protease. It was concluded that the addition of protease fed to broilers resulted in a significant reduction of NH₃ emissions from the litters and therefore reduced N excretion from poultry houses, contributing to a more sustainable animal protein production.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-005 A triple-strain probiotic approach in laying hens**V. Van Hoeck¹, R. Rodriguez-Sanchez¹, A. Abdelqader², N. Smeets¹, J. Maertens¹¹Kemin Europa N.V., Herentals, Belgium, ²University of Jordan, Amman, Jordan

Increased gut colonization by beneficial bacteria makes the gut environment less conducive to colonization by pathogenic bacteria that have a negative impact on the animal's performance. The objectives of this study were to evaluate a triple-strain probiotic (Bacillus spp. ATCC PTA-6737, PTA-127113 and PTA-127114) and its effect on laying performance, egg quality, and intestinal morphology. A total of 128 HiSex laying hens (22 weeks old) were randomly assigned to 4 treatments, with 16 replicates per treatment and 2 hens per replicate. The triple-strain probiotic was included in the diet as follows; 0 CFU/kg (T1=control), 3x10⁸ CFU/kg (T2=minimum recommended dose), 3x10⁹ CFU/kg (T3=maximum recommended dose), and 3x10¹¹ CFU/kg (T4=the 100x overdose). The study was conducted for 12 weeks. FCR was improved in all groups supplemented with the triple-strain probiotic in the 2nd (weeks 5-8) and 3rd (weeks 9-12) phases of the study (P<0.0001). When considering the entire trial period, hens supplemented with the triple-strain probiotic at 3x10⁹ CFU/kg (T3) showed higher egg mass (54.7g vs. 53.3g; P=0.04) and lower FCR (1.939 vs. 1.985; P<0.003) than the control animals. In all probiotic supplemented animals, increased eggshell thickness (by >7%), breaking strength (by >15%), and Haugh Unit (by >5-10%) were observed in comparison with the control eggs (P<0.05). Interestingly, the overdose dose (T4) did not negatively affect any of the performance and egg quality parameters measured in this experiment, which implies a wide margin of safety of the product. The triple-strain probiotic supplementation showed positive effects on ileum morphology by increasing (P<0.0001) villi height (by >10%), width (by >30%) and surface area (by >46%) in all treated groups compared to their control counterparts. In conclusion, the dietary use of this triple-strain probiotic for laying hens is highly recommended to improve laying performance, egg weight, egg mass, eggshell characteristics, the overall egg quality parameters and intestinal morphology.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-006 Are digestible calcium values formulated in broiler diets with existing digestible calcium values for individual feed ingredients similar to the digestible calcium values determine in-vivo?**K. Venter^{2,1}, C.R. Angel³, C. Jansen van Rensburg², P.W. Plumstead¹¹Neuro Livestock Research, Brits, South Africa, ²University of Pretoria, Hatfield, South Africa, ³Department of Animal and Avian Sciences, University of Maryland, MD, United States

The main macro nutrients such as amino acids and phosphorous are formulated on a digestible basis. One exception to this is the nutrient Ca which to date is still formulated on a total system. One of the limitations for the industry moving from a total Ca system to a digestible Ca (dCa) system has been the lack of robust values of dCa for ingredients and factors affecting this digestibility. The objective of the current study was to validate whether formulating diets with existing dCa and dP values for some common poultry ingredients would be similar to values determined with these diets when fed to broilers in the presence and absence of phytase. The experimental diets were formulated using ingredient Ca and P digestibility values as per Venter et al. (2022) to be similar to commercial broiler diets containing wheat, corn, soybean meal, full-fat soybean, rapeseed meal and sunflower meal. The limestone used was one for which dCa had been determined (Venter et al., 2022) that had a Ca digestibility coefficient of 57.6%. Diets were fed to broilers to determine in-vivo dCa and dP to compare formulated vs actual in-vivo dCa and dP. A single basal was mixed and divided in two. To these two parts phytase was added at either 0 or 1000 FTU/kg, to allow for validation of dCa and dP values in the absence and presence of phytase. Ross 308 males were reared to 18 d and then moved to battery cages. Experimental diets were fed to 8 replicates per treatment (6 birds/replicate) for 36 hrs, before distal ileal digesta collection. Data were analysed using JMP Pro 16.0 (SAS, Institute, Cary, NC) using a one-way ANOVA and means separated using a protected Tukey HSD ($P \leq 0.05$ as significant). Broilers fed diets supplemented with phytase had higher ($P < 0.05$) Ca digestibility compared to those fed diets without phytase (64.05% vs 54.43%). Phytase supplementation also increased ($P < 0.05$) P digestibility of the diet from 38.56% to 73.01%. The dP obtained in-vivo in the absence and presence of phytase (0.363% & 0.407%) was close to the theoretical value (0.358% & 0.405%) formulated based on ingredient dCa and dP. The dCa obtained in-vivo in the absence and presence of phytase (0.143% & 0.280%) was close to the theoretical formulation values (0.137% & 0.278%). This study starts to validate that determined ingredient's dCa and dP can be used to formulate diets based on ingredient dCa and dP values as formulated and in-vivo determined values were very similar.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-007 Bakery by-products in poultry diet: effects on performance, blood parameters and fatty acid profile of meat**K. Srikanthithasan¹, A. Giorgino¹, M. Gariglio¹, E. Diaz¹, A. Schiavone¹, E. Fiorilla¹, S. Bergagna², M. Profitì¹, C. Forte¹¹Department of Veterinary Sciences, University of Turin, Turin, Italy, ²Istituto Zooprofilattico Sperimentale del Piemonte, Liguria e Valle d'Aosta (Italy), Turin, Italy

Feed-food competition is one of the most debated aspects of livestock. A change in feed resources is needed to increase sustainability and meet consumers' demands. The estimated 5 million tons of former foodstuffs produced annually in Europe could represent a resource. Efforts have been made to recover the potential nutritional value of ex-food that longer suitable for human consumption. Among them, bakery by-products (BBP) have been proven to be effective in ruminants' and pigs' diets, but few studies evaluated their effects on poultry diet. The aim of this study was to evaluate the effect of different levels of BBP in broiler diet as a substitute for both corn and soybean meals on growth performance, blood parameters, and fatty acid profile (FA) of meat. In total, 200 one-day-old male ROSS-308 chicks were assigned to four dietary treatments according to their average live weight (LW 38.0 g $\pm$ 0.11) (5 replicates, 10 birds/pen). The 4 dietary treatments were: Control (CTR: commercial feed), L-BBP (6.25% BBP), M-BBP (12.5% BBP), and H-BBP (25% BBP). Growth performance was evaluated throughout the trial. Blood samples were collected on day 33 for biochemical analysis. The fatty acid profile (FA) of the thigh and breast meat was determined by gas chromatography. The data showed no differences in LW and average daily gain among groups, although the inclusion of BBP in the diet decreased the average daily feed intake (g/d) and positively affected ($p < 0.05$) feed conversion ratio at 1-33 days (CTR: 62.5 g/d, 1.57 and H-BBP: 57.5 g/d, 1.39 respectively). The fatty acid profile of breast and thigh meat showed a linear increase for saturated FA (SFA), monounsaturated FA, and the ω -6 to ω -3 ratio while polyunsaturated FA (PUFA) and the ratio of PUFA to SFA decreased linearly with increasing BBP levels ($p < 0.05$). A linear increase in blood cholesterol, triglycerides, and serum glutamic-pyruvic transaminase ($p < 0.05$) was also registered. This can be described as an impact of the fat raw material that is used in bakery products. Taken together, the results show that dietary raw materials could be partially substituted with up to 25% BBP improving performance in terms of feed intake and efficacy. However, the results recorded in blood lipid metabolism and meat FA profile are worth of attention, considering human health and the balance between SFA and PUFA.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-008 Can modulating egg weight by dietary amino acids improve the eggshell quality in old laying hens?**R. Akbari Moghaddam Kakhki¹, C. Alfonso-Carrillo¹, A. García-Ruiz¹¹Poultry R&D, Trouw Nutrition, El Viso de San Juan, Toledo, 45215, Spain

The increase in egg weight (EW) implies a larger egg size, meaning a larger surface area to be mineralized. The increase in the surface area reduces the mamillary knobs density and the size of the calcite crystals, which results in the deterioration of the mechanical properties of the eggshell, accounting for around 20% egg downgrade after 65 weeks of age. Nutrition is a key factor in determining EW. Dietary nutrient modifications can maintain EW in categories that offer the highest profit for producers while maintaining an acceptable eggshell quality. Thus, a preliminary study was designed to evaluate the effect of levels of digestible lysine (dLYS) and the ratio of digestible sulfur amino acids (dTSAA) to manipulate the EW to improve the eggshell quality without impacting the number of eggs in old laying hens. 288 62-wk old ISA Brown were procured and kept in individual cages. Two levels of dLYS intake, including 700 (requirement) and 650 mg/b/d, and four ratios of dTSAA:dLYS of 75, 80, 85 and 90% (recommended ratio to dLYS) formed a factorial arrangement (2x4). Cages were assigned to 8 dietary treatments with 36 replications each. The eggshell-breaking strength (ESBS) and EW were measured before offering dietary treatments (baseline; 61-wk) and 74-wk (termination). The percentage change of ESBS or EW was calculated by dividing the difference of 74-wk value to baseline values by the baseline values, multiplied by 100. The results showed that lowering the ratio of dTSAA to 75 reduced the feed intake compared with ratios of 85 and 90 ($P = 0.002$). The effect of dTSAA on EW and egg mass was dependent on dLYS ($P < 0.001$). At 650 mg dLYS intake, EW and egg mass responded to dTSAA ratio in a quadratic manner, reaching the maximum at the ratio of 85 (regressed at 589 and 583 mg/b/d, respectively). The reduction in dLYS intake from 700 to 650 mg/b/d improved the percentage change of ESBS from -13.58% to -9.02 % ($P = 0.020$). Meanwhile, the percentage change for EW decreased from +1.68% to +0.57% by reducing dLYS intake from 700 to 650 mg/b/d. The interaction of dLYS x dTSAA and the main effect of dTSAA did not affect the percentage change. In conclusion, although dTSAA affected the production performance, ESBS was not affected by dTSAA. Lowering dLYS intake decelerated EW increase and deterioration in eggshell quality during 62 to 74 weeks of age, showing the potential of amino acids to manage EW and improve eggshell quality in old laying hens.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-009 Carvacrol diffuses from amnion to yolk where it remains stable in pre-hatch chicks**M. Meijer¹, H. van den Brand², S. Niknafs¹, M. Navarro¹, A.A. Khaskheli¹, E. Roura¹¹The University of Queensland, Brisbane, Australia, ²Wageningen University and Research, Wageningen, Netherlands

The use of dietary oregano essential oil (OEO) has been showing consistent positive effects on broiler gut health. Given the functional traits of OEO, the potential use of in ovo applications is gaining attention. It is a general practice in commercial hatcheries to vaccinate eggs into the amnion at embryonic day (E)17.5. However, the value of delivering OEO or its main compound carvacrol into the amnion has yet to be shown. This study aimed to determine the diffusion rate of carvacrol to embryonic tissues after injection in the amniotic fluid on E17.5. It was hypothesised that carvacrol would quickly diffuse from the amniotic fluid into lipophilic tissues (i.e., yolk). The experiment was set up as a 2x3 factorial design, consisting of two OEO solutions and three sampling timepoints. Incubated Ross 308 eggs were injected at E17.5 in the amnion with 0.5mL of a 1.75% v/v OEO solution, with (1:1) or without (0:1) the surfactant polysorbate 80. On three timepoints (3, 6 and 9h) after injection, amniotic fluid, blood and yolk ($n=6$ /timepoint) were collected. As control, eggs were injected with 0.9% saline and the same samples were collected, but only after 3h. Samples were analysed for carvacrol content using GC-MS. Difference in carvacrol content was analysed using PROC MIXED in SAS 9.4. In both amniotic fluid and blood, main effects of OEO solution ($P=0.01$ and $P<.0001$, resp.), and timepoint ($P=0.03$ and $P<.0001$, resp.), and their interaction ($P=0.04$ and $P<.0001$, resp.) were found. The highest carvacrol content was detected at 3h after injection, determined by the 1:1 OEO solution. In yolk, there was a significant ($P<.0001$) effect of OEO solution, indicating that the highest carvacrol content was found when injected with surfactant (1:1). Overall the results showed that carvacrol diffuses to blood and yolk within 3h when applied with surfactant (1:1). The presence in blood may be due to direct diffusion or through ingestion by the developing embryo, while diffusion into the yolk may be a function of the lipophilic nature of carvacrol. Given the persistence of carvacrol in the yolk it is speculated that OEO can reach the GIT via the yolk stalk during the peri-hatching phase, thus potentially affecting gut health. In conclusion, A) the use of a surfactant is essential for carvacrol diffusion to embryonic tissues and B) carvacrol diffuses from amniotic fluid to yolk prior to the 3h timepoint. Carvacrol presence in yolk remains consistent until at least 9h.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-010 Comparative efficacy of dietary IntelliBond copper, manganese, and zinc with organic minerals on egg production and quality in broiler breeders from 42 to 63 weeks of age**R. Bakhshalinejad¹, S. Torrey^{1,2}, M.Z. Fan¹, A.K. Shoveller¹, E. Kiarie¹¹Department of Animal Biosciences, University of Guelph, Guelph, Ontario, Canada, ²Trouw Nutrition North America, Puslinch, Ontario, Canada

Increased demand for quality broiler chicks has elicited interest in dietary strategies that can enhance broiler breeder reproductive performance. Dietary trace minerals (TM), in particular copper (Cu), manganese (Mn) and zinc (Zn) play a vital role in reproduction, immunity and chick robustness. However, the choice of TM in poultry rations is driven by efficacy and cost. Herein we investigated comparative efficacy of hydroxychloride (HC) sources of Cu, Mn, and Zn vs. organic (OR) equivalents in broiler breeder nutrition. A total of 408, Ross 708 broiler breeders were placed in floor pens (17 females, 2 yield plus males) in two rooms and allocated to one of two diets in a complete randomized block design (n=12). The pens were 9.25 m² (40% scratching area with wood shavings, and 60% plastic slat area at 0.45 m above the scratching area). The diets were formulated to meet or exceed nutrient specifications with either HC or OR sources for Cu, Mn, and Zn. Birds were fed and managed in accordance with breeder guide from 42 to 63 weeks of age (woa). Each pen had a hen trough feeder (5 cm deep × 13 cm wide × 152 cm long with rooster-exclusion grills) and rooster round feeder 60 cm above the ground. Egg count was recorded daily at 08:00 hrs and categorized as normal and abnormal (shell-less, broken, misshapen, and dirty). Egg quality parameters (yolk color, albumen height, Haugh unit, eggshell thickness, and eggshell breaking strength) were assessed at 4-week intervals. Individual hen body weight (BW) was recorded at 5-week intervals for calculation of BW uniformity. At the end of the trial, 4 hens/pen were necropsied for liver, gizzard, spleen, kidney, and thymus weights. There were no (P>0.05) effects of TM sources or interaction between source and age on egg production rate (EPR), egg weight, Haugh unit, or eggshell quality. Abnormal eggs were less 1% and there was no diet or age effect (P>0.05). Breeders fed HC had darker (P=0.0125) yolk color than OR birds. Organ weights were not different (P>0.05) between the two diets. In conclusion, egg production rate, egg weight and eggshell quality data demonstrated that hydroxychloride TM was as effective as organic TM in broiler breeder nutrition.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-011 Comparison of feed and water supplementation of *Saccharomyces cerevisiae* boulardii on gut morphology and microbiota in broilers**A. Dodovski¹, S. Bozinovski¹, T. Ristovski¹, M. Kjosevski¹¹Ss. Cyril and Methodius University in Skopje, Faculty of Veterinary Medicine - Skopje, Skopje, Macedonia

In this study, we evaluated the effects of two different supplementation regimes of *Saccharomyces cerevisiae* boulardii (SCB) on intestinal morphology and microbiota in broilers. From the previous study, we chose the most beneficial dose of SCB and added it as such in feed (G1) or at 50% of it in water (G3). The trial was done on three groups of 50 chicks per group during the whole grow-out period of 42 days. Group 1 (G1) received 500 g/1000 kg of SCB 1,5x10¹⁰ CFU/g, group 2 (G2) was the control group, and group 3 (G3) received 250 g/1000 l of SCB 1,5x10¹⁰ CFU/g. Each group consisted of 25 chicks per replicate. At slaughter, portions of the duodenum and jejunum were collected for morphometrical analysis, and fresh fecal content was also collected for microbiome analysis. A computer morphometric program was used for morphometric measurement of the duodenal villi height and base width of the villi. Each segment was embedded in paraffin and placed onto a glass slide and stained by hematoxylin-eosin for examination with a light microscope. Only the villi with intact lamina propria were measured. The villus height was measured as the distance from the apex to the junction with the crypt. To assign taxonomic information to each OTU, DC-MEGABLAST alignments of cluster representative sequences to the sequence database were performed. Hereby, sequence identity of 70% across at least 80% of the representative sequence was a minimal requirement for considering reference sequences. Further processing of OTUs and taxonomic assignments were performed using the QIIME software package. Abundances of bacterial taxonomic units were normalized using lineage-specific copy numbers of the relevant marker genes to improve estimates. Average villus height was the highest in G1 at 1224,3 µm, the lowest was in G2 at 1056,1 µm, and in G3 was 1091,5 µm. Considering the microbiome profiling data, the predominant fecal populations were Bacillaceae and Thermoactinomyces for G1, Bacillaceae, Thermobacillus, and Brevibacillus for G2 and Bacillaceae, Thermoactinomyces and Rickenellaceae for G3. Unlike G1, two of the tested fecal samples revealed clostridial (in G2 and G3) and streptococcal communities (in G2). Based on the data obtained in our study, feed supplementation with 500 g of SCB 1,5x10¹⁰ CFU/g /1000 kg compared to an equivalent quantity of SCB added in water shows a better effect on gut morphology, integrity, and intestinal microbiota in broilers.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-012 Complete Life-Cycle Assessment of a low dietary crude protein strategy in broiler production system from England**N. Braconi¹, D. Castellana¹, H. Blonk¹, N. Martin², W. Lambert², J. Le Cour Grandmaison²¹Blonk Sustainability, Gouda, Netherlands, ²METEX ANIMAL NUTRITION, Paris, France

Lowering the dietary crude protein (CP) content of broiler feeds may be a suitable solution to reduce environmental impacts of broiler production as it plays both on the feed composition and on the nitrogen emissions. The goal of this study was therefore to conduct a Life Cycle Assessment (LCA) to analyze the cradle-to-gate environmental performance of a typical broiler production system from England. The study uniqueness was to use LCA results of feed-grade amino acids (AA) as primary data in the life cycle inventory. LCA data on the production of the AA were provided by METEX NØØVISTAGO, and previously validated in an ISO-conform LCA peer-reviewed study (available in Agribalyse 3.1, 2022). The present LCA study was based on ISO 14040/44, peer-reviewed and aligned with the currently available methodological frameworks. The LCA functional unit for the broiler system was 1 kg of live weight broiler at farm gate. One-day old chicks were purchased and raised for 41 days to a target weight of 2.5 kg, with a 3-phase feeding program. Global warming potential (GWP) and GWP excluding land use change, acidification (terrestrial and freshwater) and eutrophication (terrestrial) were obtained. The main change to the systems was a reduction in the dietary CP content of 1 %-point, the soybean meal being partially replaced by wheat and feed-grade AA. As part of a sensitivity analysis, AA origin was switched from European (Baseline) to Chinese origin. The broiler LCA results in the baseline were: 2.93 and 1.21 kg CO₂eq/kg for GWP and GWP excluding land-use change, 0.04 mol H⁺/kg for acidification and 0.16 mol Neq/kg for eutrophication. Reducing dietary CP reduced GWP by 9.6% (SD ± 1.3%) but had no effect on GWP excluding LUC (SD ± 0.1%), meaning that the benefits are obtained by the replacement of soybean meal by feedstuffs with no associated land-use change value and a lower GWP value (cereals and AA). The present strategy reduced acidification and eutrophication by 7.7% (SD ± 0.2%) and 7.9% (SD ± 0.2%), respectively, linked to a reduction in associated nitrogen emissions. In case of Chinese AA, reducing dietary CP by 1 %-point reduced GWP only by 7.2%, and increased GWP excluding land-use change by 5.8%. Reducing dietary CP by 1 %-point positively affected GWP, acidification and eutrophication of broiler production but using different origin of AA influences the final LCA results of broilers: stronger benefits are noticed with European AA compared to Chinese AA.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-013 Cosabody and Narasin synergistically improve broiler performance in enteritis challenged birds**P. Paul¹, K. Livingston¹¹Optum Immunity, Waterloo, United States

Cosabody is a non-pharmaceutical egg product that supports native immune response by neutralizing pathogen-permissive compounds. Broiler performance was evaluated when Cosabody was fed during a necrotic enteritis challenge alone or in shuttle combination with Narasin. 1,200 male Cobb 500 chicks were allotted to 1 of 8 treatment groups consisting of cocci vaccinated-unchallenged control, unvaccinated-challenged control, cocci vaccinated-challenged and treated with either low, moderate, or high dose (100, 125 and 150 units/US ton) of cosabody, and a bioshuttle combination whereby chicks were unvaccinated-challenged and fed diets with cosabody (150 units/US ton) + narasin. Cosabody-supplemented diets were given 0-28D while narasin was provided 0-42D. Challenged birds were orally gavaged using *C. perfringens* broth culture on 12, 13 and 14D to induce necrotic enteritis. The study ran for 42D with 50 chicks/pen and 3 replicates per treatment. Pen was the experimental unit. Growth performance data were collected from all groups and analyzed by using the SAS[®] system (SAS Institute, Cary, NC), version 9.4 using two-sided tests at 0.05 level. Cosabody and narasin both improved growth performance during stater and grower phases. After disease induction, a separation in growth and performance (Adj. FCR, Adj. GF and WAFC) was observed and the benefit from including Cosabody was dose dependent. In the Finisher phase, all three treatment groups were effective in improving growth and performance (observed in Final BW, ADG, Adj. ADG, FCR, Adj. FCR, GF, Adj. GF EBI and WAFC). Overall, Cosabody inclusion at 150 CBU/ton had growth performance benefits compared to inclusion at lower dosage (observed in Adj. FCR, Adj. GF and WAFC) except at 125 CBU/ton. In the presence of a controlled NE challenge a dose of 100 CBU/ton of Cosabody or greater is effective in improving performance. The improvement in NE lesion scores gives clinical relevance and further supports the benefit of including Cosabody in the diet at a dose of 100 CBU/ton or greater. The inclusion of Cosabody in combination with Narasin had most significant growth performance benefits (comparable to Narasin alone). In the finisher phase and overall, the Cosabody shuttle with narasin performed at par with Narasin alone but significantly superior to control groups. In sum, Cosabody provides an alternative that can be used in a shuttle combination to avoid using narasin alone throughout the life of the bird.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-014** Cosabody cooperatively enhances the effect of ionophores on broiler performance in Coccidiosis control modelK. Livingston¹, P. Paul¹¹Optum Immunity, Waterloo, United States

Cosabody is an all-natural dried egg product that supports the intestinal immune response by neutralizing pathogen-permissive compounds. We assessed the effect of Cosabody and ionophore interaction on coccidiosis pathology in broiler chickens using five experimental groups of birds (25 pens, 20 birds/pen). Except non-challenged group (NT), remaining groups were induced with coccidiosis on D7 (challenged control: Ctrl, Cosabody: CBY, ionophores: IP, and Cosabody + ionophores: CBY+IP). Birds in experimental groups were either fed Cosabody-supplemented (0.5 kg/MT) diet or were administered with Maxiban (0-25D, 0.65 kg/MT) and Monteban (25-42D, 0.8 kg/MT). Growth performance data (body weight: BW, feed intake: ADFI, adjusted average daily gain: ADG, feed conversion ratio: FCR, gain efficiency: GE and European broiler index: EBI) were collected from all groups on day 0, 12, 25 and 42 representing respective phases. Gross lesions were scored on D12 and D25. Data analyzed by using the SAS® system (SAS Institute, Cary, NC), version 9.4, and all tests were performed using two-sided tests at 0.05 level. For each variable, calculations were done on a per pen basis, as pens were the experimental units. Birds treated with CBY+IP had higher ADG compared to all other cocci-challenged groups in grower and finisher phases of study ($P<0.05$). ADFI was higher in both IP and CBY+IP groups in starter and grower phases. Similarly, overall (0-42D) mortality-adjusted FCR was lower in CBY+IP group compared to CBY only treatment. Interestingly, birds in IP and CBY+IP experimental groups were heavier compared to other challenged groups ($P<0.01$) at the end of starter and finisher phases. Finally, EBI in CBY+IP and IP groups was higher than challenged control in finisher phase ($P<0.05$). As a feed additive, Cosabody improves overall effect of ionophores on growth performance of cocci-challenged birds, suggesting a synergistic supplementation. Its known role in inhibiting a tolerogenic and pro-pathogenic immune milieu enable Cosabody as a prophylactic feed additive that can be used in combination with ionophores to improve growth performance in coccidiosis challenge.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-015** Degradation kinetics of maize tocopherols during storage of grain and complete feeds of differing in commercial hybridsK. Kljak¹, D. Zurak¹, V. Gunjević¹, Z. Svečnjak¹, M. Duvnjak¹, G. Kiš¹, D. Grbeša¹¹University of Zagreb Faculty of Agriculture, Zagreb, Croatia (Hrvatska)

Tocopherols are a group of eight naturally occurring compounds commonly known as vitamin E that have health-promoting effects and improve the quality of animal products. Maize grain is considered a good source of tocopherols, however, tocopherols are susceptible to oxidation which can lead to their degradation during grain processing and storage. The aim of the present study was to determine and compare the tocopherol degradation rate in whole grain and complete feeds. Fifteen commercial hybrids from six breeding companies were used in the study, and 15 complete feeds for laying hens were prepared to differ only in the maize hybrid. The grain was ground through a 6 mm sieve immediately before the preparation of the complete feeds. Grain and complete feeds of the tested hybrids were stored at 20 ± 2 °C and sampled after 0, 14, 28, 56, and 84 days of storage. Tocopherols [α -, γ - and δ -tocopherol (α T, γ T and δ T), α - and γ -tocotrienol (α T3 and γ T3) and total tocopherols (TT)] were quantified using RP-HPLC. Tocopherol degradation followed first-order kinetics, and the rate of degradation of individual and total tocopherols was estimated. At the beginning of storage, maize hybrids had TT content ranging from 24.60 to 42.49 μ g/g DM, with γ T being the most abundant tocopherol (54-80%). After 84 days of storage, a higher loss of α T, γ T, α T3 and TT was observed in complete feeds than in whole grains (on average 17.3, 10.1, 22.5, and 12.8 vs. 39.9, 17.5, 29.8, and 27.2%, respectively). The degradation rate of these tocopherols was up to three times higher in complete feeds than in grains ($P<0.05$; 0.0038 vs. 0.0017 1/day for TT). The observed results suggest that the processing of maize grain for preparation and the presence of potential oxidising compounds such as minerals contribute to tocopherol loss in complete feeds. The hybrid significantly affected the tocopherol degradation rate in both grains and complete feeds ($P<0.05$), and the ranges for TT were 0.0007-0.0032 1/day and 0.0018-0.0061 1/day, respectively. In conclusion, tocopherol degradation increases when maize is a component of complete feeds, however, the extent of degradation is lower in grains of some hybrids and thus could retain more tocopherols during storage. This work has been fully supported by Croatian Science Foundation under the project ColourMaize (IP-2019-04-9063). The work of doctoral student Dora Zurak has been fully supported by the "Young researchers" career development project - training of doctoral students" of the Croatian Science Foundation.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-016** Determining a methionine matrix value for added betaine without and with added choline in broiler dietsW.D. Mansilla¹, S. Saraswathy², A.I. García-Ruiz¹¹Poultry Research Center, Trouw Nutrition, El Viso de San Juan, Spain, ²Global Nutrition Formulation, Trouw Nutrition, Amersfoort, Netherlands

In the liver, betaine is metabolized to dimethylglycine. In this process, homocysteine is converted back to methionine with a potential sparing effect for dietary methionine. The present study aimed to calculate a methionine matrix value for added betaine at two concentrations of added choline. In total, 3,720 male broiler chickens were used; birds were allocated in 120-floor pens with 31 birds per pen. Birds were fed a common starter diet (0 to 10d) that met the Met+Cys requirement, with 300 ppm choline and no added betaine. During the grower (10 to 29d) and finisher (29 to 35d) phases, five diets with 0.2% added betaine and decreasing Met contents were formulated. The Met titration met 75.0, 81.25, 87.5, 93.75, and 100% of the estimated Met+Cys requirement (Met+Cys: Lys ratio was 0.76). A sixth treatment was formulated without added betaine and met 100% of the Met+Cys requirement. The treatment differences were achieved by only changing the betaine and DL-Met inclusion in the diets; AME and other SID amino acids were kept similar among treatments. These six treatments were replicated at two concentrations of added choline in the premix (0 and 300 ppm in the final diets). A curvilinear-plateau model was fitted to the betaine-added, Met+Cys titration within each choline content. The model equations were reverse used to obtain an equivalent Met+Cys requirement coverage that predicted the results of the 100% Met+Cys, non-added betaine treatment within each choline content. The difference between the obtained Met+Cys content and the 100% requirement was considered the capacity of 0.2% betaine to replace DL-Met. On days 29 and 35 and at 0 ppm added choline, BW decreased rapidly relative to the Met+Cys contents without a plateau. Thus, dietary betaine did not spare Met when choline was not added. In contrast, when choline was added at 300 ppm, the BW only decreased when the dietary Met+Cys content was below 86.4% of the estimated requirement, suggesting that about 14.6% of the Met+Cys requirement can be replaced with 0.2% added betaine. Considering the betaine and DL-Met ingredient purity (96 and 99.5%, respectively), 1 g of betaine provided 0.637 g of SID-Met when choline was added. The latter sparing effect resulted in 52.1% molar efficiency of the added betaine. In conclusion, a SID-Met matrix value of 0.637 g can be attributed to 1 g of betaine when choline is added at 300 ppm; this matrix value can be used when betaine is added at up to 0.2% in the diet.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-017** Dietary addition of quercetin or 1,25-dihydroxyvitamin D3 improves eggshell and bone qualities of aged laying hens by regulating calcium transport in uterus and bonesY. Fu^{2,1}, M. Schroyen¹, J. Zhou², H. Zhang², S. Wu², J. Wang², G. Qi²¹Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium, ²Institute of Feed Research, Chinese Academy of Agricultural Sciences, Beijing, China

Quercetin (QUE) is a plant flavonol and has a chemical structure and oestrogenic activity similar to 17 β -oestradiol. The QUE or 1,25-dihydroxyvitamin D3 (OHD) addition may enhance Ca transport by inducing the expression of Ca transporters, which may improve eggshell and bone qualities of laying hens. This study examined the effects of dietary addition of QUE or OHD on the eggshell quality, bone parameters and Ca transport in uterus and bones of aged laying hens. A total of 360 60-wk-old Hy-Line Brown layers were randomly allocated to 3 dietary treatments: a basal diet, a basal diet supplemented with 500 mg/kg QUE or a basal diet supplemented with 5 μ g/kg OHD. The basal diet contained 3.5% Ca and 3 600 IU/kg vitamin D3, which met the recommendations for laying hens. The trial lasted for 12 weeks. Eggshell quality was tested every 4 weeks, and bone parameters and Ca transport in uterus and bones were examined at the end of the trial. All analyses were performed using SAS 9.4 (SAS Inc.). Statistical significances were determined by one-way ANOVA, followed by a Duncan's test. Results showed that dietary addition of QUE or OHD could improve eggshell breaking strength at the end of the 8th and 12th wk ($P < 0.05$). Total eggshell Ca and P content were increased in the dietary QUE or OHD addition group ($P < 0.05$). Dietary addition of QUE or OHD increased the stiffness, total Ca and P content of the femur ($P < 0.05$). During the initiation stage of eggshell calcification, the expression of transient receptor potential cation channel subfamily V member 6 (TRPV6) and calbindin (CALB) genes were upregulated in the uterus of hens fed with OHD ($P < 0.05$). Dietary QUE addition increased the uterine mRNA levels of tartrate-resistant acid phosphatase (TRAP) at the initiation stage of eggshell calcification and of TRPV6, Ca²⁺ ATPase and CALB at the growth stage of eggshell calcification ($P < 0.05$). The femurs in hens fed with QUE or OHD expressed relatively higher mRNA levels of alkaline phosphatase (ALP), osteopontin and TRAP at the initiation stage of eggshell calcification, while they expressed a higher level of TRAP mRNA and a lower level of ALP mRNA in the growth stage of eggshell calcification ($P < 0.05$). Overall, dietary QUE or OHD addition could improve eggshell and femur qualities, which may be related to the altered expression levels of Ca transport-related mRNA in the uterus and bone remodeling-related mRNA in the femur during the eggshell calcification.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-018 Dietary hydrolyzed yeast improved intestinal morphology and immune response of broilers under stress challenge**Y. Ruangpanit¹, K. Rassamidatta¹, A. Phaiboon¹, N. Chanaksorn², P. Carcano³¹Department of Animal Science, Faculty of Agriculture, Kasetsart University, Kamphaeng Saen Campus, Nakhon-Pathom 73140, Thailand, ²Innovad (Thailand) company limited 90/119 Bangkaew, Bangplee, Samutprakarn 10540, Thailand, ³Prosol S.P.A. Via Carso, 99 24040, Madone (BG), Italy

Raising broilers under high stocking density could lead to stress which induce inflammatory response, impair gut health and immune function. Hydrolyzed yeasts have a cell wall comprising mainly β -glucans and mannan-oligosaccharides and cell content with glutamic acid and nucleic acid that could positively influencing intestinal health and animal performances. The aim of this study was to investigate the supplementation of hydrolyzed on growth performance, intestinal morphology, and immune response of broilers under stress from high stock density (45 kg/m²). A total of 1,176, one day-old Ross 308 broilers were randomly assigned into 3 dietary treatments with 0, 250 and 500 g/ton of hydrolyzed yeast (I-CARE, PROSOL S.P.A, Italy) using Randomized Complete Block Design (RCBD). Each treatment consisted of 14 replicates (7 males and 7 females) with 26 males and 30 females per replication. All birds were raised in evaporative cooling system house. All diets were formulated according to Ross 308 recommendation. The trial was run for 42 days using 3 phase feeding (starter, grower and finisher). Feed in pellet form and water were provided Ad-libitum throughout the experiment. Feeding hydrolyzed yeast had no effect on growth performances but improved jejunum morphology of broilers by significantly lowering crypt depth and increasing villi height/crypt depth ratio ($P < 0.05$). ND titer was increased in broilers fed hydrolyzed yeast ($P < 0.01$). Heterophile production was increased ($P < 0.01$), while lymphocyte was decreased ($P < 0.01$) which led to an increase in H/L ratio ($P < 0.05$). The results from the present study indicated that feeding hydrolyzed yeast positively improving gut morphology and immune status of broiler under high stock density.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-019 Dietary xylo-oligosaccharides result in decreased abundance of epithelial healing and cell motility proteins indicating improved gut integrity in broiler chickens**C. Castro¹, S. Niknafs¹, G. Gonzalez-Ortiz², X. Tan¹, M. Bedford², E. Roura¹¹Centre for Nutrition and Food Sciences, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia, ²AB Vista, Marlborough, Wiltshire, United Kingdom

Xylo-oligosaccharides (XOS) improve gut health by positively impacting the gut microbiota and intestinal morphology, while decreasing the inflammatory response. The maintenance of the intestinal epithelial barrier is critical to achieve a healthy gut. On the contrary, a loss of barrier integrity results in the activation of healing mechanisms aimed at restoring epithelial functions. Some of these mechanisms include an increased expression of key proteins responsible for cellular junctions and motility. This study aimed at evaluating the impact of XOS on gut health by assessing the jejunal proteome in chickens. We hypothesized that XOS supplementation would enhance gut health and integrity, thus, decreasing the need for epithelial healing-related proteins. One-day-old broiler chickens were assigned for 42 days into: a) control diet consisting of a corn/soybean meal-based mash diet; or b) control diet supplemented with 0.5% XOS. Each treatment was randomly distributed across eight pens ($n=8$), with 64 birds per treatment. Consistent with previous results from our group and others, XOS resulted in a significant improvement in feed conversion ratio at the end of the rearing period when one chicken per pen was selected and euthanized, and jejunum was collected for proteomic analysis. The proteomic data was analyzed using MSstats in R and followed by functional enrichment analysis. XOS supplementation was associated with downregulation of several biological pathways as a result of significantly lower abundance of proteins in gap junctions ($P=0.0328$), regulation of cell-cell adhesion ($P=0.0433$), and actin cytoskeleton reorganization ($P<0.0092$). In particular, the results showed significantly decreased abundance of proteins CDC42, RAC1, and VIL1. The first two are activated upon injury as part of the healing response to restore epithelial integrity. Similarly, VIL1 is involved in the actin cytoskeleton reorganization and critical in accelerating cell migration after injury. Furthermore, ADA, which has been proposed as an inflammatory biomarker, was downregulated in XOS supplemented chickens. In conclusion, these data suggest that XOS may contribute to foster a healthy gut by maintaining the integrity of the intestinal epithelial barrier as evidenced by the downregulation of wound-healing related proteins and inflammatory biomarker. Overall, these results reflect a beneficial effect of XOS in promoting a stable intestinal barrier and decreasing gut inflammation.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-020 Digestibility of standard and low-input diets in chicken commercial hybrids, local breeds, and crossbreds**

M. Birolo¹, A. Huerta², A. Pascual³, F. Bordignon¹, F. Pirrone², C. Castellini⁴, A. Trocino^{1,2}, G. Xiccato¹

¹Dipartimento di Agronomia, Animali, Alimenti, Risorse naturali e Ambiente - Università di Padova, Legnaro, Padova, Italy, ²Dipartimento di Biomedicina Comparata e Alimentazione - Università di Padova, Legnaro, Padova, Italy, ³A.I.A. - Agricola Italiana Alimentare S.p.A, San Martino Buon Albergo, Verona, Italy, ⁴Dipartimento di Scienze Agrarie, Alimentarie ed Ambientali, Università di Perugia, Perugia, Italy

Sustainability in alternative poultry meat production chains implies the use of local chicken breeds and low-input diets based on raw materials with low environmental impact. The present study evaluated the diet digestibility of a fast-growing commercial hybrid (Ross 308), two local breeds (Bionda Piemontese, BP; Robusta Maculata, RM) and their crosses with a moderate-growth strain (Sasso, SA). A total of 228 male chickens were housed in 20 collective pens (9-13 animals/pen) according to a bi-factorial design with 5 genotypes (Ross 308, n = 49; BP, n = 38; RM, n = 46; BP×SA, n = 48; RM×SA, n = 47) and 2 grower diets differing for apparent metabolizable energy (AME) and crude protein (CP) content (Standard diet, ST: AME 14.2 MJ/kg; CP 18.7% vs. Low-input diet, LI: AME 13.0 MJ/kg; CP 16.7%). In the LI diet, soybean meal from GMO imported soybean was replaced with soybean meal from local GMO-free soybean and faba bean (*Vicia faba* L. minor) meal. From hatching to 19 d of age, all birds received the same starter diet (AME 14.4 MJ/kg; CP 24.0%); the experimental grower diets were administered from 20 d of age until slaughtering (47 d for Ross 308 and 105 d for other genotypes). From 34 to 40 d of age samples of feces were collected from each pen, dried, and analysed for dry matter (DM), CP, ether extract (EE), gross energy (GE) and acid-insoluble ash (AIA) content. AIA was used as a marker to determine the apparent digestibility coefficient (ADC) of the dietary DM, CP, EE, and GE. The ADC of DM was equal to 0.70 on average, without significant differences among genotypes as it was for the ADC of CP, EE, and GE. The use of LI diet decreased the ADC of DM ($P < 0.01$), CP ($P < 0.001$), and GE ($P < 0.01$). No significant interaction was detected between genotype and diet effects. In conclusion, the use of a low-input diet reduced the apparent digestibility of protein and energy in growing chickens, regardless of the genotype. However, a wider evaluation of the animal response in terms of growth performance, welfare, slaughter yield, and meat quality traits is required to establish the chicken genotype that better fit with the rearing conditions of alternative production systems. Acknowledgements: The present research was funded by PRIN project (Prot. 2017S229WC; year 2017).

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-021 Distribution of intestinal intraepithelial and lamina propria lymphocytes influenced by feed additives and host-related factors of broilers**

Y. Duangnumsaeng^{2,1}, J. Zentek², F. Goodarzi Boroojeni²

¹Faculty of Veterinary Science, Prince of Songkla University, Hatyai, Thailand, ²Institute of Animal Nutrition, Department of Veterinary Medicine, Berlin, Germany

Intestinal T cells provide a first line of immune defense. This study examined the effect of age, breed, sex and probiotic or phytobiotic supplementation on CD3+ T cell density in the ileum and caecum of broilers. A total of 2,880 one-day-old male and female broiler chicks from two breeds, Ross-308 and Cobb-500, were randomly allocated to 72 pens. Each pen consisted of 40 chicks of each sex and each breed. Broilers were offered 3 experimental diets including a standard wheat-soybean based diet without or with supplementation of either a probiotic (2.4×10^9 CFU/kg diet; *Bacillus subtilis* DSM32324 and DSM32325 and *B. amyloliquefaciens* DSM25840) or a phytobiotic (165 ppm procyanidins and 585 ppm polyphenols) product. At day 7, 21, and 35 of age, one chicken per pen was sacrificed to dissect the middle part of the ileum and the distal part of the caecum. The intestinal tissue was stained with an anti-CD3 antibody. The density of positive cells (CD3+, number per 10,000 μm^2) was measured in the lamina epithelialis (LE) and propria (LP) of the ileal villus (upper and lower part) and crypt as well as caecal crypt. Data were subjected to ANOVA using GLM procedure with a 3 (diet) $\times$ 3 (age) $\times$ 2 (breed) $\times$ 2 (sex) factorial arrangement. Overall, the CD3+ density was greater in the LP than LE of all investigated regions (ileal villus and crypt and caecal crypt). Age affected CD3+ density ($p < 0.05$), but no impacts for breed, sex and diet were observed in both intestinal locations ($p > 0.05$). CD3+ density in the tip of ileal villi increased from day 7 to 21 by 125 and 96 % in the LE and LP respectively, but at the base of villi these increases were 105 and 65% ($p < 0.05$). From day 21 to 35, CD3+ density decreased by 23 and 41 % in the LE and LP at the villi tip and by 32 and 47 % at the base, respectively ($p < 0.05$). In contrast, CD3+ density in the ileal crypt increased from day 7 to 35 by 87 and 185% in the LE and LP, respectively ($p < 0.05$). In the caecal crypt, CD3+ density increased from day 7 to 35, by 111 and 76 % in the LE and LP, respectively ($p < 0.05$). There was an interaction between age, dietary treatment and sex on CD3+ density in the LP of the caecal crypt ($p < 0.05$). In conclusion, breed, sex, and diet had no effect on CD3+ density in the gut. This study showed age-dependent variations in CD3+ T cell density along the crypt-villus axis of the ileum and caecum. This could be a result of the immunological responses to various luminal stimuli.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-022 Effect of a monoglyceride blend alone and in combination with butyric acid esters on the performance and gut response regarding stress homeostasis in broilers**P. Konieczka¹, A. Holthausen², A. Drazbo¹, E. von Heimendahl², L. Barnard³, K. Kozłowski¹¹Uniwersytet Warmińsko-Mazurski w Olsztynie, Olsztyn, Poland, ²Eastman Chemical Company, Langenfeld, Germany, ³Eastman Chemical Company, Newport, United Kingdom

Dietary short (SCFAs) and medium-chain fatty acids (MCFAs), play a key role in cellular signaling pathways and energy metabolism of cells. Specifically butyric acid modulates the activation of NF-κB, a key factor in inflammatory response, and inhibits the formation of pro-inflammatory cytokines. The aim of the present study was to assess the effect of a supplementation with an alpha-monoglyceride (MG) blend of SCFAs and MCFAs alone, and in combination with Mono- and Tri-butylin (MTB), on performance and inflammatory parameters of broiler chickens. A total of 510 one-day-old male Ross 308 broiler chickens (45.57g ±0.5g) were randomly allocated to 3 treatments (30 pens; 17 birds/replicate). The wheat/corn/soybean meal based basal diet (control) was supplemented with MG (1,000 g/ton feed in all phases); butyric acid (130g/ton in the starter feed; 80g/ton in grower and finisher feed) provided as MTB was added to MG (MG+MTB). Growth performance was determined on a weekly basis. 10 birds per treatment were euthanized at day 35, jejunal tissue samples were taken for analysis of transcript level of selected genes determining gut integrity using RT-PCR method. At day 14, body weight (BW) and average daily weight gain (ADWG) was significantly improved (4.87%) by the combination MG+MTB (BW 0.466kg, p=0.004; ADWG 61.9 g/d, p=0.024) compared to the untreated control (BW 0.446kg, ADWG 28.6), whereas no difference was observed when MG was supplemented alone. At day 35, MG supplementation alone improved BW (2.234kg, p=0.024) by +4.38% and ADWG (62.5 g/d, p=0.024) by +4.48% compared to control (BW 2.141kg, ADWG 59.9). In contrast to the starter phase, no further improvement was observed, when MTB was added to MG. Jejunal tight junction gene expression of OCLN and CLDN-1 (both P<0.001) was reduced by combination MG+MTB, whereas the MUC-2 gene expression was reduced by MG alone (P=0.031). This could be a result of a reduced expression of NF-κB in the MG group and even more in the MG+MTB (P<0.001) compared to control, indicating a lower inflammation level. Our findings indicate that dietary supplementation of MG improves body weight gain of birds whereas additional supplementation with MTB improved weight gain also at the early stage of growth. Both additives significantly reduced mRNA expression level of selected tight junction genes. However, their combined usage in the diet was more effective, potentially indicating their stress-ameliorative effect in the host gut.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-023 Effect of dietary methylsulfonylmethane supplementation during 1-42 day of age on growth performance and carcass characteristics of broilers**Z. Li¹, J.C.D.P. Dorigam¹, B. Gutierrez²¹Evonik Operations GmbH, Hanau-Wolfgang, Essen, Germany, ²Evonik España Portugal S. A. U, Onzonilla, León, Spain

Methylsulfonylmethane (MSM) is an organosulfur compound which has been reported to play a role in anti-inflammation, anti-oxidation, immune modulation, and sulfur donation. To investigate the effect of dietary MSM supplementation during 1-42 day (d) of age on growth performance and carcass characteristics of broilers. A total of 240 1-d old male Cobb500 birds (42.0 ± 0.1 g) were allocated to 2 treatments receiving basal diet or basal diet + 0.05% MSM, respectively, with 12 replicates containing 10 birds in each treatment. Birds were housed under standard housing conditions with diets and water provided ad libitum. Body weight (BW) and feed intake (FI) were recorded weekly from d 1 to d 42. On d 42, after fasting for 8 hours, 4 birds from each replicate were selected based on the average BW of each replicate and slaughtered for carcass and breast meat (BM) weight. In addition, litter moisture was determined on d 28 and 42. Foot pad lesions score (FPLS) was determined on d 42. Data was analyzed with SAS software using one-way ANOVA followed by LSD test. Dietary MSM supplementation significantly improved feed conversion ratio of birds during 1-42 d of age (1.584 vs. 1.637 g/g, SEM = 0.05, P = 0.01) while the average daily gain (49.21 vs. 50.76 g/d, SEM = 2.79, P = 0.21) and average daily FI (80.33 vs. 80.48 g/d, SEM = 2.90, P = 0.91) during 1-42 d period were not affected by the treatments. On d 42, supplementary MSM tended to increase the live weight of birds (2.21 vs. 2.16 kg, SEM = 0.13, P = 0.07) and significantly increased the BM yield of birds (18.83 vs. 17.57%, SEM = 1.64, P < 0.001). Carcass yield (83.40 vs 83.41%, SEM = 1.25, P=0.95) did not differ between the treatments. The average FPLS (0.551 vs. 0.487, SEM = 0.19, P = 0.73) of birds did not differ between the treatments. However, litter moisture on d 42 was reduced in the MSM treated birds compared to the birds fed with basal diet (21.86 vs. 25.07%, P = 0.02). In conclusion, the results showed that dietary supplementation of 0.05% MSM during 1-42 d of age improved broilers' feed conversion ratio and breast meat yields, and reduced litter moisture of the birds.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-024 Effect of dietary Phytase and NSP'ase on performance and egg quality of Lohmann white-classics**Y. Cufadar¹, S. Golzar Adabi², L. Nollet³, E.T. Gül¹¹Department of Animal Science, Feeds and Animal Nutrition, Faculty of Agriculture, Selçuk University, Konya, Turkey, ²Huvepharma, 6144, Kartal, Istanbul, Turkey, ³Huvepharma, Uitbreidingstraat 80, 2600, Antwerpen, Belgium

This study was carried out to determine the effects of dietary NSP'ase plus two different levels of phytase on performance and egg quality in white laying hens. All diets were isocaloric (2800 kcal/kg ME) and isonitrogenous (0.65 and 0.6 % dig. Lys and dig Met + Cys respectively) and contained 0.35 and 3.75 g/kg of avP and Ca. Dietary treatments consisted of a positive control as T1 (a diet without any enzyme), T2 and T3 supplemented with graded phytase levels (OptiPhos Plus, 500 and 1000 FTU/kg diet), and a level of NSP'ase (Hostazym X, 1500 EPU/kg) for both, and finally T3 diet supplemented with 250 g/ton of feed lecithin which served as T4. All diets were reformulated with company's claimed matrix values for Ca, P, amino acids and energy. Totally 112 Lohmann white classic laying hens were raised in 3-floor battery cages (45 × 43 cm) from 30 to 56 weeks of age. The cages were equipped with two nipple drinkers inside and one galvanized feeder outside. Data for all response variables were analysed in a completely randomized block design consisting of 4 treatments and 7 replicate blocks with 4 birds in each by using the general ANOVA procedure of SAS released 9.2. Whenever significant differences (P<0.05) were detected among treatments, means were separated using Tukey's test. Egg production, live weight, feed intake, feed conversion ratio (FCR), and internal and external egg quality were determined on monthly basis and reported here as an average of whole period. Dietary treatments had no significant effect on the performance parameters (P>0.05) except for FCR. Birds on T2, T3, and T4 diets had higher FCR compared to birds fed on T1 diet (P<0.05). Dietary treatments had no significant effect on the internal and external egg quality parameters (P>0.05). Birds receiving enzymes had higher yolk colour index than the birds in control (P<0.05). The income per layer for T2, T3 and T4 compared to T1 improved by 4.84, 4.84 and 6.18%, respectively. It can be concluded that applying enzymes in laying hen diets can ameliorate total income especially by decreasing the feed cost.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-025 Effect of Feeding Different Dietary Concentrations of Zinc and Copper on Haematological and Bone Morphometric Parameter of Growing Turkey Chicks (Poult)**J. Agashe¹, C. Deo¹, A. Biswas¹, S. Bhanja¹, S. Jadhav², G. Kullori¹, M. Nampalle¹¹ICAR-Central Avian Research Institute, Bareilly, India, ²Division of Animal Nutrition, IVRI, Bareilly, India

At present, new generation birds demand for timely revision of essential nutrients and their sources in the diets. NRC (1994) stated that 70 and 65 mg Zn/kg during 0-4 and 4-8wks respectively and 8 mg Cu/kg diet during 0-8wks of age in diet of turkey chicks. Biological trial was conducted to understand the response of combination of different dietary levels of zinc (Zn) and copper (Cu) on haematological and bone morphometry of turkey chicks (poult). 288 day old CARI VIRAT turkey chicks (poult) were grouped under completely randomized design into nine dietary treatments for 8 weeks comprising varying combinations of three levels of zinc in Phase-I (0-4 week) 50, 70 & 90 mg Zn/kg of diet and Phase-II (5-8 weeks) 45, 65, & 85 mg Zn/kg of diet each with three levels of Copper in Phase I & II (0-8 week) 8, 12 and 16 mg Cu/kg in basal diet in a 3×3 factorial experiment. Statistical significance was declared at P<0.05 using the Tukey's multiple comparison test. At 8th weeks post-hatch blood samples were collected from jugular vein of eight birds per treatment group for estimation of Hb, PCV and birds were sacrificed to collect left tibia bone samples to study the bone morphometry. The results revealed that non-significantly increase in packed cell volume and haemoglobin were recorded in group which was fed with combination of 70 & 65 mg Zn/kg with 16 mg Cu /kg in diet. However significantly (P<0.05) higher tibia length, weight & proximal width, But non-significantly higher in mid width was recorded in group which was fed with combination of 70 & 65 mg Zn/kg with 16 mg Cu /kg in diet during . Based on the results it was concluded that a dietary combination of 70 and 65 mg Zn/kg in diet during 0-4 & 5-8 weeks respectively with 16 mg Cu/kg in diet was found optimum to maintain adequate level of Hb and Packed cell volume of blood and skeletal health in growing turkey chicks (poult). Reference- NRC (National Research Council). 1994. Nutrient Requirements of Poultry. 9th revised edition. National Academy Press, Washington, DC, USA

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-026 Effect of the rearing system on calcium, phosphorus and cholecalciferol vitamin intake, productive performance, egg quality traits and keel bone damage in laying hens**D. Chiattelli¹, R. Piscitelli², F. Sirri², C. Castellini¹, A. Cartoni Mancinelli¹¹Department of Agricultural, Environmental and Food Science, University of Perugia, Italy, ²Department of Agricultural and Food Sciences Alma Mater Studiorum, University of Bologna, Italy

Laying hens are characterized by a dynamic bone turnover due to the calcium (Ca) metabolism linked to daily egg production. Several factors such as an impaired Ca to Phosphorus (P) ratio, inadequate Ca level in the diet, improper gastrointestinal Ca absorption and low cholecalciferol vitamin (D3) synthesis could lead to an excessive mobilization of Ca from the skeleton potentially resulting in bone fragility. The aim of the study was to evaluate the effect of the rearing system on Ca, P and vitamin D3 intake and their effects on egg and eggshell quality traits and incidence of keel bone damage. A total of 60 Leghorn laying hens (18 weeks of age) were raised in either barn or free-range rearing system (BA and FR; 3 replicates of 10 hens each). All animals were fed ad libitum a commercial diet and the FR group had access to pasture. Egg deposition and mortality rate were recorded daily, while feed intake was registered weekly. The grass intake in the FR system was also estimated by the use of 4 exclusion areas/pen. At 38 weeks of age, 100 eggs for each group were collected and the egg physical quality assessed. Results showed that FR hens, probably due to their grass consumption (100 g/hen/d of fresh matter), had lower feed intake than the BA ones (116 vs. 161 g/hen/d respectively; $P < 0.001$) and consequently assumed lower amount of dietary Ca, P and Vitamin D3 ($P < 0.001$). Surprisingly, FR hens showed higher egg numbers compared to BA hens (5.3 vs. 4.9 eggs/hen/week, respectively; $P < 0.02$), whereas they had lower egg weights (59 vs. 61 g; $P < 0.001$) outbalancing total egg mass production (312 vs. 298 $P > 0.05$). Although only a tendency was observed for eggshell breaking strength and keel bone damage ($P = 0.06$), it emerged that yolks from FR eggs presented higher redness (a^* : 0.14 vs. 0.03; $P < 0.001$) and lower lightness and yellowness (L^* : 56.3 vs. 53.5; b^* : 39.6 vs. 36.1; $P < 0.001$). Therefore, even though the access to pasture remarkably reduced the dietary intake of Ca, P and vitamin D3, eggshell breaking strength and keel bone damage were not significantly different between BA and FR groups. This might suggest that the endogenous synthesis of vitamin D3 due to sunlight exposure, the insect and beetle consumption of FR hens could have partially compensated the reduced intake of Ca and vitamin D3. In addition, eggs from FR groups presented a different color profile, potentially due to the grazing activity and the related intake of bioactive compounds of FR hens.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-027 Effect of varying levels of amaranth leaf meal on performance, meat, and bone characteristics of Ross 308 broiler chickens**T.G. Manyelo^{2,1}, N.A. Sebola², J.W. Ng'ambi¹, M. Mabelebele²¹University of Limpopo, Department of Agricultural Economics and Animal Production, Sovenga, 0727, South Africa, ²University of South Africa, Department of Agriculture and Animal Health, College of Agriculture and Environmental Sciences, Florida, 1710, South Africa

This study aimed to determine amaranth leaf meal inclusion levels on performance, meat, and bone characteristics of Ross 308 broiler chickens. A total of 200, day-old, Ross 308 broiler chicks were randomly allocated to five dietary treatments in a complete randomised design, with each group having four replicates with ten chicks each. Amaranth leaf meal (ALM) inclusion levels used in this study were 0, 5, 10, 15, and 20%. Diets were formulated to be isoenergetic and isonitrogenous. Bodyweight and feed intake were measured weekly to calculate the feed conversion ratio. Meat and bone traits of broiler chickens fed amaranth leaf meal at varying levels were also measured whereas the general linear model of statistical analysis software was used to analyse collected data. Amaranth leaf meal inclusion level did not affect ($p > 0.05$) initial weight, final weight, average daily gain, and average daily feed intake of Ross 308 broiler chickens aged one to 42 days. Drumstick weight, breast meat pH, breast meat L* and shear force was optimized at amaranth inclusion levels of 5.71, 4.50, 9.03, and 7.65%, respectively. Ross 308 broiler chickens given diets with 0 and 10% ALM inclusion levels, had higher ($p < 0.05$) cooking loss than those on diets with 5, 15, and 20% of ALM inclusion levels. Chickens fed with a diet having a 15% ALM inclusion level, had a greater ($p < 0.05$) tibia diameter than those on 0, 5, 10, and 20% ALM inclusion levels. Whereas those fed 5 and 15% ALM inclusion levels, had greater ($p < 0.05$) femur diameters than those on 0, 10, and 20% ALM inclusion levels. Chickens offered diets with 15% ALM inclusion level, had longer ($p < 0.05$) tibia lengths than those on diets having 0, 5, and 10% ALM. It can be concluded that amaranth leaf meal can be included in the diets of Ross 308 broiler chickens aged one to 42 days at 5, 10, and 15% levels without adverse effects on productivity, meat quality, and the bone characteristics of the chickens. This augurs well for poultry farmers in many parts of Africa where the production of vegetable amaranth is in abundance.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-028 Effectiveness of starch digestion using different starch sources: Are broiler chickens and pigs different?**

L. Schmidt Bassi^{1,2}, M. Hejdysz³, P. Kołodziejwski⁴, A. Smith⁵, J.O. Berti Sorbara⁵, A. Cowieson⁵, S. Kaczmarek¹, B. Svihus²

¹Department of Animal Nutrition, Poznań University of Life Sciences, Poznań, Poland, ²Faculty of Biosciences, Norwegian University of Life Sciences, Ås, Norway, ³Department of Animal Breeding and Animal Product Quality Assessment, Poznań University of Life Sciences, Poznań, Poland, ⁴Department of Animal Physiology and Biochemistry and Biostructure, Poznań University of Life Sciences, Poznań, Poland, ⁵DSM Nutritional Products, Kaiseraugst, Switzerland

An experiment was conducted to investigate the hypotheses that broilers and pigs may have distinct starch digestion capacities. Moreover, different starch sources were used to assess possible interactions with both species. In total, 10 replicates of 2 broilers (14-d-old) or 1 pig (averaging 20 kg body weight) each were distributed into a 3x2 randomized factorial design with 3 dietary treatments (maize, barley, oats-based pelleted diets) and the 2 species. Particle sizes of ground corn, barley, and oats were 506, 598, and 520 µm, respectively. Nutritional composition of the diet was equal for both species and titanium was used as a marker. Experimental diets were fed to both species for 10 days, and at the last day, contents from gizzard, stomach, duodenum, jejunum, and ileum were collected, as well as the pancreas and segments from small intestine. Other analysis that are not described below include amylase and lipase activity in the pancreas and small intestine; pancreatic amylase RNA expression; number of glucose transporters in the intestinal tissue. The results indicate that overall, both species were similarly efficient on digesting starch, even though they differed on some aspects. For instance, broilers had higher ileal digestibility of dry matter (DM; 0.69) and crude protein (CP; 0.75) than pigs (0.66 and 0.67), presented 90% of particles in the duodenal digesta below 325 µm compared to 864 µm in pigs ($P<0.05$), and had a lower gizzard pH (3.68) than stomach of pigs (4.48; $P<0.05$) regardless of dietary treatments. Despite that, main effects from diets along with interactions between treatments suggest that starch utilization is more potently related to its dietary sources. In the jejunum, particle size of the digesta was lower in broilers fed oats compared to other treatments, and oat diets led to higher starch digestibility (0.96) than maize and barley regardless of species. Dry matter and crude protein jejunal digestibility was lower in pigs fed barley than other treatments ($P<0.05$). In the ileum, using oats increased viscosity of broilers compared to maize, and dry matter and crude protein digestibility were higher for maize and barley diets compared to oats regardless of species, but starch digestibility was higher for broilers fed oats (0.99) than broilers fed barley (0.94; $P<0.05$), further establishing that oats provided, in general, a superior starch availability.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-029 Effects of a commercial triple-strain Bacillus-based probiotic on broiler performance and welfare**

A. Meuter¹, A. Inoue², S. Lerner¹, I.C.L. Almeida Paz³

¹Chr. Hansen, A/S, Hørsholm, Denmark, ²Chr. Hansen Ind. e Com. L, Valinhos, Brazil, ³FMVZ/UNESP - Faculdade de Medicina Veterinária e Zootecnia, Botucatu, Brazil

Previous investigations have shown bi-directional interactions within the gut-brain-microbiome axis. Gut microbes communicate to the central nervous system through at least three parallel and interacting channels involving nervous, endocrine, and immune signaling mechanisms. A commercial triple-strain Bacillus-based probiotic was tested to determine its effect on the performance and welfare of broilers. Four treatments were tested with eight replicate groups, each containing 400 day-of-hatch AP95 male broilers. On top of a standard diet, the treatments were: 1) no supplement (Negative Control, NC), 2) Halquinol (Positive Control, PC), 3) Probiotic (PRO), and 4) Organic Acid and Essential Oil (OA+EO). Body weight (BW) and feed intake of birds 1 to 42 d were measured to calculate feed conversion ratio (FCR). Behavioural responses were measured using latency-to-lie and approximation tests. Plasma concentrations of corticosterone (CORT) and serotonin (5HT) were measured as indicators of stress. Intestinal morphology was measured using villus height (VH), villus width (VW), and villus to crypt ratio (V/C). Data were analyzed using JMP and Tukey's HSD was used for means separation. Compared with NC (1.51), PC (1.52), and OA+EO (1.51), FCR was lower ($P<0.05$) in PRO (1.48). BW at 42 d was greater ($P<0.05$) in PRO (3,206 g) compared with NC (3,084 g), PC (3,120 g), and OA+EO (3,166 g). Birds fed an effective probiotic were more comfortable and less skittish compared with other treatment groups, as evidenced by longer standing times and allowed proximity ($P<0.05$). PRO had lower CORT (80 µg/mL) and higher 5HT (402 µg/mL) compared to NC (166 and 100 µg/mL), PC (183 and 91 µg/mL), and OA+EO (133 and 316 µg/mL), respectively ($P<0.05$). Furthermore, the mechanisms that enable the beneficial synaptic actions of 5HT (5-HTT, SLC6A4, and TPH1) were expressed to a greater degree in PRO. For all measures of intestinal morphology, response values were numerically highest in PRO. Based on the dimensions of the duodenal microvilli, birds fed PRO had 23% greater surface area for absorption of nutrients compared to the NC. In conclusion, the commercial triple-strain Bacillus-based probiotic improved the performance and well-being of broilers via the gut-brain-microbiome axis.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-030 Effects of butyrate or butyric glycerides in combination with different selenium sources as strategies to improve performance of the aged laying hens**T. Goossens¹, D. Cardoso¹, G. Gong², Z. Xiong², B. Mallmann¹, O. Lemâle³, L. Sun²¹Adisseo, Antony, France, ²Huazhong Agricultural University, Hubei (Wuhan), China, ³Adisseo NL, Raamsdonksveer, Netherlands

In recent years, interest is growing for nutritional strategies that can be implemented to support the health and performance of laying hens, thereby improving the profitability and sustainability of egg production. The objective of this trial was to investigate the effects of two sources of butyrate (coated sodium butyrate and butyrate glycerides) either with or without the addition of an organic selenium (OH-SeMet) on the performance of aged laying birds. 900 forty-five-week-old Hy-Line brown hens with similar performance were randomly allocated to five treatment groups with 10 replicates of 18 animals each. The experiment lasted 20 weeks. The experimental diets were based on commercial feeds supplemented with 0.3 mg/kg of sodium selenite (Control), and with 240 mg/kg butyric acid, either as coated butyrate (a 24% butyric acid product) (T2), or as butyric glycerides (a 40% butyric acid product) (T3). In treatments 4 and 5, 0.3 mg/kg of Se from OH-SeMet was used, combined with the coated butyrate (T4) or with the butyric glycerides (T5). Data was evaluated using ANOVA. Significant differences were considered at $p \leq 0.05$, and a Tukey test was used to compare separated means. Results showed that supplementation with the different nutritional strategies supported laying performance in a T5 > T4 > T3 > T2 > Control trend, with T4 and T5 performing significantly better than Control. T4 and T5 did not differ statistically. The FCR was improved by supplementation of butyrate-based products: we observed a numerical improvement for T2 and a significant difference in T3. This effect was further increased with the additional inclusion of OH-SeMet in the diet. Compared to the Control group, T5-treated birds were also characterized by significantly lower serum malondialdehyde (MDA), IL-6 and alanine aminotransferase (ALT) values and higher serum total anti-oxidation competence (T-AOC), glutathione peroxidase (GPX) and IgA, IgG and IgM levels. Interestingly, in these animals, lower MDA and higher GPX values were also found in the liver and uterus. In summary, this trial adds evidence to the potential of butyrate additives, alone or in combination with OH-SeMet, as effective nutritional strategies to improve laying performance. This effect might at least be partially explained by their modulation of the redox status and immunity-related responses. Analyses are ongoing to explore whether the two butyrate supplements exert their effect via distinct modes of action.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-031 Effects of combination of butyrins/valerins and butyrins alone on growth performances and carcass quality of broiler chicken**T. Poeikhampha¹, M. Kamphon², L. Li³¹Department of Animal Science, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand, ²Perstorp Animal Nutrition, Bangkok, Thailand, ³Perstorp Animal Nutrition, New South Wales, Australia

Antibiotic resistance is a worldwide health problem that involves the transfer of bacteria and genes between animals, environment, and humans. Therefore, the use of antibiotics as a growth promoter are prohibited worldwide, there has been considerable interest in the use of the feed additive as an alternative to antibiotics in animal feed. Thus, this study aimed to study the effects of a butyrins and valerins mixture and butyrins alone as an alternative growth promotor on growth performance and carcass quality of broilers. A total of 630 male broiler chickens (ROSS 308) were divided into 3 groups with 6 pens per group, and each pen consists of 35 birds following a Completely Randomized Design. The evaporation cooling system was used to monitor ambient temperature and humidity in the experimental house. Throughout the 35 days of the feeding period, birds received 3 types of experimental diets: 1) basal diet without feed additive supplementation (control group); 2) control group + mixture of butyrins and valerins supplementation and 3) control + butyrins supplementation. Feeding period was divided into starting period (1-10 days), growing period (11-24 days) and finishing period (25-35 days). The body weight and feed intake of the birds were measured during the switchover period (10, 24 and 35 days) to calculate the body weight gain, feed intake, feed conversion ratio and mortality. The end of 35 days, 2 birds per replicate showing closest to the average body weight in the pen were selected (12 birds/treatment) to determination of carcass quality and footpad dermatitis (FPD) score. The results of this study indicated that birds received butyrins supplementation had significantly lower feed conversion ratio over the control group ($p < 0.05$); but showed no significant effect on the overall feed intake. Birds fed a diet supplemented with the combination of butyrins and valerins had significantly heavier final body weight ($p < 0.05$). In this study, the carcass quality and footpad dermatitis (FPD) score did not differ among the dietary treatments. In conclusion: supplementation of the butyrins and valerins mixture or butyrins alone could improve growth performance without negative impact on carcass quality and footpad dermatitis. The butyrins and valerins mixture and butyrins can be used as a feed additive in antibiotic free broiler production. Key words: Butyric acid mixture with Valeric acid, Tributyrin, Growth Performance, Carcass Quality, Broiler chicken.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-032 Effects of dietary amino acid supply on amino acid metabolism in broilers**A. Jansman¹, J. van der Meulen¹, P. van Wikselaar¹, W. Lambert²¹Wageningen Livestock Research, Wageningen, Netherlands, ²Ajinomoto Animal Nutrition Europe (currently METEX ANIMAL NUTRITION), Paris, France

Protein efficiency in broilers can be increased by lowering dietary protein content and considering next limiting essential (EAA) and non-essential amino acids (NEAA). We studied potential next limiting essential and 'non-essential amino acids' in low protein (LP) diets using a novel in vivo amino acid dilution technique. Three dietary treatments were evaluated from in the grower phase of birds (d 17-27 of age). Birds were fed a control diet (I, control; CP 211 g/kg) (treatment I) or one of two LP diets (CP 180 g/kg), one with supposed deficiencies in the EAA Ile, Arg, His, Leu and Phe (II) and one with low concentrations of NEAA Glu, Gln, Gly, Pro, Ser and Tyr (III). The irreversible loss rate (ILR) and plasma pool size of Glu, Gln, Gly, His, Ile, Leu, Lys, Met, Phe, Pro, Ser, Thr, Trp, Tyr and Val were studied based on the change in plasma isotopic enrichment of individual AA in time after an intravenously administered bolus of U-13C-labelled AA. For essential amino acids, the ILR was significantly affected by treatment for Leu, Lys, Met, Phe, Thr and Val ($P < 0.05$) and showed a trend for Trp. Compared to treatment I, the ILR was higher in treatment II (low CP and low EAA) for Lys, Met, Thr and Val and lower for Phe ($P < 0.05$). The ILR was higher in treatment III (low CP and low NEAA) for Leu, Lys, Met, Phe, and Val compared to treatment I. For NEAA, the ILR was significantly affected by treatment for Gln, Gly, Pro, Ser ($P < 0.05$) and showed a trend for Tyr. Compared to treatment I, the ILR in II was higher for Gly and Ser and lower for Tyr ($P < 0.05$). The ILR was higher in treatment III and did not differ significantly from treatment I for all NEAA evaluated. It was concluded that both the systemic flux (irreversible loss rate) as well as the plasma pool size of AA respond to variation in the dietary supply and likely to differences in requirements for body protein synthesis. We proposed a methodology to compare the results of an amino acid flux study for determining the relative extent of limitation of amino acids based on the ratio between the ILR and the plasma pool size. The results suggest that Phe + Tyr and His are among the next limiting essential amino acids (after Lys, Met + Cys, Thr, Trp and Val) for broilers in the growing phase when feeding LP diets. We also observed that the dietary supply of Gly and Ser could be critical in supporting body protein synthesis and performance when feeding LP diets.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-033 Effects of novel docosahexaenoic acid (DHA) sources on egg production, egg quality and enrichment of eggs and tissues in Lohmann LSL lite hens**A.N. Maina¹, E. Lewis², E.G. Kiarie¹¹Department of Animal Bioscience, University of Guelph, Guelph, Canada, ²Food Innovation, Humanativ, Netterville, Co Meath, Ireland

Enriching table eggs with omega-3 fatty acids (n-3FA) such as docosahexaenoic acid (DHA) is a well-accepted practice with tremendous benefits to the egg industry and consumers. Including fish oils in hen diets is the typical approach for producing DHA-enriched table eggs; however, issues around cost, sustainability, and product acceptance have necessitated searching for alternatives. This study assessed the effects of feeding hens two non-fish-derived oil sources of DHA on egg production, egg quality, and DHA enrichment in eggs and tissues. The oil sources were: OmegaPro (OP) and Algal oil (AO). A total of 400 Lohman LSL lite 46 weeks old hens were housed in enriched cages equipped with perch, scratch pad, and nest (10 birds per cage). Five diets were allocated (n=8) for 12-week trial. The iso-caloric and -nitrogenous diets were: Control corn and soybean meal-based (C), C+0.25%OP, C+ 0.76%OP, C+0.23%AO, and C+0.69%AO; OP and AO diets supplied similar DHA at each level. Egg production indices (lay rate, FCR, egg weight, eggshell quality) were monitored for ten weeks. One egg/cage was randomly selected on weeks 4, 5, 6, 9, and 12 for fatty acids (FA) analyses, while diet samples were analyzed for FA on weeks 1, 6, and 12. At the end of the trial, one bird/cage was euthanized for breast and thigh samples for FA analyses. The statistical model had the cage as the experimental unit; diet, time, and treatment x time interaction were fixed factors. Tukey's test was used to separate means and significance declared at $P < 0.05$. The ratio n6 to n3 in diets C, C+0.23%OP, C+0.76%OP, C+0.25%AO, and 0.69%AO was 12.0, 6.36, 3.52, 7.10, and 3.45, respectively. There was no difference ($P \geq 0.05$) between C and DHA-fed birds on egg production indices. Diet had effects ($P < 0.01$) on the concentration of DHA in eggs, with OP and AO showing linear and quadratic DHA enrichment ($P \leq 0.01$). The concentration of DHA for the C, C+0.23%OP, C+0.76%OP, C+0.25%AO, and 0.69%AO was 84, 195, 286, 183, and 297 mg/100g of egg, respectively, and both DHA sources had linear and quadratic increases ($P < 0.01$) on egg DHA deposition. There was no interaction ($P = 0.99$) between diet and sampling time point on the enrichment of DHA in eggs. Oil inclusion had linear-quadratic effects ($P < 0.01$) on DHA deposition in breast and thigh tissues. In conclusion, the results showed that enriching hen diets with the two DHA sources increased the concentration of DHA in eggs and tissues.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-034 Effects of stepwise matrix application of a novel consensus bacterial 6-phytase variant on growth performance, bone quality, economic and sustainability benefits in broilers**A. Bello^{2,1}, S. Haldar³, A.E. Ghane⁴, A. de Kreij⁴, Y. Dersjant-Li¹¹Danisco Animal Nutrition & Health, IFF, Oegstgeest, Netherlands, ²Danisco Animal Nutrition & Health, IFF, Wilmington, United States, ³Agrivet Research & Advisory P Ltd, Kolkata, India, ⁴Danisco Animal Nutrition & Health, IFF, Nucleos, Singapore

The drive to further reduce feed cost and improve environmental sustainability in animal food production necessitates the utilization of phytase full potential in broiler production. This study evaluated the stepwise application of a novel consensus bacterial 6-phytase variant's (PhyG) matrix on growth performance, bone quality, and economic and sustainability benefits in broilers from 1-42 d of age. A total of 2,100 Ross 308 male broilers were randomly assigned to 70 floor pens with 30 birds per pen, 10 pens per treatment. The diets were corn-soybean meal-rapeseed meal-based and were fed as crumble during starter phase (1-10 d) and pellet during grower (10-21 d), finisher 1 (21-35 d), and finisher 2 (35-42 d) phases. The 7 dietary treatments were 1) a nutrient and energy adequate positive control (PC); 2) PC reduced in available P by 0.22 % point (p), Ca by 0.23% p, and Na by 0.05% p at each of the 4 phases (NC1); 3) NC1 reduced in ME by 72 - 51 kcal/kg across the 4 phases (NC2); 4) NC2 reduced in digestible AA by up to 0.06% p across the 4 phases (NC3) and diets 5); 6); and 7) were the NC1, NC2, and NC3 respectively supplemented with PhyG at 1,250 FTU/kg (NC1+PhyG, NC2+PhyG and NC3+PhyG). Data were analyzed with JMP 16.1 and means were separated using Tukey HSD test ($P \leq 0.05$ as significant). The 42 d BW was not reduced ($P > 0.05$) by the mineral only reduction in NC1 (2,677 g) but reduced ($P < 0.05$) by the mineral and ME reduction in NC2 (2,598 g) and the minerals, ME, and dig AA reduction in NC3 (2,596 g) vs PC (2,844 g) and these were alleviated by the use of PhyG in NC1+PhyG (2,938 g), NC2+PhyG (2,923 g) and NC3+PhyG (2,893 g). There were no differences between diets on the 1-42 d FCR ($P > 0.05$). Bone ash was reduced ($P < 0.05$) by NC1 (41.1%), NC2 (39.7%), and NC3 (40.1%) vs PC (45.0%) while it was restored by NC1+PhyG (43.7%), NC2+PhyG (43.8%) and NC3+PhyG (44.5%). The estimated 1-42 d feed cost, €/kg BWG reduced ($P < 0.05$) by NC2+PhyG (0.63) and NC3+PhyG (0.62) vs PC (0.67) was intermediate with NC1+PhyG (0.65). Total carbon footprint, g CO₂ eq/kg BWG was reduced by NC3+PhyG (2,518) vs PC (2,706) and intermediate with NC1+PhyG (2,637) and NC2+PhyG (2,580). In conclusion, application of full matrix (minerals plus dig AA and energy matrix) increased production benefit compared to application of mineral matrix only for the novel consensus bacterial 6-phytase variant, which could also improve the sustainability in broiler meat production.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-035 Effects of varying dietary calcium levels on broiler performance, litter quality, and pododermatitis**K. Venter¹, C.R. Angel², P.W. Plumstead¹¹Neuro Livestock Research, Brits, South Africa, ²Department of Animal and Avian Sciences, University of Maryland, MD, United States

Analyzed calcium (Ca) levels in commercial broiler diets often deviate substantially from minimum formulated values. Dietary Ca below or in excess of requirements can impact bone mineralization and broiler performance. Excess Ca has also been shown to increase litter moisture increasing the risk of foot pad dermatitis (FPD). The objective of this study was to evaluate the detrimental effect of over-or under- supplementation of Ca on broiler performance, litter quality, and pododermatitis. Ross 308 straight run broilers were randomly assigned to 5 dietary treatments (Trt) with 12 pens of 70 birds per Trt. Diets were pelleted and formulated as typical South African corn soybean-based diets, fed in 4 phases (pre-starter (PS), 1-7 d; starter (S), 8-16 d; grower (G), 17-22 d and finisher (F), 23-32 d). The same digestible P was used in all Trt by phase. Diet Ca varied by Trt as follows: low Ca (LCa), medium-low Ca (MLCa), commercial Ca (CCa), medium-high Ca (MHCa), high Ca (HCa) with concentrations of 0.71%, 0.82%, 0.94%, 1.19% and 1.49% in PS, 0.67%, 0.77%, 0.87%, 1.07%, 1.39% in S, 0.64%, 0.74%, 0.84%, 0.99% and 1.29 in G, 0.64%, 0.69%, 0.74%, 0.94%, and 1.19% in F, respectively. Litter samples were taken at 32 d to determine the moisture content. Broiler body weight (BW) and feed intake (FI) were determined on d 7, 16, 22 and 32 and feed conversion ratio (FCR calculated). Hock and foot pad scoring were evaluated at 32 d using a 5-point and 3-point scoring system, respectively. Data were analyzed using JMP Pro 16.0 (SAS, Institute, Cary, NC) using a one-way ANOVA and means separated [protected Tukey HSD ($P \leq 0.05$ as significant)]. Categorical data were analyzed using a Rao-Scott chi-square (Lavassani et al., 2009). Broilers fed diets containing Ca below (LCa, MLCa) and above (MHCa, HCa) the CCa Trt had reduced performance ($P < 0.05$) at 32 d BW (2015.3, 2022.1, 2014.1 & 1859.0 vs. 2074.9g, respectively) and FCR (1.42, 1.41, 1.40 & 1.44 vs. 1.38, respectively). There was a stepwise increase in litter moisture starting with litter from broilers fed LCa (48.6%) diet and ending with those fed the HCa diet (55.9%). Birds fed the LCa Trt had the best ($P < 0.05$) paw and hock score, and there was a reduction (worse) in paw score as the Ca level increased. In conclusion, the excess or inadequate supplementation of Ca in commercial broiler diets can detrimentally impact broiler performance, litter quality, and bird welfare.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-036** Egg production parameters, microbiome modulation and environmental benefits of using a precision biotic in laying hensM. Umar Faruk¹, P. Segobola¹, E. Amaya¹, B. Blokker¹, M. Segura-Wang¹, M.I. Lorenzo²¹DSM Nutritional Products AG, Kaiseraugst, Switzerland, ²Imasde Agroalimentaria, S.L. , Madrid, Spain

The efficacy of a novel precision biotic (Symphiome™) on zootechnical performance, microbiome metabolism and environmental impact in laying hens was evaluated. 210 Isa Brown laying hens were allocated to one of the two treatments and replicated with 21 cages, each containing 5 hens in an environmentally controlled room. The basal diet is a corn, wheat, soybean meal, contained 16% crude protein, 2767 kcal/kg ME was fed to the control group (T1) or supplemented with Symphiome™ at 900 g/ton (T2). Experimental diets and water are offered ad-libitum from 22 to 42 weeks of hen age. Initial and terminal body weight (BW) were recorded. Every 28 days interval, feed intake (FI), hen-day egg production (EP), and egg weight (EW) were recorded. Egg mass and feed conversion ratio were calculated. At the end of the study, caecum and ileum contents were collected for metagenomic sequencing to analyze the functional potential of the microbiome. Shifts in the functional profiles were assessed using a Local Fisher discriminant analysis, and pathway importance was assessed using a random forest classifier for treatment group. Animal Production System tool (APS) was used to assess environmental impact of this study according to the methodology in the FAO LEAP (2016), IPCC (2006) & EMEP/EEA (2016). Performance data was subjected to a student t-test. T2 significantly increased the terminal BW (1.879 g vs 1.825 g), increased hen-day egg production (95% vs 90.9%), egg mass (58.5 g vs 55g), and feed conversion ratio (2.15 vs 2.27) compared to T1. Egg size was higher with T2 resulting to increase in the percentage of XL eggs (3.7% vs 0.2%). In the cecum, T2 modulated pathways involved in amino acid fermentation and carbon metabolism, particularly lysine, arginine, biotin, and pyruvate. Pyruvate metabolism pathway, play a key role on the energy metabolism. In the ileum, T1 significant modulated the functional profiles associated with fatty acid degradation and several amino acid metabolism pathways. Results from APS showed an average of 2 % reduction across the different environmental impact categories with the T1 supplemented group. It is concluded that Symphiome™ supplementation at the rate of 900 g/ton of feed improved egg production parameters in laying hens, induces a beneficial shift in the microbial metabolism both in the cecum and in the ileum and thus, constitutes an opportunity to increase the productivity and sustainability of egg production industry.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-037** Evaluating the effects of diet type, diet non-phytate phosphorus level, and storage length on egg quality of white egg laying hensA. Pescatore¹, G. Perrin¹, M. Jones¹, D. Gillespie¹, M. Ford¹, S. Adedokun¹¹Department of Animal and Food Sciences, University of Kentucky, Lexington, KY, United States

The objective of this study was to investigate the influence of diet type (corn-soybean meal- vs. corn-wheat-soybean meal-based diets), dietary non-phytate phosphorus (nPP) level (90, 100, or 110% of requirement), and length of storage (unstored, day 0 vs. stored, day 45) on egg quality. This study was conducted using 504 white laying hens in a randomized complete block design with location as the blocking factor. Each treatment was replicated seven times with 12 birds per replicate. Birds received stimulatory light at 16 wk of age. The six dietary treatments were fed from 12-40 weeks of age with nutrient and energy adjusted for age or production phase. Two sets of eggs were collected at the end of week 24 of lay (week 40 of age). One set was analyzed on day 0 and the other set was weighed and stored at 4°C before analysis on day 45. Measured egg quality parameters included yolk, albumen, and eggshell weight, egg breaking strength, yolk color, albumen height, and Haugh unit while yolk, albumen, and eggshell percentages were calculated. Data were analyzed using Proc GLM of SAS appropriate for the factorial arrangement of treatments (2 x 2 x 3). Birds fed corn-wheat-SBM-based diets produced bigger (P < 0.05) eggs and neither diet type nor nPP level influenced moisture loss (~1.3%) from eggs during storage. Percent yolk was higher (P < 0.05) in stored eggs irrespective of the diet type or nPP levels while percent eggshell was not influenced by diet type, nPP level, or length of storage. The relative proportion of the egg albumen, albumen height, and Haugh unit decreased (P < 0.05) with storage while the albumen height was higher (5.5%; P < 0.05) in birds fed corn-wheat-SBM-based diet. Eggshell breaking strength was higher (P < 0.05) in birds fed a corn-wheat-SBM-based diet while interactions between diet type and nPP level showed that the corn-wheat-SBM-based diet containing 90% of nPP resulted in higher (P < 0.05) eggshell breakings strength compared to eggshell from birds fed corn-SBM-based diet containing 90 or 100% of nPP. Results from this study showed that reducing the level of nPP by 10% did not result in any negative effect on egg quality while the replacement of 50% of corn with wheat in the corn-SBM-based diet resulted in stronger eggshell and albumen height and a tendency for higher Haugh unit value. Storing eggs for 45 days resulted in higher yolk percentage, lower albumen percentage, lower albumen height, and Haugh unit value.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-038** Evaluating the link between microbial biomarkers and performance in broiler field trials evaluating gut health additivesT. Goossens¹¹Adisseo, Dendermonde, Belgium

Gut health promoting feed additives are widely used to support animal growth and performance. In this study, we wanted to further explore their effect in broilers, linking biomarker analysis in the grower period with performance at the end of the cycle, under commercial conditions. On a commercial farm, Cobb 500 birds were given a standard commercial feed (4 houses), or a feed with a coated butyrate from day 1 to 21 and a phytogenic product from day 22 to 43 (3 houses). Performance was measured over 3 consecutive cycles. Additionally, in cycle 2 and 3, necropsy and gut microbial analyses were performed on 5 birds per house around day 24. Data were evaluated using a t-test (performance and microbiota data) or χ^2 -test (necropsy), with a statistical significance level of 0.05. At the end of the trial, treated broilers were heavier than the control birds ($p < 0.05$). However, at the end of the grower period, these differences were not apparent yet. In cycle 2, necropsy results were also not distinctive, but analysis of gut microbial composition showed a selective effect of the coated butyrate supplementation. In the ileum, the relative abundance of *Lactobacillus* spp., such as *L. crispatus*, was increased ($p < 0.05$), while the level of potential pathogenic bacteria was reduced (*Enterococcus*, *E. coli*, $p < 0.05$). In the caeca, the number of butyrate-producing Ruminococcaceae and Lachnospiraceae was elevated in the treated group. In cycle 3, health of the young chicks was suboptimal, as also suggested by the observation of unabsorbed yolk sacs in $> 20\%$ of birds at the end of the grower period. In addition, blood petechiae and excessive mucus were detected in the control group, but less often in the treated group ($p < 0.05$). Treated birds also had higher levels of caecal butyrate ($p < 0.05$). This experiment provided evidence for the performance enhancing effect of the additives under evaluation. Importantly, while differences in live weight could not yet be detected around day 21, microbial analysis indicated that shifts in intestinal microbial ecology had already taken place in the treated broilers, preceding their significantly higher weight gain by the end of the production cycle. Further studying the link between biomarker analysis with performance will be crucial to gain insight in what additives do, when, and under which circumstances. Such knowledge will be crucial to apply the right additive, at the right time, according to specific production conditions.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-039** Evaluation of the dietary administration of a thermo-mechanical and enzyme-facilitated processed soybean meal on growth performance and ceca microbiota of broiler chickensM. Zampiga¹, L. Blavi², M. Karimi³, F. Sirri¹

¹Department of Agricultural and Food Sciences, Alma Mater Studiorum - University of Bologna, Bologna, Italy, ²AB Neo, PL Fraga, C/ Comunidad de Murcia, parc. LIE-1-03, 22520 Fraga (Huesca), Spain, ³AB Neo a/s, Skjernvej 42, 6920 Videbaek, Denmark

This study aimed to investigate the effects of the dietary administration of a thermo-mechanical and enzyme-facilitated processed soybean meal (TES) on growth performance and ceca microbiota composition of broiler chickens. A total of 360-day-old male Ross 308 chicks were distributed into three experimental groups (30 birds per pen, 4 pens/treatment). Treatments were a control corn-soybean meal (SBM) diet (CON group; with fish meal until 22 d), and 2 experimental diets in which the TES was included in partial replacement for SBM and fish meal: T22, in which TES was included at 10 and 5% during the starter (0-9 d) and grower phase (10-22 d), respectively, and T41, where TES was provided at 10% during the starter phase and 5% until 41 d. Body weight (BW), daily weight gain (DWG), daily feed intake (DFI), feed conversion ratio (FCR), BW uniformity, and mortality were calculated. At 9 and 22 d, ceca content was collected from 12 birds/treatment and subjected to 16S RNA sequencing. For the statistical analysis, data from T22 and T41 groups at 9 and 22 d were merged (identified as TRT group) as both received the same dietary treatment up to 22 d. At 9 d, TRT birds showed higher BW and DWG compared to CON (225 vs. 198 g and 20.3 vs. 17.4 g/bird/d, respectively; $P < 0.001$), resulting in lower FCR (1.250 vs. 1.553, respectively for TRT and CON group; $P < 0.001$). TRT group achieved higher BW than CON at 22 d (886 vs. 790 g, respectively; $P < 0.01$) along with greater DWG and lower FCR from 10 to 22 d (50.5 vs. 45.5 g/bird/d and 1.349 vs. 1.492, respectively; $P < 0.01$). No significant difference was observed on DFI and mortality. At 9 and 22 d, BW uniformity was improved in TRT group ($P < 0.05$). In the overall trial period (0 - 41 d), T22 and T41 treatments performed similarly and both out-performed CON group for DWG and FCR. As for microbiota results, the dietary administration of TES modified the ceca microbiota composition compared to CON (β -diversity; $P < 0.05$), promoting the growth of some beneficial bacteria (e.g. Lachnospiraceae family at 9 d; *Lactobacillus vaginalis* at 9 and 22 d; $P < 0.05$). Overall, although all groups performed below the expectations for the selected genotype, the dietary administration of a thermo-mechanical and enzyme-facilitated processed soybean meal had positive effects on productive performance and modified the ceca microbiota composition of broiler chickens.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-040** Evaluation of the effect of a natural antimicrobial in feed for laying hens on the productive performance and egg qualityE. Maguregui¹, D. Díez¹, A. Tesouro¹, M. Soriano¹, C. Gallardo²¹Biovet S.A., Constantí, Spain, ²Universidad Científica del Sur, Lima, Peru

AIM Microbial challenges may disrupt the balance of gut microbiota and the performance. Alquer mold Natural (AMN) is a natural antimicrobial based on cimenol ring (plant origin), which can alter the stability of the cell membrane and cause the death of a wide range of bacteria and fungi. METHODS An experiment was conducted in 2020 in laying hens to determine the efficacy of AMN to improve performance through the control of enteric pathogens, compared to organic acids (OA) and formaldehyde (FO). A total of 224 Dekalb Brown were distributed following a completely randomized design into 4 groups with 8 replicates each. Pen served as experimental unit. Trial began with 15-week-old birds and lasted for 14 weeks, including 3 weeks of rearing and 11 of laying, ending with 29-week-old hens. All groups received the same basal diet, with the following products administered continuously throughout the trial: control group without additional products, a group with AMN at 0.5 kg/t, a group with a blend of OA at 1 kg/t, and a group with 33% FO at 2 kg/t. Performance was evaluated weekly. Data was analysed with ANOVA and $P < 0.05$ was set as statistically significant. RESULTS AMN obtained numerically better results in homogeneity during rearing. In week 17, weekly weight gain (WG) and feed conversion rate (FCR) were significantly improved in all treatments compared to control, being AMN the group with best WG and FCR ($P < 0.05$). In the laying period, AMN achieved significantly higher laying rate ($P < 0.05$), and significantly lower FCR ($P < 0.05$) compared to control and FO. Compared to OA, AMN accomplished significantly better results for those parameters most weeks ($P < 0.05$), while the other weeks still reached numerically better results. Moreover, AMN significantly improved egg quality, obtaining lower dirty eggs rate and higher egg weight ($P < 0.05$) than the other groups. No significant differences were observed in mortality. CONCLUSIONS AMN significantly improved productive performance and egg quality in laying hens in the rearing and laying phase, probably due to the positive impact of AMN on gut health. OA obtained the second-best results, likely linked to its narrower spectrum of action, while FO seemed to exert a negative impact on performance, probably due to its irritant effect. These findings may be related to the fact that AMN offers a wider spectrum of action than OA, and its non-irritant nature avoids damaging the gut mucosa, as it may occur with formaldehyde.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-041** Expression of glucose transporters in the jejunum of free-range chickens fed cupuassu seed meal in the dietE.F. Alves da Silva¹, M.R. Brito dos Santos¹, A.V. de Sousa², C.J. Bruno de Oliveira¹, P.E. Naves Givisiez¹, A.L. de Barros Moreira Filho²¹Departament of Animal Science, College for Agricultural Sciences, Federal University of Paraíba (CCA/UFPB), Areia-PB, 58397-000, Brazil, ²Department of Animal Science/CCHSA, Federal University of Paraíba, Bananeiras, PB, Brazil

This study assessed the effects of diets containing levels of cupuassu seed meal (CSM) on the relative mRNA expression of intestinal nutrient transporters in free-range chickens at 42 days of age. Cupuassu seed meal is produced from the organic waste generated by cupuassu processing plants in the Amazonian region in Brazil. Free-range chicks ($n=120$) were distributed in two treatments with five replicates of 12 animals (mean weight 40.5g). CSM (CP: 8.6%; EE: 48.5%, CF: 27.8%) was used at 0 or 7% CSM replacing corn in diets with equal CP, ME, Ca, P, Na, Lys and Met. At 42 days, jejunum samples were collected from five birds per treatment. Total RNA was extracted (Qiagen RNeasy) and cDNA was synthesized (AffinityScript qPCR cDNA Synthesis, Agilent Technologies). qPCR was carried out in a StepOnePlus™ Real-Time PCR System (Applied Biosystems) and Brilliant III Ultra-Fast SYBR master mix (Agilent Technologies). Relative mRNA gene expression of sodium-dependent glucose transporter 1 (SGLT1) and glucose transporter 2 (GLUT2) was calculated by the method $2^{-\Delta\Delta Ct}$ (Livak and Schmittgen, 2001) using GAPDH as reference gene. Data were subjected to analysis of variance and means compared by Dunnett's test using R software. The relative expression of SGLT1 was not different in birds fed 0 and 7% cupuassu seed meal at 42 days of age (1.723 vs 1.176, respectively), but GLUT2 expression was downregulated (1.65 vs 1.07, respectively). According to Ferraris et al. (2001), higher fiber levels in the diet can reduce glucose and carbohydrate concentration in the intestinal lumen and reduce glucose transportation as well. Changes in cell renewal processes with increased loss of mature enterocytes from the intestinal villi, as well as microbiota modulation and metabolites produced may be related to changes in the intestinal absorption of glucose and expression of GLUT2 mRNA. Cupuassu seed meal at levels up to 7% can be included in the diet of free-range birds without affecting the expression of intestinal sodium-dependent glucose transporter 1 (SGLT1). Actual inclusion of this ingredient in poultry diets must be further assessed by performance data and net economic return evaluation. Funding: Fundação de Amparo ao Desenvolvimento das Ações Científicas e Tecnológicas e à Pesquisa de Rondônia (FAPERO) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior/CAPES (Finance code 001 and Print grant #88881.311776/2018-01)

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-042 Feeding low protein diets with reduced soybean meal inclusion in laying hens**J. van Harn¹, A. Rezaei Far¹, J. Phuc², C. Veiga²¹Wageningen Livestock Research, Wageningen, Netherlands, ²De Heus Animal Nutrition B.V., Ede, Netherlands

Providing laying hens diets with a reduced level of crude protein (CP), supplemented with free amino acids (AA) to meet the AA requirements, can help reducing the soybean meal inclusion, as imported protein source of non-EU origin. An experiment was performed with laying hens aged between 39-51 weeks in which the effects of lowering dietary the CP content from 16.1% to 14.7%, 13.5% and 12.0% on laying performance, egg quality, carbon footprint and manure composition were studied. All diets were formulated to be iso-energetic and to meet the requirements for all commercially available essential AA (Lys, M+C, Thr, Trp, Ile, Arg and Val). Each treatment was replicated six times and each replicate consisted of a block of 20 cages with 6 birds per cage. Reducing the dietary CP content from 16.1 to 14.7% resulted in comparable laying performance. Further lowering of the dietary CP content deteriorated the performance results. Laying hens fed the 12.0% CP diet had a significantly higher rate of 2nd-grade eggs compared to the other treatments. There was a negative linear relationship between the CP content of the diets and the egg weight, and albumen content of eggs. The calculated carbon footprint of the diets linearly increased with the decline of the CP content. The moisture and nitrogen content of the manure declined gradually by reducing the CP content of diets, while there was no effect on the ammonium-N content of excreta.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-043 Global warming potential of broiler diets with strongly reduced crude protein, soybean meal and energy levels**H. Enting¹, W. Lambert², J. Le Cour Grandmaison², A. Amerah¹¹CARGILL ANIMAL NUTRITION, Velddriel, Netherlands, ²METEX ANIMAL NUTRITION, Paris, France

The impact of new nutritional strategies for broilers with strongly reduced crude protein (CP), soybean meal (SBM) and reduced energy levels on performance is yet to be explored, as is the potential effect on global warming potential (GWP). An experiment with 6 dietary treatments with 6 pens per treatment was performed with 324 Ross 308 male broilers from 14 to 34 days of age, with a common starter diet fed from 0 to 14 days. Experimental diets were T1 = control at 20.6% CP, 2,875 kcal/kg AMEn and 24% of SBM; T2 = 18.6% CP & 0%-SBM; T3 = 16.6% CP & 0%-SBM with addition of L-His, L-Leu, L-Phe, L-Cys and Gly to the level of the control treatment; T4 = T3 with removal of L-His, L-Leu, L-Phe, L-Cys and Gly; T5 = T3 with a decrease of energy by 50 kcal/kg and T6 = T3 with a decrease of energy by 100 kcal/kg. The SBM was replaced by a combination of rapeseed meal and sunflower meal. Average daily feed intake (ADFI), average daily gain (ADG), feed conversion ratio (FCR), final body weight (BWf) were measured with an average BWf and 14-35d FCR for T1 of 2.64kg and 1.48, respectively. Average GWP was calculated using GFLI 2022 for macro-ingredients and Agribalyse 3.1 for micro-ingredients and feed-grade L-AA. Two scenarios were used for the origin of AA: AA from China or AA from Europe as their GWP impacts differ between the two origins. GWP of broilers was calculated using the performance and the GWP of the starter feed (0-14d), the performance data of the experimental period (14-35d) and was calculated per broiler (GWPb) and per kg (GWPkg) for the full 0-35 period. Statistical interaction was tested between treatment and AA origin by a 2-way ANOVA. ADG and BWf were significantly lower in T4 compared to T1 (-12g of ADG and -252g of BWf) and FCR was significantly higher in T4 compared to T1 (+0.08 FCR). Reduction of energy by 100kcal (T6) showed a similar BWf than T1 but significantly increased FCR (+0.05). There was a significant interaction for both GWPb and GWPkg between treatment and AA origin. Decreasing soybean meal and protein (from T1 to T4) significantly reduced GWP of broilers by 43% with European AA (from 2.1 to 1.2kgCO₂eq/kg) but only by 28% with Chinese AA (from 2.1 to 1.5kg CO₂eq/kg). The study demonstrated that a reduction of dietary CP by 2 or 4%pts from 20.6 to 16.6% together with a removal of SBM did not affect growth performance. The benefit of such strategy on GWP of broilers was positive but stronger when using European produced AA.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-044 Hydroxy trace minerals with an increased bioavailability as a more sustainable broiler production strategy**A. De Grande¹, S. Leleu¹, E. Delezie¹, A. Van der Aa², M. Brink², L. Vande Maele²¹Institute for Agricultural, Fisheries and Food Research, 9090 Melle, Belgium, ²Orffa Additives BV, Minervum 7032, 4817 ZL Breda, Netherlands

Supplementation of TM with a higher bioavailability compared to traditional inorganic sources (oxides and sulphates), is important to meet the needs of fast-growing broilers, while complying with legal limited levels. These limits have been set to avoid high mineral excretion into the environment. By using TM with higher bioavailability and absorption, lower inclusion levels can be used and consequently the excretion is reduced. In order to evaluate the difference in bioavailability between traditional inorganic TM (sulphates) and hydroxy TM (Excential Smart, Orffa), a digestibility study was conducted at ILVO (EU-reference method). One-day old Ross 308 broilers were initially housed in floor pens and fed experimental starter diets ad libitum. In order to create a nutritional challenge wheat-rye based diets, without addition of NSP enzymes was used. The basal diet was supplemented with 7.5 mg/kg Cu, 45 mg/kg Zn, and 45 mg/kg Mn, either as sulphates, or as hydroxy TM (n=6). A non-supplemented control group was also incorporated as a negative control (NC, n=6). At 10 days of age, birds were moved to digestibility units (6 units/treatment and 3 birds/unit) and a 4-day period of adaptation to experimental grower diets was included followed by a 4-day balance period. Feed intake (FI), total excreta (E) and digestibility of the main nutrients and TM were determined. All digestibility parameters were analyzed using a linear mixed model (R version 3.5.1), with treatment as a fixed factor and Tukey HSD test as post hoc test. Results show a trend towards a higher digestibility of fat and ash when hydroxy TM were supplemented compared to sulphates, which indicates a more efficient usage of feed ingredients by the broilers. The digestibility of Mn significantly improved when it was added as a hydroxy TM compared to the sulphate and NC treatment groups (18.4%, 3.8% and 7.6%, respectively). Cu digestibility was not significantly impacted. Surprisingly Zn digestibility had a high variation and was significantly the lowest for hydroxy TM, this could not be attributed to a higher deposition of Zn during starting phase in bone or tissues. The used method is not corrected for endogenous losses, which might provide an explanation, this opens prospects for further research. To conclude, this study shows an increased digestibility for hydroxy Mn, which attributes to an increased bioavailability and reduced excretion, which fits in a more sustainable broiler production strategy.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-045 Impact of crude protein reduction in broiler feed on sustainability impact factors**A. Lemme¹, K. Fenske², H. Westendarp², M. Guhe³, E. Rother¹¹EVONIK Operations GmbH, Hanau, Germany, ²University of Applied Sciences Osnabrueck, Osnabrueck, Germany, ³RAIFFEISEN Ems-Vechte, Klein-Berßen, Germany

Dietary crude protein (CP) reduction is a powerful strategy for reducing nitrogen emissions. Further sustainability impact factors might be affected as well. Therefore, CP reduction in broiler feed has been examined under commercial conditions. The environmental footprint was evaluated allowing for a life cycle analysis estimate. A broiler complex with 10 houses with 41,000 mixed sex broilers (Ross 308) each was used. Chicken were cropped at days 29 (23% of birds), 34 (17%) and 41/42. Five houses received standard feeds in a 4-phase feeding program (diet changes at days 10, 19 and 25). Five houses received CP reduced diets and in this treatment a finisher 2 diet was introduced which was blended with finisher 1 at daily changing proportions. Analysed CP in standard starter, grower 1, grower 2 and finisher diets was 22.3, 21.2, 20.9, and 19.1% whereas experimental grower 1, grower 2, finisher 1 and finisher 2 diets contained 19.6, 19.4, 18.7 and 17.5% CP. Specified amino acid levels were confirmed by analysis. Feed consumption was recorded per house and phase. Final body weights of broilers per harvest and house were received from the slaughterhouse. Nitrogen utilization and excretion were calculated based on feed analyses and the assumption of 30g N/kg broiler liveweight. Data were analysed by t-test. Production and feed details were used for calculating the environmental footprint per ton of carcass. Final average (across all crops) body weight was 2278 and 2372 g/bird in standard and CP reduced treatments (P<0.05). The respective feed conversion ratio was 1.54 and 1.52 kg/kg. Protein reduction allowed to increase N-utilization from 61.4 to 65.0% (P<0.05) while reducing N-excretions by 11% from 1681 to 1497 kg/barn (P<0.05). Global warming potential (kg CO₂ equivalents per t carcass) was reduced by 8.7% (P<0.01) which is mainly explained by feed ingredients. Land use (soil quality index) was reduced by 5.2% (P<0.05) mainly due to changes in feed composition. Acidification potential (H⁺-equivalents) and terrestrial eutrophication potential (mol N equivalents) were reduced by 7.8% and 8.3% (both P<0.05), respectively, which can almost completely be assigned to ammonia emissions. Water use (ccm equivalents) was not affected. This trial indicates that an average CP reduction by 1.1% in broiler feed reduces N-emissions considerably and improves, thereby, the ecological footprint of broiler production.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-046 Impact of dietary phosphorus supply on laying hen performance and on body, bone and eggshell mineral density**L. Léonard¹, F. Hervé^{2,1}, R. Angel³, A. Narcy², M. Létourneau Montminy¹¹Laval University, Quebec, Canada, ²INRAE UMR BOA, Nouzilly, France, ³University Maryland, College Park, United States

Phosphorus (P) is an essential nutrient for laying hens but its excretion in the environment can be deleterious when applied more than crop needs. Because plant P is poorly available for the animal, phosphate, a non-renewable and expensive resource, is added to the diet. Therefore, a precise assessment of P requirement in laying hens is crucial for sustainability. The aim of the current study was to obtain data of body composition to precise requirements through the production period and to evaluate the impact of P supply on laying performance, body composition, bone mineralization and eggshell mineral density. A total of 198 Lohmann LSC laying hens were assigned to one of the 2 diets for 58 weeks (from 19- to 75-week-of age) and raised in cage of three birds (33 replicates/treatment). The control diet was formulated according to the breeder recommendations with available P (avP) that varied from 0.4 to 0.36% and Ca from 0.39 to 0.43%, while the low P diet has 25% less avP. Seven feeding phases with a gradual decrease of crude protein and lysine as well as an increased of coarse limestone proportion were used. Every 4 weeks, 3 laying hens (1 cage) per treatment were slaughtered and scanned with Dual-X-Ray (DXA) to obtain body composition, mineral content (MC) and mineral density (MD). Every week, 20 eggs were also scanned to obtained eggshell MC and MD. Tibia, humerus and keel bone were dissected and scanned with DXA. Additionally, performance (egg production, feed intake, and egg and body weights) were measured every week per cage. There was no effect of lowering P on production performance. Through a quadratic evolution ($P < 0.001$), egg mass and laying hens' weight reach their maximum at 45 (62,8 g) and 53 (1,80 kg) weeks of age respectively. Eggs, body and bones mineralization were not different between the control and the low P group. Tibia, humerus, and keel bone mineralization were not impacted by the treatment. While tibia and humerus BMD remained stable from 22 to 74 week of age, keel bone mineralization increased from 0.05 g/cm² to 0.15 g/cm² ($P < 0.001$). In sum, it appears that a reduction of avP by 25% through the laying period did not impair bone and eggshell quality and hens' performances were still in line with the market recommendations. The integration of these data will be useful to develop a mechanistic model able to predict P requirements in laying hen.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-047 Impact of dietary sodium diformate on broiler performance - a meta-analysis**C. Lückstädt¹¹ADDCON, Bitterfeld-Wolfen, Germany

Organic acids are considered one of the most promising tools for antibiotic reduction strategies, as in addition to their antimicrobial property, organic acids provide many extra benefits such as improving the intestinal health, optimising the intestinal pH and thereby improving nutrient digestibility. Formic acid is especially noteworthy for its antibacterial impact. An important limitation, however, is that organic acids, including formic acid, are rapidly metabolised in the foregut (crop to gizzard) of birds, which will reduce their impact on growth performance. As such, the use of a double sodium salt of formic acid has become more prevalent in poultry diets, as it has been proven to be effective against pathogenic bacteria along the whole gastro-intestinal tract. Dietary sodium diformate (Formi NDF, ADDCON - hereafter abbreviated as NDF) has been widely used in poultry production since more than 15 years and numerous publications and conference contributions on its use in broilers have been published. This study analyzed the average impact from all documented broiler studies on the effect of the additive on the performance parameters weight gain, feed conversion ratio (FCR), mortality and productivity (European Broiler Index, EBI). The final dataset contained the results of 28 trials with NDF inclusion (0.1% - 0.6%), carried out world-wide. The total number of broilers in both scientific and commercial trials was more than 1.75 million. Results are expressed as percentage difference from the negative control. The average level of dietary NDF inclusion from the dataset was 0.23%. Only a tendency of an increased feed intake (1.3%) was observed ($P < 0.1$). However, the performance of broilers based on daily weight gain was highly significantly increased by 4.6% ($P < 0.0001$). Furthermore, the FCR was also significantly improved (3.3% lower; $P < 0.001$). Survival was increased on average by 2.5% ($P < 0.01$). Finally, the EBI also improved highly significantly due to the inclusion of NDF by 11.1% ($P < 0.0001$). It is concluded that dietary sodium diformate (Formi NDF) is an effective and sustainable tool to enhance broiler performance under a wide range of production conditions.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-048 Impact of different feed vitamin levels on broiler health and performance**J. Hernandez¹¹DSM Nutritional Products, Kaiseraugst, Switzerland

Vitamins are irreplaceable micro-ingredients in feed. The objective of this study was to evaluate the impact of 2 vitamin levels on performance, bone development and antioxidant status in broiler feed. 936 one day old male Ross 308 broilers allocated at random to 36 floor-pens; 26 chickens per pen and 18 pens (replicates) per treatment. Experimental groups: T1, industry vitamin levels in Spain (DSM 2022) vs T2, 2022 OVN® (Optimum Vitamin Nutrition) broiler guidelines. Corn/wheat/barley/soybean meal diet with three phase mash feeds (1-14 days; 15-28 days; 29-42 days) all with phytase and antibiotic-free. Statistical analysis and interpretation: Analysis of Variance (ANOVA). Data were analysed as a completely randomised block design by GLM of SPSS v. 28.0. Body weight, weight gain, feed intake, and feed efficiency at 1, 28 and 42 days. General health, medical treatment and mortality were evaluated daily. Vitamin E content in blood at 28 and 42 days and GPx at 14 and 42 days were measured in 2 broilers/pen. Tibia bone strength at 28 and 42 days and breast meat MDA at 0, 3 and 6d after defrosting were also evaluated in those birds. At 28 days of age, T2 (OVN) broilers showed a significant increment ($p < 0.0001$) in body weight (100 grams) and average daily gain (3.7 g/d) and feed intake (5.4 g/d; $p = 0.002$) with a lower bird mortality (-1.5 percent units; $p = 0.0378$). During the 0-42-day period, OVN levels significantly decreased mortality (0.4% OVN vs 2.4% in T1; $p = 0.0077$) with a higher daily feed intake (3.2 g; $p = 0.0174$) and a near-significant better daily gain (1.4 g; 0.0654). Tibia diameter ($p = 0.0032$) and breaking strength ($p = 0.0073$) significantly increased at 28 days in OVN diet. No significant differences were observed at 42 days. Plasma vitamin E levels at 28 ($p = 0.0006$) and 42 days ($p < 0.0001$) and glutathione peroxidase (GPx) at 42 days of age ($p = 0.0214$) were significantly increased with OVN diets. Breast meat oxidation (MDA) significantly decreased at 3 ($p = 0.0006$) and 6 days ($p = 0.0002$) after defrosting in OVN treatment. OVN broiler diet significantly improved zootechnical performance during the 0-42d fattening period by reducing mortality and increasing weight gain and feed intake, the antioxidant status of animals by increasing blood vitamin E at 28 and 42 days and plasma GPx at 42 days of age and meat quality and oxidative stability of breast meat after 3-6 days of defrosting Key words: vitamins, broilers, performance, health, antioxidant.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-049 Impact of graded levels of exogenous xylanase in wheat-soy diet on growth performance, energy utilisation and nutrient digestibility of young broilers**V. Pirgozliev¹, S. Mansbridge¹, I. Whiting¹, A. Jozwik², K. Kljak³, A. Atanasov^{4,2}, S. Rose¹

¹The National Institute of Poultry Husbandry, Harper Adams University, Shropshire, TF10 8NB, UK, ²Institute of Genetics and Animal Biotechnology of the Polish Academy of Sciences, 05-552 Magdalenka, Poland, ³Department of Animal Nutrition, Faculty of Agriculture, University of Zagreb, Croatia, ⁴Ludwig Boltzmann Institute for Digital Health and Patient Safety, Medical University of Vienna, 1090 Vienna, Austria

Commercial applications of xylanase enzymes are commonly added to poultry diets for improved performance and intestinal health. However, there is contradictory evidence on the impact of graded levels of exogenous xylanase on broiler growth performance, dietary available energy and nutrient digestibility. Some authors reported an improved growth performance and nutrient availability in broilers fed graded levels of xylanase, others did not observe any impact or even reported a negative influence. This experiment evaluated the effects of feeding graded levels of endo-1,4-beta-xylanase (XYL) produced by *Aspergillus oryzae* (Ronozyme WX, DSM, Switzerland) at 0, 200, 400, 600 and 800 FXU/kg in a wheat-soy-based diet containing 206 g/kg CP and 12.67 MJ/kg ME (approximately 100 kcal lower than breeder's recommendations; negative control (NC)). An unsupplemented positive control (PC) diet formulated to contain 210 g/kg CP and 13.15 MJ/kg was also used in the study, resulting in six diets in total. Each diet was fed to male Ross 308 broilers from 7 to 21d age, in 8 pens (2 birds each) per treatment group, following randomisation. Growth performance of chickens, including daily feed intake (FI), weight gain (WG) and feed conversion ratio (FCR) were measured. Dietary N-corrected apparent metabolisable energy (AMEn), total tract coefficients of dry matter (DMD), nitrogen (ND), fat (FD) and neutral detergent fibres (NDFD) digestibility were also determined. Data were analysed by ANOVA followed by Duncan's multiple range test. Polynomial contrasts were also performed to test for linear and quadratic relationships between XYL dose and the variables. There were no differences ($P > 0.05$) in FI and WG, although birds fed PC had better FCR compared to NC fed birds ($P < 0.05$). The PC had higher AMEn and DMD compared to NC ($P < 0.05$). No difference in NDFD between NC and PC was detected ($P > 0.05$). There was a curvilinear ($P < 0.05$) relationship between AMEn, DMD and NDFD and XYL dietary levels. Overall, the diet supplemented with 600 FXU had 5.3%, 5.0% and 51.5% improvement on AMEn, DMD and NDFD, respectively, compared with the NC. However, at 21 d of age, feeding graded levels of XYL did not appear to influence the growth performance of the birds.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-050 Impact of low phosphorus levels on broiler chickens' growth performance and bone mineralization at two calcium to phosphorus ratios**M. Mireaux¹, F. Richard², C. Hamelin², K. Bebin²¹Deltavit, Janzé, France, ²CCPA, Janzé, France

Phosphate incorporation in animal diets need to be reduced for environmental and economic reasons but also because supply is limited. The objective of this study was to evaluate the response of broiler chickens to phosphate reduction at two different calcium (Ca) to phosphorus ratios. A total of 240 male day-old Ross 308 broiler chickens were randomly assigned to 5 groups with 12 replicate cages of 4 broilers each. The design was an incomplete factorial design with two Ca to available phosphorus (aP) ratios: 2.1 (R2.1) and 1.8 (R1.8) and high or low doses of aP, plus an intermediate level for the 2.1 ratio. In the starter (0-10), grower (10-21), finisher 1 (21-28) and 2 (28-35 days) diets, aP levels were: 4.8, 4.0, 3.4 and 3.0 g/kg for the high levels and 4.0, 3.2, 2.5 and 2.5 for the low levels. The intermediate levels were: 4.4, 3.6, 3.0 and 2.5 g/kg. Birds had unrestricted access to feed and water. At 35 days of age, 12 birds per group were euthanized, left tibias excised, and tibia parameters (weight, length, diameter, breaking strength, stiffness, ash in grams per bone and percentage of ash, Ca and P) measured. Significant interaction between aP level and Ca to aP ratio was often observed: on body weight (BW), Average Daily Gain (ADG), Average Daily Feed Intake (ADFI) and Feed Conversion Ratio (FCR) in starter, on BW in grower, and on FCR in finisher 2. Globally, decreasing aP level had negative effect at R1.8 (significant for FCR: 1.5 ± 0.02 vs. 1.47 ± 0.02 , $P=0.002$) but no or little effect at R2.1 on BW (2614 ± 74 vs. 2624 ± 70 kg at low and high aP levels), ADG (73.4 ± 2.1 vs. 73.7 ± 2.0 g/day) or ADFI (110 ± 3.2 g/day for both; $P>0.76$). FCR was always degraded with lower aP levels but more so at R1.8. Bone mineralization was deteriorated by low aP levels as well as, to a lower extent, low Ca to aP ratio. Bone breaking strength was 284 ± 63 and 214 ± 88 N at high and low aP levels respectively at R2.1 but only 234 ± 81 and 178 ± 75 N at R1.8 ($P=0.006$). At R2.1, tibia ash contents were 2.88 ± 0.22 , 2.79 ± 0.27 and 2.64 ± 0.26 g of dry matter at high, medium and low aP levels but only 2.81 ± 0.31 and 2.35 ± 0.25 g at R1.8 ($P<0.001$). In conclusion, aP level in the diets could be reduced with maintained growth only with good monitoring of Ca level and caution, because feed efficiency and bone mineralization are quickly degraded.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-051 Impact of trace element source and level on growth performance and phytase efficacy**H. Philipp^{1,2}, V. Sommerfeld², A. Monteiro³, M. Rodehutschord², O.A. Olukosi¹¹University of Georgia, Athens, United States, ²University of Hohenheim, Stuttgart, Germany, ³Animine, Annecy, France

The objective of this study was to investigate whether an interaction between phytase level and trace mineral source (TMS) exists in broiler diets and whether this affects growth performance, bone mineralization and prececal (pc) mineral digestibility. A total of 896-day-old male broilers (Cobb 500) were allocated to 56 floor pens (16 broilers/pen) of 7 treatments with 8 replicates each. Factors were phytase level (0 or 750 FTU/kg) and TMS, a combination of Mn, Cu and Zn (100, 125, 100 mg/kg feed) supplemented either as sulphates, oxides or organic TM. A phytase supplemented diet with NRC recommended levels of TM (supplemented as sulphates) was used as a control. Experimental diets were corn-soybean meal based and fed for ad libitum consumption in 2 phases. From d 0 to d 12 broilers were fed mashed starter diets with non-phytate P content (NPP) of 4.3 g/kg. Pelleted grower diets were fed from d 12 to d 28 (NPP: 3.0 g/kg). Growth performance, bone mineralization and pc mineral digestibility were determined on d 28. Data were analyzed in a 2x3+1 factorial nested design using the MIXED procedure of SAS (version 9.4). The factors phytase and TMS were included in the full factorial arrangement and compared to the control treatment. Growth performance traits were not affected by phytase x TMS interaction. Birds fed the control diet showed higher average daily feed intake (ADFI), gain (ADG) and lower feed conversion ratio (FCR) compared to the mean of birds receiving treatment 1 to 6 (ADFI, FCR: $P = 0.02$, ADG: $P < 0.01$). Birds fed sulphates or oxides tended to have higher ADG than birds fed organic TM ($P = 0.06$). Organic TM diets had higher FCR compared to oxides or sulphates diets ($P = 0.01$). In phytase-supplemented diets tibia ash amount ($P = 0.02$) and concentration ($P < 0.01$) were significantly increased. Phytase x TMS affected pc P digestibility ($P < 0.05$). Phytase supplementation increased pc P digestibility ($P < 0.05$). No differences between TMS were observed in phytase-supplemented diets, but in non-phytase supplemented diets, birds fed organic TM had significantly higher P digestibility than birds fed oxides or sulphates. Birds receiving the control diet had lower Ca digestibility than birds receiving any other treatment ($P < 0.05$). In conclusion, differences observed in growth performance were not reflected in bone ash or pc digestibility. Under the conditions of this study, trace mineral source does not seem to be a factor influencing phytase efficacy.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-052 Impact of Zn source and dietary level on prececal P digestibility, InsP6 disappearance and ileal myo-inositol concentration in broiler chickens**H. Philippi^{2,1}, V. Sommerfeld², A. Monteiro³, O.A. Olukosi¹, M. Rodehutscord²¹University of Georgia, Athens, United States, ²University of Hohenheim, Stuttgart, Germany, ³Animine, Annecy, France

The objective of this study was to investigate whether Zn source, dietary level or both affect phytase efficacy in broilers. A total of 640 d-old male broilers (Ross 308) were allocated to 64 floor pens of 8 treatments with 8 replicates each. The factors were phytase level (0 or 750 FTU/kg, Quantum®Blue, AB Vista, UK), Zn source (none or ZnSO₄*7H₂O, Sigma Aldrich, USA or ZnO, HiZox®, Animine, FR) and Zn supplementation level (0, 30, 90 mg/kg). From d0 to d7 broilers were fed a nutrient adequate starter diet. Pelleted experimental diets were fed ad libitum from d7 to d28. The diets were based on corn, soybean meal, rapeseed meal, and rice bran with native Zn content of 30 mg/kg and non-phytate P content of 3.6 g/kg. Prececal (pc) P digestibility, InsP6 disappearance, and ileal myo-inositol (MI) concentration were measured on d28. Data were analyzed in a 2x3+2 factorial nested design using the MIXED procedure of SAS (version 9.4). The factors phytase and Zn source were included in the full factorial arrangement. The 2 additional treatments, both of which included high Zn levels (90 mg/kg) and phytase supplementation, were added to test the effect of Zn level. Prececal P digestibility, InsP6 disappearance and ileal concentration of InsP3-6 were not affected by interaction (phytase x Zn source). The addition of phytase significantly increased pc P digestibility, InsP6 disappearance and ileal InsP4,5 concentration ($P < 0.01$). There was no significant difference between treatments with 30 mg vs. 90 mg Zn for pc P digestibility and InsP6 disappearance. There was a significant phytase x Zn source interaction for ileal MI concentration ($P = 0.03$). Significantly lowest ileal MI concentration was shown in broilers fed diets without phytase supplementation ($P < 0.01$). Highest MI concentrations were observed in birds that received phytase and Zn supplementation ($P < 0.01$). For treatment with phytase but without Zn supplementation MI concentration was intermediate. In conclusion, neither Zn source nor Zn level seem to be relevant influencing factors for phytase efficacy on InsP6 degradation. However, there was an indication that endogenous phosphatases were affected by Zn. Those enzymes are produced by either enterocytes or microorganisms and contribute to degradation of InsP, especially of lower InsP. The increase of ileal MI concentration in diets supplemented with Zn and phytase, indicates higher endogenous phosphatase activity.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-053 In ovo injection of twenty essential oils: hatchability and organ weights at hatch in broiler chickens**S. Niknafs¹, A.A. Khaskheli¹, M. M Y Meijer¹, X. Zhou², T. Aumiller², E. Roura¹¹The University of Queensland, Brisbane, Australia, ²Delacon Biotechnik GmbH, Engerwitzdorf, Austria

Plant essential oils (EOs) and extracts have shown beneficial effects on different aspects of gut functionality in chickens, including the immune system, digestion and absorption, nutrient metabolism, and the microbiome. However, little is known about the impacts of EOs on embryonic development of the chick. The objective of this study was to investigate the impact of in ovo injection of different EOs on embryonic development of broiler chickens. Twenty different EOs (oregano, spearmint, clove, patchouli, turmeric, black pepper, rosemary, eucalyptus, thyme, cassia, lemon, star anise, eugenol, ylang ylang, geranium, ginger, tea tree, sandalwood, peppermint, and lavender) were injected individually into the amniotic fluid of growing embryos at day 17.5 of incubation (n=24 eggs per treatment). Each EO treatment consisted of 1ml solution made of 5µl of EO, 5µl of emulsifier polysorbate 80, and 990µl physiological saline. Two control treatments (injected only with saline or only with polysorbate 80 solution) were also included. At hatch, several parameters were measured, including hatchability, live weight at hatch, and organ weight (residual yolk, proventriculus and gizzard, intestine, liver, heart). There was no effect of the emulsifier polysorbate 80 on hatchability and other parameters compared to the saline control ($P > 0.05$; 95.5% vs 95.8%). None of the EOs significantly ($P > 0.05$) affected the live weight and organ weights. Eugenol, tea tree, and clove oils significantly reduced hatchability compared to the control group injected with saline ($P < 0.05$; 58.3%, 75%, and 66.7% respectively compared to 95.8%). For these three oils, the level of toxicity (LD50) observed in rodents is above 1000mg/kg. Thus, our results suggest that chicken embryos are more sensitive to these three oils than rodents. In contrast, the other 17 EOs did not affect hatchability or any of the other post-hatch parameters and were selected for additional studies on the development of gut functionality. In conclusion, in ovo injection of eugenol, tea tree, and clove oils at 5µl/egg significantly reduced survivability of broiler embryos. However, most EOs showed no negative effect on any of the measured parameters. Potential beneficial impact of in ovo injection of these EOs on gut functionality and post-hatching performance warrants further investigation.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-054 In vivo performance and carcass traits of Japanese quail (*Coturnix japonica*) fed diets supplemented with *Hermetia illucens* oil**N.F. Addeo¹, E. Atallah², S. Vozzo¹, T.M. Mahayri², F. Bovera¹, G. Moniello²¹Department of Veterinary Medicine and Animal Production, Via F. Delpino, 1, 80137 Napoli, Italy, Naples, Italy,²Department of Veterinary Medicine, University of Sassari, Via Vienna, 2, 07100 Sassari, Italy., Sassari, Italy

Insect-derived products are a promising and valuable ingredient for poultry feed. However, more emphasis should be given to their effects on avian species different from chicken, such as quail (*Coturnix japonica*). This paper provides novel information about the impact of graded dietary levels of *Hermetia illucens* (HI) larvae oil on quails' growth and carcass traits. A total of 100, seven-days-old male Japanese quail (JQ) with an average live weight of 36.03g ± 0.16, were equally divided into 4 groups (5 replicates of 5 birds each). Up to 42 d, the control group (CON) diet was supplemented with 100% corn oil; HI25, HI50 and HI100 groups were fed with a diet in which HI oil replaced 25, 50 and 100% the corn oil, respectively. The total percentage of oil inclusion in the diets was 5g/100g. The data were analyzed by one-way ANOVA using the GLM procedure and the means' comparison was performed using the orthogonal contrast analysis (SAS, 2002). HI larvae oil resulted rich in saturated fatty acids (SFA) and lauric acid (C12:0) was the major constituent (37.71% of total FA), followed by palmitic (C16:0) and stearic acid (C18:0), with 17.11 and the 2.79 %; low percentages of C16:0 and C:18:0 (10.85 and 1.51%, respectively) were present in corn oil in which lauric acid was not detected. A substantial difference was found among the values of MUFA, PUFA, in corn and in HI oil (15.68 and 13.51%, respectively). During the whole experimental period the live body weight (average 221.8 g), feed intake (18.8 g/d), daily weight gain (6.8 g/d) and feed conversion ratio (2.75 g/g) resulted not different among the groups. At 42 days of age all the birds were slaughtered. The carcass yield was 72.0% in the CON group, 70.7 in HI25, 71.8 in HI50 and 70.8 in HI100 (P = 0.673). From the analysis of the organs, it emerged that the gastro-intestinal tract weight, expressed as a percentage of live weight was 12.7 in CON, 13.7 in HI25, 12.4 in HI50 and 14.9 in HI100, showing a P value (0.0749) tending towards significance. This is probably given by the percentage of jejunum, which was higher in the HI100 group (9.87) than in the HI25 group (8.51%, P = 0.0341). Despite the differences in term of fatty acid profile of the two oils, their inclusion level in the diets did not allow to reach statistically differences among the tested characteristics. However, our results indicate that HI oil can be used as into quail diets, without negative effects on bird performance.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-055 Influence of phytase dosage and dietary phytate concentration on prececal phytate disappearance and amino acid digestibility in broilers**S. Wolfrum¹, W. Siegert¹, V. Sommerfeld¹, D. Feuerstein², M. Rodehutschord¹¹University of Hohenheim, Stuttgart, Germany, ²BASF SE, Lampertheim, Germany

Phosphatases such as supplemented phytase are needed to release phosphorus (P) from phytate (InsP6). InsP6 can form complexes with proteins in the digestive tract of broilers, which can impair the prececal (pc) amino acid (AA) digestibility. Hence, increased dietary InsP6 and supplemented phytase dosage may affect formation of InsP6-protein-complexes and thereby influence AA digestibility. The objective was to investigate the relationship between phytase dosage and dietary InsP6 concentration in regard to pc InsP6 disappearance and pc AA digestibility. Twelve experimental diets mainly consisting of maize were mixed, containing 4 InsP6 concentrations (1.6, 2.1, 2.7, and 3.3 g/kg dry matter) and 3 phytase dosages (500, 1,500 and 3,000 FTU/kg; Natuphos E). The InsP6 content of the feed was increased by substituting maize starch by a 50/20/20/10 mixture of soybean meal, rapeseed meal, sunflower meal, and rice bran, which concurrently increased dietary P, calcium, and crude protein concentrations. A commercial starter diet was provided to male broiler chickens for 14 days post hatch. From day 14, the broilers were housed in metabolism units in groups of 10 and 7 units were allocated to each diet. On day 22 and 23, digesta from the terminal small intestine was obtained and analysed for InsP6, AA, and TiO2. The InsP6 × phytase interaction was not significant for pc digestibility of any AA but for pc InsP6 disappearance (P=0.007). At 500 FTU/kg, pc InsP6 disappearance linearly decreased with increasing dietary InsP6 from 83% to 56% (P≤0.022). At 1,500 and 3,000 FTU/kg, pc InsP6 disappearance decreased from 91% to 83% with increasing dietary InsP6 (P≤0.046) but did not differ between the phytase dosages. While the main effect of phytase was not significant in variance analysis, pairwise comparison showed significantly higher digestibility of lysine, methionine, isoleucine, and aspartic acid at 3,000 FTU/kg compared to 500 FTU/kg. Except for cysteine, pc digestibility of all AA decreased with increasing dietary InsP6 by ~4 percentage points (P<0.001), likely due to the digestibility of supplemented protein feeds being lower than that of the other feed ingredients. In conclusion, the effects of phytase on AA digestibility were not influenced by increasing inclusion of InsP6 from a mixture of protein feeds. Increasing phytase supplementation above 500 FTU/kg had a greater effect on InsP6 disappearance than on amino acid digestibility.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-056 Influence of use of organic minerals in laying hen diets on productive performance, egg quality and bone strength**Z. Janječić¹, G. Kiš¹, M. Janječić¹, I. Kos¹, I. Vnučec¹, D. Bedeković¹¹University of Zagreb Faculty of Agriculture, Zagreb, Croatia (Hrvatska)

Organic mineral sources have several advantages compared to inorganic sources, namely: protection against unwanted chemical reactions in the gastrointestinal tract, easy passage through the intact wall of the small intestine and better absorption. The aim of this research was to study the effect of organic and inorganic sources of microelements zinc, manganese, copper, iron and selenium in the feeding of laying hens on production indicators, eggshell quality and bone strength. The research was conducted on 30 TETRA - SL brown laying hens aged 35 to 50 weeks, divided by random selection into two experimental treatments. Each treatment contained 15 hens, housed individually in a 30 cm wide x 45 cm deep metal battery cage. All hens were fed corn-soybean meal a feed mixture, in which the following was added to the feed of the control group (K): 50 ppm Zn, 75 ppm Mn, 36 ppm Fe, 4 ppm Cu, 0.15 ppm Se in the form of inorganic salts ZnO, MnO, CuSO₄, FeSO₄ i Na₂SeO₃ which in the feed of the experimental group (P) were completely replaced by microelements in the form of proteins, i.e. selenized yeast, in levels: 30 ppm Zn, 30 ppm Mn, 5 ppm Fe, 5 ppm Cu, 0.2 ppm Se. At the end of the study, 10 hens from each group were sacrificed and tibias from both legs were separated - the left tibia for ash determination and the right tibia for mechanical properties in the three-point bending test. Data of egg production (%), feed intake (g/bird/day), feed conversion ratio (kg/kg egg), egg weight (g), thin and cracked eggshells (%), eggshell Ca content and bone strength were submitted to ANOVA, and when necessary means were discriminated by Tukey's test at 5% of probability with the use of PROC GLM of SAS software (SAS, 2000). Nutritional treatment showed no influence on egg production, egg weight, consumption and feed conversion ($P > 0.05$). The introduction of organic microelements improved ($P < 0.05$) the eggshell strength in group P compared to group K; shell breaking force was 36.68 vs 30.79 N and led to a higher Ca content in tibia ash; 184.48 vs 179.77 g/kg. Similarly, in group (P) there was a higher ($P < 0.05$) resistance to bone fracture compared to group (K); 155.90 vs 108.66 (N). The obtained results indicate that the use of organic minerals could significantly reduce damage to eggshells and damage of the bones in an alternative way of keeping laying hens.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-057 Interaction of wheat bran particle size and stimbiotic supplementation on growth performance and ceca pH of broilers fed corn-based diets**S. Veluri¹, M.R. Bedford², G. Gonzaleaz-Ortiz², O.A. Olukosi¹¹Department of Poultry Science, University of Georgia, Athens, United States, ²AB Vista and Feed Ingredients, Marlborough, United Kingdom

The current study evaluated the interactive effects of wheat bran (WB) particle size and stimbiotic (STB) supplementation in corn-based diets fed to broiler chickens. A 42-day study was conducted with 720-day-old Cobb 500 (off-sex) male broiler chicks allocated to 6 treatments with 8 replicates and 15 birds/replicate. Treatments were arranged in a 3x2 factorial, with the factors as WB inclusion (no WB, 50 g/kg coarse WB, or 50 g/kg fine WB) and STB supplementation (0 or 100 g/ton of feed) in corn-based diets. Coarse and fine WB used in this study had average particle sizes of 1044 microns and 460 microns, respectively. Diets were fed in three phases: starter (0 to 10 d), grower (10 to 28 d), and finisher (28 to 42 d). Gizzard, jejunum, and ceca contents were collected at d 18, and d 42 to determine digesta pH. In the starter phase, there was a significant main effect of STB ($P < 0.05$) and WB ($P < 0.05$) on feed intake and FCR. The inclusion of WB ($P < 0.05$) and STB supplementation ($P < 0.05$) increased FCR due to a higher feed intake in diets with WB ($P < 0.05$) and STB ($P < 0.05$) supplementation. There was significant WBxSTB for feed intake ($P < 0.05$) during the grower phase. Birds receiving diets with coarse WB and STB supplementation had the lowest FI ($P < 0.05$) compared to other treatments. By day 28, compared with the diet with no WB, coarse WB inclusion increased ($P < 0.05$) FCR, whereas fine WB inclusion had the opposite effect. There was significant WBxSTB for weight gain during the finisher phase ($P < 0.05$) and overall growth period ($P < 0.05$). During the finisher phase, fine WB inclusion decreased the weight gain ($P < 0.05$), but STB supplementation increased the weight gain ($P < 0.05$). Coarse WB inclusion produced similar weight gain with or without STB supplementation. In the overall phase, WBxSTB shows that STB supplementation in fine WB diets increased weight gain ($P < 0.05$), but in coarse WB diets, STB supplementation tended to decrease weight gain ($P < 0.10$). Stimbiotic supplementation decreased the ceca pH at d 18 ($P < 0.05$), but there were no significant interactions nor main effects for ceca pH on d 42. There were no significant interactions nor main effects for gizzard or jejunum pH on d 18. In conclusion, STB and WB increased FCR on d 10; however, by d 42, STB supplementation promoted greater weight gain in broiler chickens receiving diets with fine WB but had minimal effect in diets with coarse WB.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-058 Intestinal health and selenium: effect of selenomethionine on epithelial barrier function in Caco-2 cells**A. Garcia-Vara¹, J. Campo-Sabariz¹, R. Ferrer¹, R. Martim.Venegas¹*¹Departament de Bioquímica i Fisiologia, Facultat de Farmàcia i Ciències de l'Alimentació, Universitat de Barcelona. Institut de Recerca en Nutrició i Seguretat Alimentària (INSA-UB), Universitat de Barcelona., BARCELONA, Spain*

Selenium (Se) is an essential element necessary for a wide range of functions in the body, as it is part of the enzyme family of selenoproteins, such as glutathione peroxidase (GPX) and selenoprotein P1 (SELENOP). In poultry diets, the incorporation of Se is an effective way to reduce the negative effects of oxidative stress. In fact, oxidative stress is tightly related to intestinal health as it affects the intestinal barrier function. The aim of this study is to investigate the role of selenomethionine (Se-Met) in supporting selenoprotein expression and epithelial barrier function in intestinal Caco-2 cells. A model of Se deprived Caco-2 cells was used: after one week of growth, fetal bovine serum (FBS) was removed for 6 days. Then cells were incubated for 72 h with Se-Met. GPX activity, SELENOP protein and gene expression, and GPX1 and GPX2 gene expression were studied. Moreover, the potential beneficial role of Se-Met in an in vitro model of intestinal inflammation was investigated by incubation of intestinal Caco-2 cells with TNF α . Paracellular permeability was assessed from transepithelial electrical resistance (TER). Se-Met supplementation increased GPX activity (Control, 5.99 ± 0.33 nmol/min-mg protein; Se-Met, 11.44 ± 1.84 nmol/min-mg protein, $p < 0.05$), GPX1 gene expression (1.43 fold change respect to control, $p < 0.05$) and GPX2 gene expression (1.76 fold change respect to control, $p < 0.05$) as well as, SELENOP protein (Control, 3.26 ± 0.21 ng/mg protein; Se-Met, 5.95 ± 1.01 ng/mg protein; Se-Met, $p < 0.05$) and gene expression (1.54 fold change respect to control, $p < 0.05$). Moreover, while the incubation with TNF α decreases TER values, cells incubated with Se-Met show similar results to those obtained in control conditions. In conclusion, our results indicate that Se supplementation, through the enhancement of selenoprotein expression protected epithelial barrier function in cultures incubated with TNF α . Therefore, Se is an important pivotal key that could contribute to maintain intestinal health.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-059 Intestine morphology and performance of free-range chickens fed different levels of cupuassu seed meal**E.F. Alves da Silva¹, A.V. de Sousa², D. Silva Santos³, M.V. Barbosa Macedo¹, P. E. Naves Givisiez¹, C.J. Bruno de Oliveira¹, A.L. de Barros Moreira Filho²*¹Departament of Animal Science, College for Agricultural Sciences, Federal University of Paraíba (CCA/UFPB), Areia-PB, 58397-000, Brazil, ²Department of Animal Science/CCHSA, Federal University of Paraíba, Bananeiras, PB, Brazil, ³Department of Animal Science, São Paulo State University (FCAV/Unesp), Jaboticabal, SP, Brazil*

Free-range chickens were fed diets containing cupuassu seed meal (CSM, 0, 7, 14, 21 and 28%) to assess intestine histology at 56d and performance at 63d. CSM is an alternative ingredient for animal nutrition that would result in proper destination of the organic waste generated by cupuassu processing plants in the Amazonian region in Brazil. Free-range chicks were distributed in five treatments with five replicates of 12 animals (mean weight 40.5g). CSM (CP: 8.6%; EE: 48.5%, CF: 27.8%) was used at 0, 7, 14, 21 or 28% CSM replacing corn in diets with equal CP, ME, Ca, P, Na, Lys and Met. Jejunum and ileum were sampled at 56d from five birds/treatment for histometric analysis using hematoxylin-eosin staining. Villus height (VH), crypt depth (CD), villus:crypt ratio (VCR), villus width (VW), muscular thickness (MT), and absorption area (AA) were measured. Ten measurements per variable were used to calculate the average value per bird. Body weight (BW), weight gain (WG), feed intake (FI) and feed conversion (FC) were assessed (1 to 63d). Data were subjected to analysis of variance in a completely randomized design (five treatments; five repetitions/treatment for each variable) and means compared to the control by Dunnett's test ($P < 0.05$) using R. Mean values in the jejunum of control birds for VH (1241 μ m), VCR (11.6 μ m/ μ m), VW (123 μ m) and AA (153.7 mm²) were greater than in birds fed 7%, 14%, 21% and 28% CSM, whereas CD (108 μ m) and MT (113 μ m) decreased in control birds compared with CSM birds. Similarly, ileum mean values were higher in control birds for VH (653 μ m), VCR (6.09 μ m/ μ m), VW (115 μ m) and AA (74.9 mm²) than in CSM birds, and CD (107 μ m) and MT (173 μ m) decreased in control birds compared with CSM birds, except VW of birds fed 7 and 14% of CSM and AA of 7% birds, which were similar to 0% birds. The increase in dietary fiber levels may negatively affect the digestive morphology. WG and FC decreased in CSM birds compared with 0% CSM (WG: 2.6, 2.3, 1.9, 1.9, 1.5kg; FC: 2.8, 2.9, 3.3, 3.3, 3.9 for 0, 7, 14, 21 and 28%, respectively). FI (kg) was similar for 0 and 7% CSM birds (7.3 and 6.8, respectively, $P > 0.05$), but lower with increasing levels of CSM (6.5, 6.4 and 6.1kg, respectively, $P < 0.05$). Cupuassu seed meal for free-range birds in the Amazonian region must be further evaluated as an alternative ingredient at levels lower than 7%. Funding: FAPERO and CAPES (Finance code 001 and PPrint #88881.311776/2018-01)

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-060 Kernel physical properties affect the carotenoid profile of yolks from hens fed diets differing in maize hybrid**

V. Gunjević¹, D. Zurak¹, Z. Svečnjak¹, M. Duvnjak¹, G. Kiš¹, D. Bedeković¹, Z. Janječić¹, V. Prirgozliev², D. Grbeša¹, K. Kljak¹

¹University of Zagreb Faculty of Agriculture, Svetošimunska cesta 25, Zagreb, Croatia (Hrvatska), ²National Institute of Poultry Husbandry, Harper Adams University, Shropshire, TF10 8NB, United Kingdom

Maize is the most commonly used cereal for poultry diets and is considered a valuable source of carotenoids. The carotenoid profile varies between maize hybrids. However, the kernel structure, which is also determined by genotype, could affect the carotenoid release during digestion and thus their deposition in the yolk. The aim of this study was to investigate the effect of kernel physical properties on the content of total and individual carotenoids in the yolk of hens fed diets differing only in maize hybrid. Fifteen high-yielding maize hybrids from six seed producers were used to prepare the treatment diets without the addition of other pigment sources. By three in each cage, 225 Lohmann Brown hens were allocated to 15 dietary treatments in a completely randomised design (15 treatments×5 cages). The experiment lasted 12 weeks, and eggs for analysis were collected once a week for five weeks after stabilisation of total carotenoid content. The carotenoid profile [content of lutein (L), zeaxanthin (Z), α - and β -cryptoxanthin (α CX and β CX), β -carotene (β C) and total carotenoids (TC)] of the yolks was determined using HPLC method. Each hybrid was analysed for physical properties in terms of kernel sphericity, test weight (TW), Stenvert hardness [milling time (SMT), milling height (SMH) and -to-fine ratio (SC /F)], breakage susceptibility (BS), density, and flotation index (FI). Dietary treatments differed in yolk carotenoid profile ($P < 0.001$) with ranges (μ g/g) of 8.88-17.64 for L, 9.14-25.65 for Z, 0.23-1.01 for α CX, 0.28-1.02 for β CX and 0.25-0.54 for β C. Maize hybrids differed in all physical properties tested ($P < 0.001$) with ranges 0.615-0.701 for kernel sphericity, 65.35-75.61 kg/hL for TW, 1.82-3.44 s for SMT, 91.4-114.8 mm for SMH, 0.262-0.718 for SC /F, 35.85-79.42 for BS, 1.154-1.265 g/mL for density, and 7.4-99.6% for FI. The content of L, β CX, and TC in the yolks correlated with most of the determined maize properties, whereas the content of L, α CX, and β C correlated only with BS. The content of L, β CX and TC in the yolks correlated positively with kernel sphericity, TW, SMT, SC /F, BS and density, whose higher values indicate higher kernel hardness, and negatively with SMH and FI, whose lower values indicate higher kernel hardness. The obtained results indicate that maize hybrids with higher kernel hardness used to prepare hen diet will result in higher contents of Z, β CX and TC in the yolk compared to hybrids with lower hardness.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-061 Lysozyme, essential oils and vitamins' mixture of additive supports respiratory health and improves antibody titres after viral vaccinations in hens**

I. Giannenas¹, I. Stylianaki², T. Mantzios³, S. Savvidou⁴, S. Dokou¹, G. Papadopoulos⁵, S. Vasilopoulos¹, A. Patsias⁶, J. RAJ⁷, J. Bošnjak-Neumüller⁷, M. Vasiljević⁷, M. Pajic⁸, V. Tsiouris³

¹Laboratory of Nutrition, Faculty of Veterinary Medicine, Aristotle University, 54124, Thessaloniki, Greece, ²Laboratory of Pathology, Faculty of Veterinary Medicine, Aristotle University, 54124, Thessaloniki, Greece, ³Unit of Avian Medicine, Clinic of Farm Animals, Aristotle University of Thessaloniki, Stavrou Voutyra 11, 54627, Thessaloniki, Greece, ⁴Research Institute of Animal Science, Hellenic Agricultural Organization- DIMITRA, 58100, Paralimni, Giannitsa, Greece, ⁵Laboratory of Animal Husbandry, Faculty of Veterinary Medicine, Aristotle University, 54124, Thessaloniki, Greece, ⁶PINDOS APSI, Ioannina, Greece, ⁷PATENT CO. DOO, MIsicevo, Yugoslavia - Serbia, ⁸Department for Epizootiology, Clinical Diagnostic, Pathology and DDD, Scientific Veterinary Institute "Novi Sad", Rumački Put 20, 21000, Novisad, Yugoslavia - Serbia

Health of respiratory tract in layers is important for laying performance and egg quality. Viral diseases or even standard vaccination may impair trachea epithelium and impose oxidative stress. Here, we investigated the effects of supplementation with a water additive Immunohype™ (PATENT CO. DOO) containing lysozyme, essential oil compounds and vitamins to detect their effects on oral vaccinations of layers at the level of 1g/L. In this trial effects on performance, trachea function, egg traits, eggshell quality, and egg oxidative stability in young layers raised in a commercial farm were measured. Three hundred and twenty, 24-week-old Lohmann-type hens were allocated in 32 cages and Hen body weight (BW) was measured at the beginning and end of the trial and egg production and feed intake were recorded daily. In order to vaccinate groups of layers separately, layers were moved to land-based cages and were watered by bell drinkers. At week 25, half of the layers were orally vaccinated against infectious bronchitis (IB) and Newcastle disease (ND), whereas blood sampling was conducted to evaluate antibody (AB) titers. At the end of the trial, eggs were evaluated for egg weight, eggshell breaking strength, and thickness, Haugh units and yolk color, rate of lipid oxidation in fresh and refrigerated stored shell eggs and albumen protein oxidation. Hens were also blood sampled and euthanized for histomorphological evaluation of the trachea. ANOVA was performed to analyse all data; significance was set at 5% ($P=0.05$). Additive supplementation increased AB titers by 1 log, and significantly supported trachea after vaccinal application, showing a score of 1.5 indicating no lesions or mild epithelial hyperplasia and subepithelial lymphoid infiltrate and ciliated cells being round and detached from the surface, whereas control vaccinated layers showed score of 2.8, with moderate epithelial hyperplasia and subepithelial lymphoid infiltrate, complete loss of cilia and decreased number of mucous glands. Some control layers had extensive epithelial hyperplasia and subepithelial lymphoid infiltration. The layers with lysozyme, essential oil compounds and vitamins also showed 10% increased egg production rate, and tended to increase egg weight without difference in feed intake or egg quality characteristics but also improved oxidative stability in fresh and stored eggs, reducing both lipid peroxidation in yolk, and protein carbonyls in albumen.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-062 Marigold (*Calendula officinalis*) extract supplementation may improve the oxidative status of broilers fed with high level of n-3 or n-6 PUFA**V. Rezar¹, A. Levart¹, A. Nemec Svete², J. Salobir¹¹University of Ljubljana, Biotechnical Faculty, Department of Animal Science, Jamnikarjeva 101, 1000 Ljubljana, Slovenia, ²University of Ljubljana, Veterinary Faculty, Clinic for Surgery and Small Animal Medicine, Gerbičeva 60, 1000 Ljubljana, Slovenia

Polyunsaturated fatty acids (PUFA) are essential for health and normal physiological function. One of the effective solutions to increase the accumulation of PUFAs in chicken products is to adjust the fatty acid composition in poultry feed. However, the high intake of PUFA increases the animals' need for antioxidants. Marigold (*Calendula officinalis*) extract has antioxidant properties due to its content of polyphenols and carotenoids and could serve as an alternative to the synthetic antioxidants. To evaluate the effect of marigold extract on the oxidative status of chickens, an in vivo study was performed in which oxidative stress was induced by a high intake of n-3 or n-6 PUFA. In the experiment, sixty 1-d-old male broiler chickens (Ross 308) were individually caged in wire-floored cages and assigned divided into four groups. The diets differed in fat sources and contained 7 % of linseed (Lin) or walnut oil (Wal), were supplemented with propylene glycol extracts from marigold flower tops (Mar), or were not supplemented in the control groups (Cont). Broiler body weight and feed intake were recorded weekly and just before slaughter. After the birds were killed on day 38, blood and liver samples were collected. In blood, the concentration of malondialdehyde (MDA) and vitamin E (α -tocopherol (T) and γ -T), the antioxidant capacity of water-soluble compounds (ACW), levels of isoprostanes and 8-hydroxy-2'-deoxyguanosine (8-OHdG), and the activity of glutathione peroxidase (GSH-Px) and superoxide dismutase (SOD) were measured. In the liver, MDA, α T and γ T, and ACW were analysed. Data were analysed using the GLM procedures of the SAS/STAT module. Differences determined by a Tukey's multiple comparison test were considered significant at $p < 0.05$. No differences were found in feed consumption and body weight gain. The addition of linseed oil significantly increased MDA formation in plasma and liver compared with walnut oil, whereas marigold extract significantly decreased MDA formation in plasma with both oils but not in liver. Neither oil nor marigold extract affected α T and γ T concentrations in plasma or liver. The addition of marigold extract increased plasma ACW. The addition of walnut oil increased the level of isoprostanes in serum. The addition of marigold extract had a positive effect on the oxidative status of broiler chickens, in which oxidative stress is induced by a high intake of n-3 or n-6 PUFA.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-063 Methionine source and level modulate gut pH, amino acid transporters and metabolism related genes in broiler chickens**L. Gong¹, T. Mahmood², Y. Mercier², Y. Guo¹¹College of Animal Science and Technology, China Agricultural University, Beijing, China, ²Adisseo France S.A.S, Commeny, France

This study investigated the effect of methionine (Met) source and level on growth, chyme pH, jejunal chyme enzyme activity, metabolic enzymes-related gene expression in the liver, and gene expression profile of Met transporters of broiler chickens. Two Met sources (DL-Met and OH-Met) and three digestible TSAA / Lys levels i.e., 0.58, 0.74, and 0.90% corresponding to low, control (Arbor Acre recommended) and high levels, respectively were used in a 2 × 3 factorial design. A total of 720, 1-day-old AA male broiler chicks were randomly assigned to 6 treatments with 10 replicates of 12 chicks. Growth performance was recorded during the study period from 1-21 d. At day 21, one bird per replicate pen was selected to collect chyme and tissue samples from intestinal segments for subsequent analyses. The growth performance data did not show significant difference between Met sources. However, the higher TSAA level reduced the feed intake and body weight compared with other two TSAA levels ($P < 0.05$), while FCR remained unaltered. Supplementation of OH-Met acidified the chyme pH of the crop ($P = 0.008$) and enhanced the activity of jejunal lipase ($P = 0.015$). In addition, OH-Met downregulated the gene expression of AHCY in the liver ($P = 0.003$). A significant source × level interaction was observed on the gene expression of CBS in the liver ($P < 0.05$). Further, OH-Met upregulated the gene expression of duodenal b0,+AT, but downregulated duodenal MCT1, jejunal b0,+AT, γ +LAT2, and MCT4 transporters ($P < 0.05$). Compared with the control, the low TSAA treatment upregulated the gene expression of duodenal MCT4, jejunal γ +LAT1, γ +LAT2, LAT1, and MCT4 transporters ($P < 0.05$), whereas high TSAA supplementation significantly downregulated the expression of duodenal LAT1 and b0,+AT transporters in the jejunum ($P < 0.05$). A significant source × level interaction was observed in the gene expression of ATB0,+, and γ +LAT2 in the duodenum and LAT1 and MCT1 transporters in the ileum ($P < 0.05$). In conclusion, both Met sources supported similar growth performance, however, OH-Met had more crop chyme acidifying capacity and support higher lipase activity in jejunal chyme. Our study also showed that known Met transporters have a distinct transcriptional pattern of expression along the different intestinal segments conditional to change with source and level of Met. These findings provide insights into the molecular basis for further study and application of the two sources of Met.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-064 Methionine to sulfur amino acids ratio is not a limiting factor for broiler performance fed with low protein diets**D.I. Batonon-Alavo¹, T. Mahmood², Y. Mercier³¹Adisseo Canada, Montreal, Canada, ²Adisseo Animal Nutrition DMCC, Dubai, United Arab Emirates, ³CERN, Adisseo France S.A.S., Malicorne, France

Decreasing crude protein in broiler diets has been identified as a good means to reduce nitrogen excretion. Accordingly, the digestible methionine (dMet) to sulfur amino acids (SAA) ratio increases with the decrease of crude protein (CP) in broiler chickens' diets. We hypothesized that balancing dMet/dSAA by adding L-Cysteine would be a lever to improve performance under low protein diets. This study aimed to determine the optimal dMet/dSAA when broiler chickens are fed with low CP diets. One-day Ross 308 male broilers were fed with a common starter diet from 0 to 10-d. From 11 to 24-d, 960 birds were allocated to 6 treatments consisting of 8 replicates of 20 birds each. A positive control (PC; 21% CP, 0.67 dMet/dSAA) and 5 low CP including a negative control (NC; 18% CP, 0.72 dMet/dSAA) were formulated at the same dSAA. Importantly, dMet/dSAA was decreased stepwise through L-Cysteine addition as followed: 0.73, 0.66, 0.60, and 0.54%. Glycine was included at 0.37% except in the NC, to match the level of PC group (1.57%). All nutrients, including dMet and dSAA, matched or exceeded Aviagen (2019) recommendations. Performance parameters were recorded from 10 to 24-d and analyzed with a 1-way ANOVA. Means were compared using Tukey test. A linear regression was also performed to determine the effect of reducing dMet/dSAA. Despite being non-significant at 10-d, the 10-d body weight was included as a covariate for the grower period (11-24 d). It showed a significant effect ($p < 0.001$) for the subsequent statistical analyses. At 24-d, the body weight, body weight gain, and feed conversion ratio (FCR) were significantly affected by the experimental treatments ($p < 0.001$) whereas no significant difference was found for the feed intake. The positive control presented a better FCR compared to low CP treatments. Negative control (dMet/SAA = 0.72) presented a significantly ($P < 0.05$) higher FCR (1.27) compared to similar dMet/SAA ratio = 0.73 (1.25) with Glycine addition. Moreover, there is no significant linear relationship between other growth parameters and dMet/dSAA ($P > 0.05$) although the FCR tended to deteriorate with decreasing dMet/dSAA ($p = 0.09$). These results showed that with an adequate dietary Gly+Ser level, balancing dMet over the dSAA with only methionine up to 0.73 did not impair broilers' performance fed with low CP diets. These results also showed an impact of Gly+Ser level and high dMet/SAA ratio that need to be further explored.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-065 Microbial phytase inclusion improves dietary Ca and P digestibility but cannot fully restore the compromised growth performance in broilers fed a Ca-deficient diet**Y. Hu^{3,2,1}, J. van Harn², J. van Baal³, W. Hendriks³, A. Dijkslag⁴, M. van Krimpen², P. Bikker²¹De Heus Animal Nutrition B.V., Ede, Netherlands, ²Wageningen Livestock Research, Wageningen, Netherlands, ³Wageningen University & Research, Wageningen, Netherlands, ⁴ForFarmers, Lochem, Netherlands

The hypothesis was tested that microbial phytase improves intestinal calcium (Ca) and phosphorus (P) absorption thereby allowing a lower dietary Ca inclusion to reduce its negative impact on P absorption while maintaining growth performance. One-day-old male Ross 308 broilers (25 birds/pen, nine pens/treatment) were assigned to one of eight experimental diets in a 4x2 factorial design including four dietary Ca to retainable P (rP) ratios (1.3, 1.8, 2.3 and 2.8) and two microbial phytase levels (0 vs 1000 FTU/kg). Dietary rP was fixed at 3.2, 2.5 and 2.2 g/kg at starter (day 0-10), grower (day 10-29) and finisher (day 29-36) period, respectively, which was 80% of the CVB (2018) recommendation. On day 21-23, eight birds per pen were euthanized to collect digesta from proximal and distal half of jejunum as well as distal half of ileum for analysis of Ca and P digestibility. Tibia bones were collected from three of the eight dissected broilers for stiffness (breaking strength) analysis. Results indicated that the dietary phytase inclusion in the low Ca/rP diets (1.3 and 1.8) increased apparent Ca digestibility in the distal ileum ($P=0.023$) but not the proximal or distal jejunum, suggesting that microbial phytase could improve intestinal Ca absorption thereby allowing a somewhat lower dietary Ca inclusion to reduce its negative effect on dietary P absorption. Furthermore, microbial phytase increased apparent P digestibility in all measured gut segments, which was greater in the higher Ca/rP diets in the distal jejunum and distal ileum ($P=0.021$ and 0.001 , respectively). Incremental dietary Ca/rP linearly increased tibia stiffness, with a larger effect in the microbial phytase supplemented diets ($P<0.001$). Nevertheless, broilers fed the lowest Ca/rP diet had the lowest body weight gain and highest feed conversion ratio ($P<0.001$) irrespective of dietary phytase inclusion (no interaction effect), suggesting that the positive effect of microbial phytase on intestinal Ca absorption was not potent to fully compensate Ca deficiency in the present study. In conclusion, despite the improvement in apparent Ca digestibility, inclusion of dietary phytase could not fully restore the compromised growth performance of broilers fed a Ca-deficient diet.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-066 Modified wheat bran as feed ingredient and its impact on egg quality of laying hens**

A. Dauksiene¹, R. Gruzauskas², D. Klupsaite¹, V. Starkute¹, V. Lele¹, P. Zavistanaviciute¹, E. Mozuriene¹, E. Zokaityte¹, E. Bartkiene¹

¹Lithuanian University of Health Sciences, Kaunas, Lithuania, ²Kaunas University of Technology, Kaunas, Lithuania

Utilization of wheat bran (WB) as low-cost food industrial waste, obtained from the dry milling of wheat to flour can be possibility for achieving lower feed cost and sustainable poultry nutrition. However, direct use of WB in feed is limited due to antinutritional factors such as non-starch polysaccharides or phytic acid, low protein quality and high fiber content of WB. The nutritional value of WB could be improved by extrusion and solid-state fermentation. This study investigated the feeding effects of extruded and fermented WB on production performance and egg quality of laying hens. A total of 10,000 free range 20-week-old Lohman Brown Classic laying hens were allotted to two groups (5,000 hens each) with separate feeding and drinking systems per group. Control group was fed by isoenergetic and isonitrogenous basal diet, formulated according to the nutritional requirements of Lohman Brown Classic hens. In treatment group (T group) 3% of basal diet's wheat were replaced by valorized WB. Extrusion of WB was performed in a Twin Screw extruder and Lactobacillus strains *L. casei* and *L. paracasei* were used for fermentation of extruded WB. Hens were raised and experiment was performed in accordance with guidelines of EU Directive 2010/63/EU and Lithuanian legislation (Requirements for the Keeping, Maintenance and Use of Animals Intended for Science and Education Purposes). During the 6 weeks experiment, the productivity parameters were recorded; and the external and internal egg quality indices were analyzed. The results showed: (1) Compared to control group, at the end of trial, the egg laying rate and FCR were higher in T group. (2) Extruded and fermented WB increased eggshell strength by 2.3% ($p < 0.05$), yolk weight by 1.2%, improved yolk color and level of polyunsaturated fatty acids, but Haugh unit and egg weight were decreased. It could be concluded, that valorised WB in feed of hens showed tendencies to improve egg laying rate, egg quality and modifies egg's fatty acids composition. The authors acknowledge the European Innovative Partnership project No. 35BV-KK-19-1-10857-PR001.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-067 New feeding strategies for organic egg production with reduced dietary phosphorus**

S. Steinfeldt¹, S. Knorr Jensen²

¹Aarhus University, Dept. of Animal and Veterinary Sciences, Tjele, Denmark, ²Innovation Centre for Organic Farming, Aarhus, Denmark

Organic laying hens have a high demand for calcium (Ca) and phosphorous (P) to support an optimal egg-production and sustain good welfare. However, the current feeding strategies and P-level recommendations may lead to an elevated P-excretion due to oversupplying. High levels of P and supplementation of Ca via compound feed given during the day, where no shell formation occurs, can negatively affect productivity and result in leaching of excreted P to the surrounding environment. This study aimed to investigate the effects of lowered dietary levels of available phosphorous (AP) and strategic allocation of a coarse Ca source in organic laying hens from 30 weeks-of-age (WOA) to 80 WOA. 1200 Dekalb White hens were fed one of four levels of P (0.20-0.35% AP) and one of two Ca feeding strategies (Ca included in compound feed or fed separately at 4:30 PM to 7:30 AM). Production data were collected continuously throughout the experimental period. Hen weight and plumage quality were obtained seven times during the study. The hens fed the four diets with separate allocation of Ca had a high egg production throughout the study up to 80 WOA (average (av.) > 90%), independent of the P-level. An effect of P-level was found in treatments with Ca included in the feed, where hens fed the lowest level of P (0.20% AP) decreased egg production at the end of the study (av. 85% from 70-80 WOA). The highest levels of P (0.30 and 0.35% AP) with Ca included in the diets resulted in a higher egg production (av. 90% from 70-80 WOA) compared to the diet with 0.20% AP. Over the course of the study, hens receiving strategic Ca had a higher egg weight than those receiving all Ca in the compound feed (63.1 vs. 62.5g) and especially with the low P-level from 70-80 WOA (63.2 vs. 61.6g). The diet with 0.20% AP and with Ca included in the diet resulted in the poorest feed conversion ratio (FCR) compared to all other treatments in the last part of the production period (70-80 WOA; 2.45 kg feed/kg egg vs. 2.25-2.30), and the hens in this treatment also lost weight during the study. Plumage quality was high in all treatments and the mortality was low (av. 2.5% for the study period), so reducing dietary P had no effect on these parameters. The study proved that it is possible to reduce P-content in the feed considerably without impairing production results if coarse Ca is allocated as a separate source, which indicate that hens regulate their own Ca intake with this feeding strategy. Funding: Green Growth and Development programme (GUDP) under the Danish Ministry of Environment and Food

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-068 Nitrogen recycling effect of OH-Methionine: a simple action to reduce nitrogen excretion in broiler chickens**A. Barbe¹, D.I. Batonon-Alavo², T. Mahmood³, Y. Mercier¹¹CERN, Adisseo France S.A.S., Malicorne, France, ²Adisseo Canada, Montreal, Canada, ³Adisseo Animal Nutrition DMCC, Dubai, United Arab Emirates

Sustainability in animal production is partly linked to animal nitrogen excretion. Methionine (Met) is of primary importance in poultry nutrition as the first limiting amino acid and, among the commercially available forms of methionine sources, hydroxy-methionine (OH-Met) recycles part of the amino group in excess that would have been excreted to form L-Methionine. This study aimed to measure and validate the nitrogen savings effect of dietary OH-Met. Sixty, 13 days-old Ross 308 male chicks, previously reared on a common starter diet, were allocated in a random blocked design in individual battery cages and receive two experimental diets with 30 individual bird replicates each. The experimental diets were formulated to supply 21 % CP; 1.10% dLys and 2,950 Kcal/kg AMEn using Corn-Wheat-Soybean meal as main raw material. The two treatments differed only by the methionine source supplied at iso-molecular level: DL-Met (99%) at 0.34% inclusion or OH-Met (88%) at 0.39% inclusion to supply 0.90% dSAA. Birds received the dietary treatments from 13 to 22 days with a total feces collection procedure applied between 20 and 22 days. Diets were analyzed for total nitrogen and dry matter while feces were analyzed for dry matter, total nitrogen and Terpstra nitrogen to calculate uric acid in the excreta. Statistical analyses were conducted in JMP software. ANCOVA was run using the methionine source as the main effect, the block as random and the feed intake as a covariate. The analyzed total nitrogen was 3.33 and 3.28%, respectively for DL-Met and OH-Met supplemented diets. No significant difference was observed in growth performance parameters during the whole experimental period (13-22 days). During the 3 days collection period, a significant difference of nitrogen intake was observed between groups ($p < 0.001$) with 8.73 g and 8.86 g/bird ingested nitrogen ($p = 0.17$) (Terpstra nitrogen) or retained nitrogen expressed as a percentage of intake i.e., 63.23% (DL-Met) and 63.51% (OH-Met) ($p = 0.53$). The total excreted nitrogen tended to be lower (-2.7%, $p = 0.073$) with OH-Met (3.189 g) compared to DL-Met (3.261 g) and the total uric acid excreted was significantly lower (-3.9%, $p = 0.031$) in OH-Met (1.98 g) in comparison to DL-Met (2.06 g). These results demonstrated that OH-Met effectively recycles part of the nitrogen thereby reducing nitrogen excretion in broilers. These results also corroborate previously calculated energy values.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-069 Novel product with combination of Saccharomyces cerevisiae fermentation product and essential oil compounds improved broiler performance: a metanalysis**V. A. Kuttappan¹, Y. Fournis¹, C. Clemons¹¹Diamond V, Cedar Rapids, IA, United States

Saccharomyces cerevisiae fermentation product (SCFP) and essentials oil compounds are used in the poultry industry for a long time due to their proven benefits on broiler digestive health and performance. The aim of the present study was to evaluate a proprietary combination of SCFP and essential oils compounds using a metanalysis across seven independent trials. All seven trials contained two treatments, either the control (CON) or test (MBP), both receiving the same basal diet except for the inclusion of 0.4kg/MT of Dia-V MBPro (Diamond V Mills, Cedar Rapids, IA) in MBP. Commercial broiler strains were raised on corn-soybean based diets, up to 42d of age, and various performance as well as processing parameters were evaluated. All trials used a randomized block design with pens as experimental units and 16 to 48 replicates/treatment with 384 to 1440 birds/treatment. Data were analyzed using PROC MIXED model with block and study as random effect, significant difference determined at $P < 0.05$. The metanalysis showed differences ($P < 0.05$) between CON vs MBP with respect to body weight (2.97kg vs 3.04kg), and feed conversion ratio (1.61 vs 1.59) at 42d. Interestingly, improvement ($P < 0.05$) in breast yield was observed comparing CON vs MBP (30.63% vs 31.17%). No difference ($P > 0.05$) was observed on feed intake and mortality at 42d. In conclusion, the metanalysis of seven independent studies demonstrated that of MBP promotes broiler performance resulting in improved body weight (2.4%), feed conversion ratio (2 points), and breast meat yield (0.5%) compared to CON. The performance benefits of proprietary components in MBP could be due to a dual action with essential oil compounds and SCFP impacting digestive secretions in the upper part of the gut and influencing the bacterial populations in the distal part of the gut, respectively.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-070 Nutrient digestibility and digesta mean retention time in laying hens of two different breeds fed with fine vs coarse oat hulls**M.F. Habib^{1,2}, R. Kwakkel¹, S. de Vries¹¹Animal Nutrition Group, Wageningen University and Research, Wageningen, Netherlands, ²Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta, Indonesia

To limit feed-food competition, poultry will be increasingly fed with agricultural by-products that contain a high proportion of fibrous components. To optimally acknowledge the feeding value of dietary fibre, effects of dietary fibre on digestive processes need to be investigated. Previous studies reported that chicken breeds selected for certain production traits or digestion efficiency differ in their response to fibrous diets. To test the hypothesis that different breeds of laying hens vary in their response to coarse oat hulls, nutrient digestibility and digesta mean retention time were measured in 244 29-wk old laying hens in a 2x2 factorial arrangement with two laying hen breeds (DeKalb White (DW) and Bovans Black (BB)) and two oat hull (OH) structures (fine and coarse). The diets were formulated to contain 15g/kg oat hulls as the only fibre source and titanium dioxide (TiO₂, 3g/kg) as a marker for solid digesta and cobalt-ethylenediamine tetraacetic acid (Co-EDTA, 2g/kg) for liquid digesta. At 33 wk of age, birds were euthanized between 08.00 and 17.00 after lights on. Digesta from crop, proventriculus+gizzard, duodenum+jejunum, ileum, and ceca+colon were analysed for marker and nutrient concentrations. Mean retention time was calculated by dividing pool size of markers in a certain digestive tract segment by the pool size of marker ingested during 24 hours. Apparent ileal digestibility (AID) of N was greater (+3.8%-units, P<0.01) in BB vs DW hens, whereas AID of starch was only higher in BB when the fine oat hull diet was fed (breedxdiet, P=0.04). Contrastingly, apparent total tract digestibility (ATTD) of DM (-2.5%-units, P<0.01), N (-8.1%-units, P<0.01), fat (-4.2%-units, P<0.01), and NSP (-0.5%-units, P=0.03) were lower in BB vs DW hens. A higher AID for N coincided with longer retention of solid digesta in proventriculus+gizzard (+25min, P<0.01) and ceca+colon (+11min, P<0.01), and of liquid digesta in duodenum+jejunum (+12min, P<0.01) and ileum (+10min, P<0.01) in BB vs DW hens. Oat hull particle size had no effect on digestibilities and digesta retention time except a tendency for greater ATTD of fat for coarse vs fine OH (+2%-units, P=0.09) and a reduced retention of solid digesta in the hindgut (-8min, P<0.05). In conclusion, our study indicates marginal differences in responses to particle size of oat hulls between breeds. Digesta transit behaviour and nutrient digestion, however, differed between breeds, regardless of diet.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-071 On farm report of *Pediococcus acidilactici* cncm 4622 supplementation in pullets' production with new criteria for the evaluation of pullet's quality**S. Soler¹, E. Chevaux¹, M. Ligabue¹, A. Sacy¹¹Lallemand SAS, Blagnac, France

Pullet preparation is an essential factor conditioning the efficiency of layer along the production cycle. Average Body weight and weight homogeneity are today the main criterion used to evaluate pullets' quality. But recent reports point that body weight measurement is not sufficient and underline the importance of muscle development and protein retention to favor the persistency of the laying curve. The objective of this field study was to assess an on-farm measurement of muscle thickness as a pullet quality criterion. The trial started at the placement of the animals and ended at day 106. 30 000 Novo Color pullets, non-vaccinated against coccidiosis, were raised in one barn divided in 2 sections. 15000 pullets received the standard diet free of anticoccidial medications (NC) and 15000 pullets received the same diet supplemented with the probiotic *Pediococcus acidilactici* CNCM 4622 (PA - Bactocell® Lallemand SAS, at 109CFU/kg of feed). The weight of the birds was recorded through an automatic weighing scale but statistical analysis was not performed on this parameter due to the absence of technical replicate. Muscle thickness was individually measured on 20 randomly selected birds using an innovative and noninvasive method based on ultrasonography. Measurements were performed on the top of the keel bone, perpendicularly to the pectoralis muscle from the surface of the skin to the keel bone (include both pectoralis major and minor). Statistical analysis were performed on muscle thickness using a student t-test (SPSS Statistics 27.0). At the end of the trial, numerical improvement in FCR (NC:3.93 vs 3.87), body weight (NC:1373g vs 1380g), weight homogeneity (NC:83% vs 87%) and mortality (NC:3.11% vs 0.90%) were recorded. An episode of coccidiosis was detected at 35 days of rearing in the NC group and led to a 5-day treatment with Amprolium. Muscle thickness was found significantly higher in PA birds (NC:9.4 mm vs 13,3 mm; p<0.001). Interestingly, the effect of the PA under study on protein retention has already been documented in layers and in piglets and this effect could be associated to an improved digestibility or a reduction of inflammation resulting in less nutrients diverted to the immune response. The higher mortality in the NC group suggests that these birds have been more immune stimulated compared to the supplemented ones. Supplementing pullets with PA probiotic looks to be a promising nutritional strategy to secure laying hen performance.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-072 Phase dependent reduction of dietary protein levels has no negative impact on performance parameters while low or zero soybean meal (SBM) diets perform better compared to SBM fed broilers**B. Saremi¹, L. Vlerick², B. Matton¹, J. Millemcam²¹CJ Europe GmbH, Frankfurt, Germany, ²Poulpharm BV, Izegem, Belgium

Sustainability has become a key objective in animal industry. In Europe, SBM is a major protein source which has a negative impact on sustainability figures because of being mainly an imported ingredient from non-EU countries. Lowering crude protein (CP) levels is a key to reduce the SBM dependency with occasionally negative impacts on performance results. Recently, zero SBM diets with an emphasis on local raw materials have become a focus in the industry to reduce the carbon footprint. In a 3-phase feeding experiment (0-12, 13-21, 22-35 days), the dietary CP levels were reduced either only in the finisher phase (19% to 17%), in both the grower phase (20% to 19%) and finisher phase (19% to 17%), or in starter, grower and finisher phases (21% to 20%, 20% to 19%, 19% to 17%, respectively). In two additional groups, the inclusion of SBM was reduced either to a maximum of 15% SBM (low) or 0% SBM compared to a positive control (PC) group (Aviagen 2019 was modified to 115% for SID Arg to Lys and 40% for SID His to Lys). Ross 308 birds (n=1350) were divided between six groups (15 pen replicates each). The body weight (BW), daily weight gain (DWG), daily feed intake (DFI) and feed conversion ratio (FCR) were measured. At day 36, 4 birds per pen were slaughtered for carcass evaluation. Foot pad lesion scoring (FPS) was done at day 22 and 35. Differences were studied with a linear regression model. Post-hoc pairwise comparisons were made without adjustment method (P<0.05). Low CP diets had no negative impact on performance parameters. Low SBM group had a better BW and DWG at day 22 compared with PC while both zero and low SBM groups stayed superior compared to PC at day 35. Birds who received low CP diets only during finisher and grower phases had also better DWG from day 22-35 compared to the PC group. Birds of zero SBM group had a better FCR compared to PC during the starter and grower but not finisher phase. During the entire experiment the low and zero SBM groups had a superior FCR, better carcass weight and better breast meat weight compared with the PC. Low CP diets had no negative impact on FCR, carcass weight and breast meat weight. A low CP diet being fed either in finisher phase or during the three phases had a positive impact on FPS at day 35. In conclusion, low CP diets are possible to be applied to broiler diets without any negative impacts on performance parameters. Low and zero SBM diets showed performance superiority compared to a SBM based diet.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-073 Phosphorus and calcium requirements for bone mineralization of growing broilers predicted by mechanistic modelling**M. Reis^{2,1}, N. Sakomura², I. Bouvarel³, R. Angel⁴, A. Narcy⁵, M. Létourneau Montminy¹¹Laval University, Quebec, Canada, ²UNESP, Jaboticabal, Brazil, ³ITAVI, Nouzilly, France, ⁴University Maryland, College Park, United States, ⁵INRAE UMR BOA, Nouzilly, France

Phosphorus (P) is an essential nutrient in livestock feed but can pollute waterways. In order for poultry production to become less of a threat to the environment, excreta must contain as little P as possible or be efficiently used by plants. To optimize P use and enhance sustainable practices, a better understanding of the fate of dietary P by growing broilers is necessary. A model was developed to estimate the metabolic fate of calcium (Ca) and P in broiler chickens. The objective of this study was to invert (i.e. input becoming the output) the mentioned model and dynamically predict broiler requirements for Ca and P. The model is organized into three compartments: 1) digestion, accounting for Ca and P absorption; 2) soft tissue, including feather-free body protein and lipid, and feather protein predicted based on a mechanistic growth model with protein as the driver component; and 3) body ash, which accounts for deposition and mobilization of Ca, P, and miscellaneous minerals in the body. The Ca and P requirement was predicted using a factorial approach. Requirements are the amount of Ca and P that must be absorbed to maximize the growth of soft and bone tissues. A digestibility of 50% was assumed for Ca. A global sensitivity analysis was performed. The daily requirements estimated were compared with the predictions available in the literature as behavior analysis. The sensitivity analysis for digestible P requirement showed that both the percentage of P in body protein and the percentage of Ca in body ash represented 72% of the total variation observed, whereas the protein maturity ratio represented 22% of the variation. For total Ca requirement, the protein maturity ratio and the percentage of Ca in body ash represented 21 and 79% of the total variation observed. The requirements of digestible P and total Ca for broilers until day 21 were higher than Rostagno tables (0.45 vs 0.39% and 1.13 vs 0.94%) and were lower from 22 to 35 days (0.29 vs 0.31% and 0.62 vs 0.80%). The requirements of digestible P and total Ca for broilers until day 21 were close to that of Ross 308 (0.45 vs 0.45% and 1.10 vs 0.90%) and were lower from 22 to 35 days (0.29 vs 0.39% and 0.62 vs 0.78%). By its mechanistic construction, the current model allows to predict broiler requirement based on tissue growth kinetic. After trials of validation, it could be used by nutritionists to dynamically predict the concentrations of those minerals in the feed of broiler chickens.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-074 Phosphorus requirements and phytase activity in wheat- and maize-based diets for two strains of senior laying hens**S. Moeyersons^{2,1}, A. De Grande², N. Everaert¹, E. Delezie²¹Division of Animal and Human Health Engineering, Department of Biosystems, KU Leuven, Leuven, Belgium,
²Flanders Research Institute for Agriculture, Fisheries and Food, Melle, Belgium

Although the calcium and phosphorus metabolism of laying hens is frequently studied, the nutritional requirements of laying hens past 70 weeks of age are still unacquainted. Therefore, two experiments were conducted to determine the available phosphorus (avP) requirement and effect of additional phytase for diets with different feedstuffs. Experiment 1 was conducted on 480 Lohmann brown hens from 90 to 102 weeks of age housed in enriched cages, in which performance, egg quality and bone health parameters were determined. Sixteen wheat-based diets were used varying from 0.45 avP to 0.11 avP with a gradually reduction of 0.05, resulting in 8 levels of avP. At each avP level one treatment group received 300 IU additional phytase and the other group received 0 IU. Each dietary treatment had 5 replicates with 6 birds per replicate. The obtained data were analysed using a generalized linear model in R version 4.1.0. Experiment 2 was conducted on 72 Isabrown hens and 72 Dekalb White hens from 70 to 80 weeks of age, examining the same parameters. A 2x2 set-up was used with feedstuff (maize or wheat) and avP (0.45 or 0.11) as fixed factors resulting in 4 different dietary treatments, with 12 replicates consisting of 3 birds per cage. The data of this experiment were analysed using two-way ANOVA and post hoc Tukey test. In experiment 1 no indication of linear regression was observed. In the second experiment however Dekalb white hens at 80 weeks of age showed interaction between feedstuff and avP level for laying percentage ($p=0.012$), FCR ($p=0.042$) and shell thickness ($p=0.010$), in which the effect of the reduction was higher for the maize-based diet compared to a wheat-based diet. No interaction was observed for feed intake, egg mass, breaking strength and relative shell weight, for which avP level had a significant effect with respectively p -values of $p<0.001$; $p<0.001$; $p=0.045$; $p<0.001$. For Isabrown hens no interactions of feedstuff and avP level were observed for any parameters. As the avP level was reduced, a decrease of feed intake ($p=0.014$) and a decrease of egg mass ($p=0.039$) were observed. A reduction of avP led to a lower bone weight ($p=0.003$) and lower bone ash content ($p=0.021$). The results led to the conclusion that the avP level can be reduced from 0.45avP in a wheat-based diet without an inorganic phytate source. However, the different response between breeds to a phosphorus deficient diet, indicates a difference in calcium-phosphorus metabolism.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-075 Protein-rich circular ingredients can partly replace soybean meal in broiler diets**J. van Harn¹, H. Berman², A. Jansman¹, A. Dijkslag²¹Wageningen Livestock Research, Wageningen, Netherlands, ²ForFarmers, Lochem, Netherlands

Reducing soybean meal (SBM) in broiler diets by inclusion of circular protein-rich ingredients is one way to produce meat in a more sustainable way and to be less dependent on SBM-import from outside the EU. Alternative protein-rich ingredients might contain factors that limit their inclusion in diets without compromising growth performance of broilers. Therefore, a broiler experiment was performed in which six 4-phase diet programs were compared: SBM (control), peas, field beans, sunflower seed meal (SFM), rapeseed meal (RSM) as main protein sources and a SBM-free diet. In each feeding phase all diets, except SBM-free diet, contained some SBM and a maximum level of the more circular protein sources. Within a feeding phase diets were iso-caloric and had similar AA-SID concentrations. Feed and water were provided for ad libitum intake during the entire experimental period. The study was performed with 1,044 fast (FG) and 1,044 slow-growing (SG) male broilers from 0 - 38 days of age. The broilers were housed in 72 floor pens (2 m²) bedded with wood shavings (29 birds/pen). Each diet program was replicated 12 times, 6 times with FG and 6 times with SG broilers. All data were statistically analysed by ANOVA with breed (FG / SG), diet program ($n=6$) and the interaction breed * diet program as explanatory factors. Feeding pea-based diets resulted in a similar performance compared to the control diet in both FG and SG birds. FG and SG broilers fed the field bean-based diets performed similar to the control diet fed broilers. FG birds fed the SFM diets had impaired growth rate and FCR compared to the control, while with SG broilers similar results were obtained. SG birds performed better on the RSM based diets compared to the control, but FG broilers performed worse on these diets relative to the control treatment. Both FG and SG broilers showed the lowest performance on the SBM-free diet. In conclusion, partial replacement of SBM by alternative protein-rich ingredients is possible without compromising growth performance. This contributes to the development of more circular broiler production systems.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-076 Raw materials non-digestible nitrogen compounds (NDNC) as formulation predictor of nitrogen excretion in broiler chickens**T. Mahmood¹, F. Rouffineau¹, A. Cayzac¹, Y. Mercier¹¹Adisseo France S.A.S, Commeny, France

Crude protein (CP) is a common criterion for raw material characterisation using total nitrogen and an average coefficient i.e., N X 6.25. This characterisation does not distinguish nitrogen origins and utilisation meaning that depending on the raw material, difference exists between CP and the sum of digestible amino acids that can be considered as non-digestible N compounds (NDNC) which presumably will not be retained by animals. We hypothesized that NDNC criteria would better predict N excretion by considering nitrogen supply over dig. amino acids. To test this concept, we formulated four isocaloric (ME, 2950 kcal/kg) experimental diets balanced in essential amino acids: at high (H, 21.5%) and low (L, 18.8%) CP level, and three level of NDNC: H3.01; H3.9; L2.6, and L3.01. After 0-10 d on a common starter diet, 120 birds were randomly allotted to the 4 dietary treatments with 30 replicates of one bird each and experimental diets were fed from 11-23 d. A digestibility assay (20-23 d) was conducted to measure N intake, N retention (Nret), total N, uric acid-N (UA-N), and NH₃-N excretion. The data was subjected to ANOVA and means were compared by Tukey's test. Further, stepwise regression analyses were run to evaluate the impact of diet CP, true protein (TP), digestible protein (DP), NDNC, feed intake, and their respective interactions if any, on different response variables. Decreasing CP resulted in lower N intake without any effect of NDNC level (P>0.1), whereas higher NDNC induced higher N intake at high CP level (P<0.05). NDNC level showed a significant effect (P<0.05) on total N excretion irrespective of the CP level (H3.9>H3.01=L3.01>L2.6). In terms of percentage, H3.9 had the lowest Nret while L2.6 had the highest Nret (P<0.05). High NDNC at both CP levels led to high UA-N excretion (P<0.05). Likewise, NH₃-N excretion was highest in H3.9 and lowest in L2.6 group (P<0.05). The stepwise regression analyses indicated that total N and UA-N excretion were increased by the FI, NDNC and DP without interaction, while CP and TP were non-significant. Nonetheless, only FI and NDNC impacted the faecal N excretion. The scaled estimates in the regression model showed that the effect of NDNC was always proportionally higher than diet CP, TP and DP (the main effect being FI). These results indicate that the calculated NDNC of the feed formula should be of interest to accurately predict broiler nitrogen excretion leading to more sustainable feed formulation.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-077 Reduce, recycle and reuse: tomato and pepper from food waste for diets of end-of-lay hens in a sustainable egg production system. Egg quality traits**A.R. Di Rosa¹, G. Pace², F. Accetta¹, V. Lo Presti¹, V. Chiofalo^{1,3}¹Department of Veterinary Sciences, University of Messina, viale Palatucci 13, 98168 Messina, Italy, ²NUOVITA' - via degli Eucalipti 19, 97013 Comiso, Italy, ³Consortium Research of Meat and Agribusiness Chain, viale Palatucci 13, 98168 Messina, Italy

The commercial value of spent laying hens has long been considered negligible, but today consumers pay more attention to the living conditions of hens, driving the market toward ethical and sustainable farming systems. Aim of this work was to evaluate the possibility of rearing spent hens and the effect of rearing system and use of food waste on eggs quality. A total of 300 ISA Brown laying hens (20 weeks old) were raised in barn and fed with commercial diets. Hen day egg production (HDEP) and average egg weight were recorded daily. At 70 weeks of age, hens were divided into 3 groups: one group (CTRIN) was left in the farm, under the same conditions and diet. The two other groups were transferred in outdoor system and fed one with the same commercial diet (CTROU) and one (TPOU) with a basal diet and an integration of tomato (5%) and pepper (2.5%) waste collected from a commercial processing local plant. Laying performance were recorded further 30 weeks. At week 70 and at week 100, eggs were sampled for quality evaluation. Physical and chemical parameter, fatty acids profile and total polyphenols content were determined. As expected, from 24 weeks of age, egg production rates exceeded 90% until 46-48 weeks and declined to approximately 74% at 70th week of age. From week 70 CTRIN drastically reduced HDEP to 16% at week 82. CTROU and TPOU groups, after a period of adaptation, maintained an HDEP of approximately 70-75% until week 100. As regard the egg quality, the 3 groups showed similar characteristics. The weight of whole egg, at week 100, was 63.8 gr in TPOU, similar to weight of CTRIN group at week 70 (63.2 gr), while CTROU showed eggs significantly lighter (59.95 gr; p=0.038) at the end of the trial. The average weight of the eggs' components, as well as the gross composition, were not significantly (p < 0.05) different between groups. Yolk color, measured by Roche Color Fan, significantly increased for TPOU hens (12.7), followed by the CTROU (9.9) and CTRIN (7.4) groups (p<0.0001), suggesting the transfer of carotenoids from feed to eggs. Fatty acid profile was not influenced by the new rearing system or by the diet, instead the polyphenol content was higher in TPOU (4.42 mgGAE/g) in comparison with CTROU (3.5 mgGAE/g) and CTRIN group (2.39 mgGAE/g) (p=0.023). These preliminary results showed the really possibility to use the end-of-lay hens fed food waste in a sustainable niche market, for "ethic eggs" production.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-078 Reducing protein content increases metabolizable energy in broilers**

T. de Rauglaudre^{2,1}, B. Méda³, S. Fontaine⁴, W. Lambert⁴, S. Fournel¹, M. Létourneau-Montminy²

¹Département des sols et de Génie Agroalimentaire, université Laval, Québec, Canada, ²Département science animales, université Laval, Québec, Canada, ³Institut national de recherche pour l'agriculture, l'alimentation et l'environnement, Nouzilly, France, ⁴Metex animal Nutrition, Paris, France

Reducing dietary crude protein (CP) has the potential to reduce environmental impacts of poultry production. However, many studies have reported an increase in fat deposition. This suggests that CP content could impact energy metabolism. The objective of this project was therefore to study the effect of reducing CP on apparent metabolizable energy (AME), nitrogen (N) retention and AME corrected for zero N retention (AMEn). For this purpose, three experimental treatments were tested, a control diet (C; CP= 20.5 %; DEB = 224 mE/kg), a low CP diet (LCP; CP = 17.5 %; DEB = 145 mE/kg), and a low CP diet supplemented with K carbonate (LCP+K; CP = 17.7%) to bring the DEB to the level of C. The three diets were iso energy (AMEn = 3050 kcal) and SID lysine (9.5 g/kg), and feed-grade amino acids (AA) have been used to reach indispensable AA requirements. At 20-day-old, 72 chickens were randomly allocated to 18 cages of 4 birds each. After 7 days of adaptation to the experimental diets, total excreta and feed consumption were measured daily per cage for 3 days and a representative sample of excreta was collected. Compared to control, the water intake was decreased by 31% for LCP (P<0.01) and numerically by 10% for LCP+K (P=0.438), the dry matter content of the excreta was increased only for the LCP treatment (26%; P<0.001). The decrease in protein (C vs. others), has reduced the excreta N content (-24%; DM basis; P<0.001). The decrease in CP has decreased the N excretion by 34% (P<0.001) and 30% (P<0.001) in LCP and LCP+K respectively. Compared to C, AME was increased by 110 kcal/kg for LCP (+3.5%; P<0.01) and by 131 kcal/kg for LCP+K (+4.1%; P<0.001) while the AME of LCP and LCP+K were similar. This indicated that the DEB did not affect energy digestibility. Compared to C, N retention was decreased only for LCP (-23%; P<0.01), but N efficiency was increased for both LCP (6%; P<0.05) and LCP+K (11%; P<0.001). The AMEn content is increased by 199 kcal/kg for LCP (P<0.001) and by 145 kcal/kg for LCP+K (P<0.001). The obtained AMEn results were compared with the highest values of AMEn reported for feedstuff in literature to test the hypothesis of an underestimation during feed formulation. The current values are still far greater (+70 kcal) indicating that CP reduction have increased energy digestibility and maybe responsible for carcass fattening.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-079 Reduction of protein content and electrolyte balance to reduce nitrogen losses through volatilization in broilers**

T. de Rauglaudre^{2,1}, B. Méda³, S. Godbout⁴, W. Lambert⁵, S. Fournel¹, M. Létourneau-Montminy²

¹Département des sols et de Génie Agroalimentaire, université Laval, Québec, Canada, ²Département science animales, université Laval, Québec, Canada, ³Institut national de recherche pour l'agriculture, l'alimentation et l'environnement, Nouzilly, France, ⁴Institut de recherche et de développement en agroenvironnement, Québec, Canada, ⁵Metex animal Nutrition, Paris, France

Reducing crude protein (CP) content in broiler feeds has the potential to reduce environmental impacts related to nitrogen (N) volatilization such as eutrophication and acidification. As soybean meal (SBM) is rich in potassium (K), the reduction in CP also reduces the K and therefore the electrolyte balance (DEB) if not controlled. Both DEB and CP have been shown to affect water intake and litter moisture, which could increase the volatility of excreted N. The objective of this project is to study the effect of decreasing CP content and DEB on the amount and form of volatilized N. Twelve independent chambers, designed to continuously measure ammonia (NH3) and nitrous oxide (N2O) concentrations, were used. Each chamber housed simultaneously 37 male Ross 308 chickens during the two trial runs, until 35 and 37d. After a single starter diet (0-10d), three experimental diets were given to birds during growing (11-21d) and finishing (22-end) periods. A control diet (C), a low CP diet (LCP; -16 g/kg in grower and -30 g/kg in finisher) and a low CP diet with potassium carbonate (LCP+K) supplementation to bring the DEB back to the control level (230 mE/kg in grower and 220 mE/kg in finisher). Diets were pelleted and corn, SBM and canola meal based. Nitrogen retention was measured by carcass grinding. Litters were weighed and analyzed to calculate N volatilization. Results showed that lowering CP decrease N excretion by 28% (P<0.001) and increase N efficiency by 14% (P<0.001). The LCP and LCP+K treatments significantly (P<0.001) reduced N volatilization by 61% and 44%, respectively. This reduction in N volatilization is mainly driven by the reduction of NH3 which, compared to C, were reduced by 70% (P<0.001) and 48% (P<0.01) for the LCP and LCP+K respectively. The decrease in N and NH3 emissions is not only due to a reduction in N excretion. Indeed, the volatility of excreted N was decreased by 44% (P<0.001) and 25% (P<0.01) for LCP and LCP+K respectively. This decrease could be explained by, compared to C, a lower water intake (-20%, P<0.01; -12%, P=0.073) which leads to a numerically lower litter moisture (-9%, P=0.06; -4%, P=0.258) for LCP and LCP+K respectively. In addition, the decrease in DEB and CP reduced litter pH by 7% (P<0.05). Although the reduction of CP has more impact on N lost through volatilization, reducing K with CP is also impactful. The reduction of N losses through volatilization improves the sustainability of chicken meat production.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-080 Relationship of electrolyte balance and dietary calcium and phosphorus content to chicken performance**

M.A. Solano-Garcia^{2,1}, M. Létourneau-Montminy², A. Narcy³, D. Venne⁴, A.R. Alfonso-Avila¹

¹Centre de recherche en sciences animales de Deschambault - CRSAD, Deschambault, Canada, ²Université Laval, Quebec, Canada, ³Institut national de recherche pour l'agriculture, l'alimentation et l'environnement, Tours, France, ⁴Ceva Santé Animale, Scott, Canada

Calcium (Ca) and phosphorus (P) play a key role in the acid base balance. However, in chickens, current feeding strategies does not take into consideration the modulatory impact of dietary electrolyte balance (DEB) on Ca and P utilization. The objective of this project was to evaluate the impact of DEB and the contents of Ca and P in the diet on animal performances, systemic acid-base balance, and bone mineralization. A total of 3600 one-day-old male broilers (Ross 308) were randomly assigned to the 8 treatments, with 9 replicates of 50 chicks per replicate. Animals received 3 feeding phases (0-10, 11-21 and 22-34 days). They received a diet fulfilling requirement during the starter phase. Then, 2 levels of DEB were utilized (230 and 185 Meq/kg) in combination with 2 levels of Ca (0.77 and 0.54%) and 2 levels of available P (0.36 and 0.30%). In total, eight treatments were generated. Animal performances and collection of blood samples were performed on days 10, 21 and 34. In addition, 4 birds per pen were utilized for DXA measurements to obtain bone mineralization. The data were analyzed using the SAS GLIMMIX. Pre-planned orthogonal contrast was used to assess the effects of Ca, P, DEB and their interactions. The average body weight at day 10 and 34 was greater ($P \leq 0.02$; interaction Ca*DEB) when animals received LowDEB and LowCa. The ADG increase was also observed at 10, 34 and 0-34 days, feeding LowDEB and LowCa diets ($P \leq 0.04$; interaction Ca*DEB). In the same vein, the cumulative average daily feed intake (0-34 days) was greater by LowDEB and LowCa ($P=0.03$; interaction Ca*DEB). At day 21, caecal pH was increased by NormalCa as compared with LowCa ($P = 0.03$). A tendency ($P = 0.09$) to increase blood pH was observed at day 21 by NormalDEB in comparison with LowDEB. Plasma ionized Ca (iCa), at day 21, was decreased ($P = 0.001$) by LowCa diets, whereas LowP and NormalDEB diets increased iCa ($P \leq 0.04$). At day 34, blood pH, bicarbonate, total CO₂ was increased ($P \leq 0.04$) by NormalDEB, suggesting an alkalosis condition at systemic level. Bone mineral density (% BW) was increased by NormalCa and NormalP ($P = 0.004$; interaction Ca*P). These results show, as opposed to previous studies, LowDEB improve animal performances. Similarly, content of Ca and P influence animal performance and systemic acid-base balance indicators. Bone mineralization is mostly affected by dietary Ca and P contents. The interaction DEB, Ca and P in the diets should be considered to achieve an optimal animal performance.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-081 Spicy based additives as alternatives to Vitamin E supplementation as antioxidant in broiler chicken feeds**

F. Sevillano¹, M. Blanch², M.A. Ibáñez³, D. Menoyo¹

¹ETSIAAB, Departamento de Producción Agraria, Universidad Politécnica de Madrid, 28040, Madrid, Spain, ²Lucta S. A., Innovation Division, UAB Research Park, Edifici Eureka, 08193, Bellaterra, Spain, ³ETSIAAB, Departamento de Economía Agraria, Estadística y Gestión de Empresas, Universidad Politécnica de Madrid, 28040, Madrid, Spain

Vitamin E (Vit E) is included at high doses in commercial broiler feeds to boost performance because of its antioxidant function. Phytogetic feed additives with antioxidant properties might be used to spare or replace Vit E as antioxidant and reduce costs. Previous studies with an encapsulated product based on spices extracts (capsicum, black pepper, and ginger; SPICY) and others with olive pomace extract (OE), with certain antioxidant properties, have shown positive effects on broiler performance. The present study aims to test the potential use of SPICY and OE to spare Vit E in broiler feeds by comparing its incorporation at basal levels of Vit E to a diet with 100 ppm of added Vit E. To this end 640 Cobb 500 male broilers were randomly distributed among five experimental treatments (8 pens/treatment), a basal diet with no additives and no added Vit E in the premix as negative control (NC) and, four experimental diets obtained by adding different products on top of the basal diet: 100 ppm of Vit E (positive control, PC), 250 ppm of SPICY, 1.250 ppm of OE, or a combination of both products 250 ppm SPICY + 1.250 ppm OE (SPIOE). All products were supplied by Lucta, S.A., Madrid, Spain. The basal diet contained maize and soybean meal as main raw materials providing 10 ppm of Vit E. The experimental diets were fed ad libitum from 1 to 35 days of age. Body weight (BW) and feed consumption were determined by pen at 7, 14, 21, 28 and 35 d of age. A non-linear Gompertz model was used to analyze growth performance. Experimental diets significantly affected BW at the inflection point ($P < 0.05$) with animals fed PC, SPICY and SPIOE diets showing higher values than the NC and the OE fed birds. According to this model animals fed the NC and OE diets can reach 3 kg of BW in 39.1 and 38.8 days of age respectively while those fed the PC, SPICY and SPIOE would need 37.7, 38.1 and 38.2 days respectively. No significant differences among experimental diets were observed on feed intake. Animals fed the PC diet showed significantly ($P < 0.05$) better feed conversion ratio for the global period than birds fed OE, 1.27 and 1.32 respectively. It is concluded that, under our experimental conditions, a maize-soybean meal diet providing 10 ppm of basal Vit E, supplemented with 250 ppm of SPICY or 250 ppm of SPICY + 1.250 ppm OE, results in better growth performance than the basal diet alone and similar to a diet supplemented with 100 ppm of Vit E.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-082** Stretching boundaries on sustainable broiler feeding: Moist brewers' spent grains and European inclusive dietsE. Frehen-van Calmthout^{1,2}, R. Oppers², C. Jansen³, R. Kwakkel²¹ABZ De Samenwerking, Eindhoven, Netherlands, ²Animal Nutrition Group / Wageningen University, Wageningen, Netherlands, ³Cell Biology and Immunology Group / Wageningen University, Wageningen, Netherlands

The increasing demand for poultry meat in the near future, while releasing pressure of the feed over food competition, urges for the development of new feeding strategies. Several studies on moist feeding have proven the benefit on the development of the gastrointestinal tract (GIT) of broilers and GIT related parameters. A preliminary study in our project on moist feeding, including brewers' spent grains (BSG), showed positive results on several production and morphological parameters, without any negative effects on immunological factors. The present study was aimed to assess a sustainable moist diet including BSG, in the perspective of using European dietary ingredients. A 2x2 factorial design was executed with 416 male Ross broilers, including 4 treatments, with 8 repetitions. The birds were housed on wood shavings, 13 broilers per pen, using commercial climate and lighting conditions. Half of the birds were fed a non-European (T1) or European (T3) ingredient dry pellet diet, the other half were fed a moist diet including 20% BSG either as non-European (T2) or European (T4) diet. The water to feed ratio for T2 and T4 was 1:1. A linear mixed model was used as a statistical analyses except for eating pattern, where a two way type III ANOVA was used. In week 1, both body weight gain (BWG; 9.3%) and dry matter feed intake (DMFI; 15.5%) were higher ($p < 0.001$) for dry fed birds as compared to moist fed birds, irrespective of diet formulation. From week 3 onwards the moist fed birds performed better than the dry fed birds, resulting in week 5 in significant higher BWG (13.8%; $p = 0.004$) and DMFI (13.4%; $p = 0.007$). Relative weights of the proventriculus and gizzard were higher on day 7 ($p < 0.001$ and $p = 0.002$) and for the gizzard also on day 14 ($p < 0.001$) and day 35 ($p < 0.001$) for moist fed birds. Mean retention time tended to be higher ($p = 0.068$) in the small intestine for moist fed birds. Eating pattern was not influenced by any of the diets, but within a 6-hour meal feeding frequency, birds consumed 28-32% in the first hour and 12-16% in each of the remaining hours. There seems to be a great potential for introducing a sustainable moist diet including BSG and European ingredients for broiler chickens, because BW at 35 days was 8.3% higher compared to dry pellet non-European fed birds.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-083** Sustainable broiler production: total removal of added inorganic phosphate in commercial diets with or without by-products and containing phytaseY. Dersjant-li¹, A. Bello¹, J. Firman², L. Marchal¹¹Danisco Animal Nutrition & Health, IFF, 2342 BH Oegstgeest, Netherlands, ²Missouri Contract Poultry Research, Boonville, 65233, MO, United States

Previous studies showed that with supplementation of a novel consensus bacterial 6-phytase variant (PhyG), it was possible to totally remove added inorganic phosphate (iP) in broiler diets from day one, maintained or improved performance and bone ash compared to a nutrient adequate positive control (PC) without phytase. The objective of this study was to test if the phytase can totally replace iP and maintain performance and bone ash in comparison to commercial PC diets that contain phytase and xylanase. Four dietary treatments in a 2x2 factorial arrangement were used including a PC with normal phytate (PCn) and with increased phytate content (PCh), 2 iP free (IPF) diets reformulated from PC without monocalcium phosphate (IPFn and IPFh). The PCn was based on wheat, SBM and corn with less than 2% rapeseed and sunflower meal in finisher phases, with the average analyzed phytate P at 0.32%. The PCh was with additional rapeseed and sunflower meal in all phases at a higher level (up to 6% for each by-product) with the average analyzed phytate P at 0.35%. The PC diets were supplemented with 1000 FTU/kg of PhyG and 750 XU/kg xylanase, applied with Ca (about 0.2% point), dig AA (up to 0.06% point) and ME (70 kcal/kg) downspec vs. breeder recommendation. The IPF diets were with increased PhyG dose to 3000, 2000 FTU/kg in starter and grower phase respectively and maintained the same dose in finisher phase. Male Ross 308 broilers were randomly assigned to 48 pens (25 birds/pen) with 12 replicates per treatment. At day 21 and 42, four birds per pen were euthanized for tibia ash determination. Data was analyzed by two-way ANOVA. No phytate and diets interaction was observed for performance except a tendency for 1-21d FCR ($P = 0.09$). Phytate effect was seen only for 1-10d FCR ($P < 0.05$). Across phytate levels, the IPF diets maintained d42 BW (3018 vs 3019g), 1-42d FCR (1.567 vs 1.579), tibia ash at d21 (40.6 vs 41.1%) and d42 (32.9 vs 32.1%) compared to PC. An interaction between diets and phytate was seen for paw score and breast yield. Paw score was improved ($P < 0.05$) in both IPF diets compared to PCh, while PCn was intermediate. Breast yield increased ($P < 0.05$) with IPFh vs PCh. The production cost (€/kg BWG) was 2% lower with IPFn vs PCn. In conclusion, PhyG supplementation in IPF diets maintained performance, bone ash vs commercial PC, may improve paw score in diets with increased by-products, lead to production benefit and enhance sustainable broiler meat production.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-084 The apparent metabolizable energy value of black soldier fly larvae fat used in broiler chicken diets**B. Kierończyk¹, M. Rawski², K. Stuper-Szablewska³, D. Józefiak¹¹Poznań University of Life Sciences, Department of Animal Nutrition, Poznań, Poland, ²Poznań University of Life Sciences, Department of Zoology, Laboratory of Inland Fisheries and Aquaculture, Poznań, Poland, ³Poznań University of Life Sciences, Department of Chemistry, Poznań, Poland

Up to now, there is limited information about the metabolizable energy level of *Hermetia illucens* (black soldier fly) larvae fat. Due to this, this insect's dietary fat cannot be used in practical broiler chicken nutrition. Therefore, the present study aimed to investigate the apparent metabolizable energy (AME) and apparent metabolizable energy corrected to zero nitrogen balance (AMEn) levels of *H. illucens* larvae fat for broiler chickens of various ages. A total of 400 1-day-old male Ross 308 birds were randomly assigned to four dietary groups (10 replicate pens per treatment; 10 birds per pen). The following treatments were applied: H10 - basal diet without dietary fat inclusion, H103 - basal diet enriched with 30 g/kg *H. illucens* larvae fat, H106 - basal diet enriched with 60 g/kg *H. illucens* larvae fat, and H109 - basal diet enriched with 90 g/kg *H. illucens* larvae fat. Broilers had ad libitum access to mash form feed and water. Excreta samples were collected on d 14, d 28, and d 35. To establish the AME and AMEn values of *H. illucens* larvae fat, the simple linear regression method was used. The results show that the AME and AMEn values of *H. illucens* larvae fat for broiler chickens are 9 049 kcal/kg (37.86 MJ/kg) and 9 019 kcal/kg (37.74 MJ/kg), respectively. Furthermore, because of the fact that the birds' age significantly ($P < 0.001$) affected the AME and AMEn levels, the implementation of *H. illucens* larvae fat to broiler diets should be considered in each nutritional period using the recommended regression model $AME = 2\,559.758 + 62.989 \times \text{fat inclusion (\%)} + 7.405 \times \text{day of age}$ and $AMEn = 2\,543.2663 + 62.8649 \times \text{fat inclusion (\%)} + 7.3777 \times \text{day of age}$. The present data highlighted that the *H. illucens* larvae fat metabolizable energy level is similar to that of soybean oil. However, the authors do not recommend using the above-mentioned regression equations to calculate the energy level of *H. illucens* larvae fat for young birds, i.e., before 14 d of age. This work was supported by an OPUS-20 grant titled "The role of *Hermetia illucens* larvae fat in poultry nutrition - from the nutritive value to the health status of broiler chickens" (no. 2020/39/B/ NZ9/00237), which was financed by the National Science Center (Poland).

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-085 The association of different feed additives prevents the negative effects of necrotic enteritis on broilers**R. Barbalho¹, M. Bonato¹, F. Souza¹, L. Araújo², A. Kiess³, C. Castaneda³¹ICC Brazil, São Paulo, Brazil, ²University of São Paulo, Pirassununga, Brazil, ³Mississippi State University, Starkville, United States

The objective of this study was to evaluate the efficacy of a yeast cell wall, essential oil, and a probiotic in non-AGP diets of broilers challenged with *Eimeria* spp. and *Clostridium perfringens*. Seven hundred 1-day-old chicks (male) Ross x Ross 708 from a commercial hatchery were allocated to 48 pens with 15 chicks per pen for ten days. On day ten, 672 birds were moved to a biosecurity level 2 room (BSL2 facility) to acclimate. They were allocated to 96 cages in a CRBD distributed in 4 treatments with seven birds per pen and 24 replicates. They were randomly distributed in the groups: (NC) Negative control - without coccidiostats; (PC) Positive control - with coccidiostats (Maxxiban® at 72 g/MT); (AFD1) NC + Yeast Cell Wall (from *Saccharomyces cerevisiae*, ImmunoWall®) at 500 g/MT + Essential Oil (blend of Carvacrol and Thymol) at 300 g/MT; (AFD2) NC + Yeast Cell Wall (ImmunoWall®) at 500 g/MT + Essential Oil (blend of Carvacrol and Thymol) at 600 g/MT + *Saccharomyces Boulardi* 10ME (Levucell®) at 100g/MT. On day 14, all birds were individually challenged via oral gavage with a 20-fold dose of Coccivac-B52® and received 1 mL of inoculum containing a mixture of 5 *Eimeria* strains. On days 14 and 21, 1mL of *C. perfringens* (108 CFU/mL) was inoculated per bird. The performance was measured until 28 days. Samples of the Bursa of Fabricius, duodenum, jejunum, ileum, and cecum were collected at 21 and 28 days to calculate the lesion score of necrotic enteritis (NE). No statistical differences were observed ($P > 0.05$) in the NE score. Body weight gain (BWG) was improved ($p = 0.002$) in PC groups vs. the other treatments (387 g vs. NC 353 g, AFD1 361 g, and AFD2 358 g) on the first period until 14 days. However, regarding the total period (1-28 days), BWG was similar in groups PC (1185 g), AFD1 (1155 g), and AFD2 (1184 g) and differing ($P = 0.0001$) from NC (1075 g). The feed conversion rate (FCR) was improved in treatments AFD1 (1.17) and PC (1.15) ($P = 0.003$) for the first 14 days, but on the cumulative period, PC (1.32), AFD1 (1.32) and AFD2 (1.31) showed statistical differences ($P = 0.001$) from NC (1.43). The results of this study demonstrated the efficacy of the feed additives association in preventing the negative effects of NE on performance in broilers.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-086** The CEER project - Development of sustainable poultry production based on a circular economy for feeding resourcesP. Khanal¹, G. Næss¹, B.M. Dahal², H. Luitel³, S. Tiwari³, A. Ghimire², U. Tiwari³¹Faculty of Bioscience and Aquaculture, Nord University, Steinkjer, Norway, ²Department of Environmental Science and Engineering, Kathmandu University, Kathmandu, Nepal, ³Agriculture and Forestry University, Chitwan, Nepal

Establishing future sustainability within livestock requires implementing fundamental circular economic principles across multiple sectors. The poultry subsector is a central component of livestock and will play a critical role in achieving food security in the future. This requires developing sustainable poultry production by potentially identifying and utilizing alternative, sustainable, and environment-friendly feeding resources. Achieving a circular economy within the poultry feed industry requires effective collaboration between local and global actors. As an example, here we highlight the collaborative education and research activities within the livestock sector between Norway and Nepal through the CEER (Circular Economy through Education and Research) project. Knowledge, experience, and resources from local partners, institutions, and industries can contribute to establishing suitable curriculums and research activities within alternative feeding strategies. In the CEER project, three courses (Entomophagy, Sustainable Animal Nutrition, and Resource Recycling based Circular Economy) will be developed within the circular economy-based livestock sector in partner institutions in Nepal. Moreover, we aim to enhance academic knowledge through courses, lab and field exposures, and several student exchanges between North-South and South-South institutions at the master and PhD levels. These students will conduct educational and research activities that target insects, underutilized by-products, and locally available aquatic plants as alternative animal feed resources. Such actions can open the door for collaboration among agro-industries, feed industries, agricultural schools, universities, and research institutions. In addition, collaborative efforts toward developing courses, new academic programs, and specific research activities can strengthen capacity building toward a circular economy in both developed and developing countries. In conclusion, circular-economy-based livestock production, including poultry, can be achieved by maximizing the use of bioresources or by-products that are currently underutilized and have lower direct competition with human foods. This requires greater collaboration between various local and global actors and across multiple sectors for capacity building to face emerging challenges within the animal feed sector.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-087** The effect of commercial feed additives aiming at reducing antibiotic usage under commercial field conditions of intensive broiler farming in Greece and CyprusM. Simitopoulou¹¹Maria Simitopoulou, Chalkida, Greece

Commercial broiler farms, five in Greece and five in Cyprus, were involved in this study, all having a relatively high reliance on antimicrobials. All farms were arranged into five groups, two groups for Greece and three for Cyprus. For each group specific tailor made feed additive regimes, based on previous vet diagnoses, have been prepared with the objective to reduce the AB usage. The feed of the first group in Greece was supplemented with PoultryStarME (DSM-BIOMIN) a symbiotic which contains the strains *Bifidobacterium animalis* spp. *animalis*, *Lactobacillus salivarius* spp. *Salivarius* and *Enterococcus faecium*, Biotronic Top 3 & Biotronic Top Liquid (DSM-BIOMIN) which is a combination of organic acids (formic, acetic and propionic) and Digestarom PEP sol (DSM-BIOMIN) which is a mixture of flavouring compounds including E484 Glyceryl polyethyleneglycol ricinoleate. The second group's feed, in Greece, was supplemented with AdiCox (AdiFeed®), rich in phytoncides and phytoalexins, and B-Act (Huvepharma®) a probiotic feed additive that consists of viable spores of *Bacillus licheniformis* strain. The first group's feed in Cyprus was supplemented with B-Act (Huvepharma®), the second's group with Biotronic Top 3 (DSM-BIOMIN) and the third's group with Avipremium D (Vetagro®) a concentrated source of tributyrin in powder form (55% butyric acid). The timeline of on farm trials was: Historic period: 5 cycles before pre additive period. Pre additive period: 2 consecutive cycles, before any targeted additive interventions (control). Post Additive period: Immediately following, two further production cycles using one or a combination of selected additives. Between the pre and post additive period, it was showed a 50.3% decrease in the number of antibiotic treatments ($p < 0.01$), a non-significant 27.2% reduction in the days of treatment, as well as a 5.7% improvement in biological performance as measured by the EPEF ($p < 0.1$). Between the historic period against the post additive period it could be seen that again on a production cycle basis the number of antibiotic treatments was decreased by 58.7% ($p < 0.01$), a reduction of 52% in the days of treatment ($p < 0.01$) and an improvement of 16.9% ($p < 0.01$) as measured by EPEF. 'The targeted use of feed additives can be considered highly effective as it can improve the performance of the broiler farms and in parallel can reduce the use of antibiotics.'

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-088** The effect of grinding method and extent of pelleting of broiler diets on performance, feeding behavior, and digestive tract functionalityS. Dhakal¹, H. Hetland², B. Svihus¹¹Department of Animal Sciences and Aquaculture Sciences, Norwegian University of Life Sciences (NMBU), Ås, Norway, ²Fiskå Mølle, Fiskå, Norway

The effect of pelleted-only diets (POD) of three different coarsenesses and heterogenous diets (HTD, a mixture of coarse cereal particles and pellets) on broiler performance, feeding behavior, and digestive tract functionality was examined. It was hypothesized that HTD would result in a similar high feed intake to POD and that the coarser microstructure would encourage the development of the gizzard and thus improve digestive tract functionality. Maize and wheat were hammer ground using a 3mm screen and two screens with novel patterns (very coarse and moderately coarse) to increase coarseness. Three POD were produced based on these three grindings. Additionally, four diets were also produced by separating the coarse cereal particles from the very and moderately coarse grindings by sieving, pelleting the remainder of the diet, and finally mixing these into a complete HTD. Two HTD per grinding were produced with differences in the amount of fines by sieving one or two times. No significant ($P > 0.05$) difference in performance between birds fed the three POD was observed. However, HTD resulted in a lower feed intake and weight gain than POD ($P < 0.05$). Neither FCR nor ileal digestibility of starch and protein was affected ($P > 0.05$) by any of the dietary treatments. As expected, feeding HTD increased ($P < 0.05$) the relative weight of the gizzard and the weight of the gizzard contents. Particle size distribution of small intestinal contents was not affected ($P > 0.05$) by diet characteristics. Approx. 50% of the particles in the small intestine were between 0.15 mm to 0.36 mm when fed POD, confirming the extraordinary capacity of the gizzard to finely grind feed particles regardless of the coarseness of the diet. Eating time was only evaluated with moderately coarse diets (both POD and HTD), but no significant difference ($P > 0.05$) was found. The particles > 2.8 mm in the feeder disappeared first ($P < 0.05$), showing birds' preference for larger particles when offered HTD. Although the birds were able to handle the coarse microstructure of the diets without negative effects, the reduced performance in the case of HTD might be related to feed intake issues and due to particle selection behavior resulting in an imbalance in nutrient intake.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-089** The effect of oat hull inclusion level and extent of grinding of main ingredients on the performance and gizzard characteristics of broiler chickens fed oat-based pelleted dietsK. Itani¹, S. Ghimire¹, S. Dhakal¹, A. Smith², F. Steinhoff³, K. Ljøkjel³, B. Svihus¹¹Faculty of Biosciences, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway, ²DSM Nutritional Products Ltd, Heanor Gate Industrial Estate, Heanor, Derbyshire, United Kingdom, ³Felleskjøpet Fôrutvikling A.S., Trondheim, Norway

The effect of oat hull (OH) level, extent of grinding, and their interaction on the performance and gizzard characteristics of broilers were studied in this experiment. A total of 2860 one-day-old male broilers (Ross 308) were allocated to 130 floor pens bedded with wood shavings and kept on a starter diet until d10. On d11, the birds were randomly distributed among ten dietary treatments (with 13 replicate pens each) consisting of five oat-based pelleted diets of different OH levels and with main ingredients either finely- (2mm) or coarsely-ground (6mm). Using different proportions of hulled vs. dehulled oats (kernels), the following levels of OH were achieved: 0, 2.95, 6.5, 9.6 and 11.4% while the ratio of ingredients to oat kernels was kept constant for all diets. Birds and feed were weighed on d11 and 32. Gizzard contents weight and relative weight were higher with OH inclusion or coarse grinding. Gizzard contents pH decreased with coarse grinding or with increasing OH %, but the difference between diets containing 6.5, 9.6 and 11.4% OH was not significant. Fine grinding significantly improved weight gain. Feed intake was not affected by the extent of grinding but it increased with increasing OH level, although no difference was observed between the 0 and 2.95% or 9.6 and 11.4% OH. FCR increased with increasing OH, but there was no difference between the two lowest or between the two highest OH levels. There was a tendency ($p=0.08$) for an interaction between OH level and grinding where the increase in FCR was greater with coarse grinding especially at 9.6 and 11.4% OH. Feed intake corrected for OH decreased linearly ($p<0.01$), with the lowest value for 11.4% OH, but with no significant difference between the 0 and 2.95%, or between the 6.5 and 9.6%. FCR corrected for OH was significantly improved with OH inclusion, with best results at 6.5, 9.6 and 11.4% compared to the control diet, indicating better feed utilisation. Diluting the diets with OH improved gizzard development without affecting weight gain, however the poorer FCR with increasing OH was expected due to the increased feed intake as a compensatory mechanism for nutrient dilution. Importantly, broiler chickens were able to handle a diet containing 50% hulled oats (or 11.4% OH) and still maintained a similar weight gain compared to the control group. The positive effect of OH was also more obvious when they were finely ground.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-090 The effect of selenium sources on antioxidant status and performance of aging laying hens**A. Calik¹, H. Bayir¹, S. Ozbek², D. Cardoso², P. Sacakli¹¹Ankara University Faculty of Veterinary Medicine, Ankara, Turkey, ²Adisseo, Antony, France

Selenium (Se) supplementation is a standard practice in laying hens diets, using either inorganic form such as sodium selenite (SS) or organic forms like SeYeasts (SY) or pure forms of selenomethionine such as hydroxy-selenomethionine (OH-SeMet). Studies show that OH-SeMet is highly efficient in transferring Se to tissues compared to SS or SY. This transfer helps to maintain an effective antioxidant defenses and performance of layers. This trial aimed to determine the effect of Se sources on the antioxidant status and performance of ageing laying hens. 270, 63-week-old layers (Lohmann Brown Classic) were set in 1 of 3 treatments with 15 replicate cages per treatment with 6 birds per cage, in a randomized block design for 28 weeks: a 4-week adaptation period followed by a 24-week experimental period. A corn-soybean-based basal diet was formulated with the supplementation of 0.3 ppm of Se from different sources: SS, SY or OH-SeMet (Selisseo[®], Adisseo). The malonaldehyde (MDA) level in the blood was determined on 1 hen per cage. From the same hens, MDA and the fat content of the livers were measured at the end of the trial. Performance and antioxidant parameters were subjected to a one-way ANOVA. Mortality rate cracked and dirty egg percentages were compared using a Chi-square test. Statistical differences were considered significant at $p \leq 0.05$. No differences were observed between treatments for the mortality, feed intake or egg weight. OH-SeMet fed hens maintained a better FCR compared to SS (2.24 and 2.55, respectively ($p < 0.05$)), whereas SY fed layers showed an intermediate FCR of 2.42, with no differences between treatments. OH-SeMet fed birds were able to better mitigate the decrease in egg production as layers aged, resulting in a significant improvement in their performance. OH-SeMet resulted in a 9% higher laying rate than SS ($p = 0.05$), and 4.5% higher than SY. The percentage of cracked and broken eggs and dirty eggs was significantly reduced when using OH-SeMet, compared to SS and SY ($p < 0.001$). The MDA in the blood and liver decreased for the use of organic sources compared to SS ($p = 0.02$). A reduction in the liver fat content is also evidenced when organic sources were used compared to SS ($p < 0.001$). Feeding organic Se, especially OH-SeMet, to aged layers improved their production performances, and decreased the incidence of cracked, broken and dirty eggs. Organic Se improved antioxidant capacity and reduced the liver fat content of layers.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-091 The effects of carrier and production technology of phytobiotic on gastrointestinal tract development in broiler chickens**K. Lipiński¹, M. Mazur-Kuśnerek¹, Z. Antoszkiewicz¹, J. Kaliniewicz¹, P. Konieczka²¹Department of Animal Nutrition and Feed Science, University of Warmia and Mazury in Olsztyn, Poland, ²Department of Poultry Science,, University of Warmia and Mazury in Olsztyn, Poland

The aim of this study was to evaluate the effects of technology (conventional-CT and vacuum coating-VCT) and carrier type (diatomaceous earth-DE, sepiolite-S and lignocellulose-L) used in the production of phytobiotic preparations on gastrointestinal tract development in broiler chickens. The experimental materials comprised 96 male ROSS 308 broiler chickens (4 treatments, 12 replication, 2 birds per replication) which were fed complete diets (wheat, corn, barley, triticale/soybean and rapeseed meal) in mash form with the addition of phytobiotics (oregano, eucalyptus oil, anise oil, linalool, cinnamaldehyde, silica carrier, CT) or supplemented with the same phytobiotics as in the control group but produced with the use of VCT and different carriers (DE, S and L)-100 g/t. The following parameters were monitored: performance, the structure (length, weight,) and functional parameters (pH, viscosity). The SCFAs in the ceca and villus height and crypt depth in the duodenal of chickens were measured. Final body weights were significantly higher in the VCT groups than in control group (by ca. 4.6%). No significant differences in the weights of the crop, gizzard, proventriculus or cecum were observed between groups, whereas the weight of the small intestine varied. Birds fed diets supplemented with phytobiotics produced with the use of VCT were characterized by a shorter cecum (17.61, 17.02, 15.93 vs. 18.83 cm/kg BW, $P < 0.01$), and lower weight of the small intestine when L was used as a carrier (18.22 vs 21.27 g/kg BW, $P < 0.05$), compared with the control group. The use of DE and S as carriers for phytobiotics had a positive effect on height of intestinal villi (1566.8, 1593.3 vs. 1376.5 μm , $P < 0.05$). Chickens fed diets supplemented with phytobiotics produced with the use of VCT had lower pH in the digesta obtained from the gizzard and proventriculus as well as the cecum when DE was used ($P < 0.05$). Birds fed diets supplemented with phytobiotics produced with the use of VCT and DE as a carrier were characterized by higher (80.26 vs 71.48 $\mu\text{mol/g}$, $P < 0.05$) cecal concentrations of acetic acid and SCFAs (111.75 vs 106.64 $\mu\text{mol/g}$, $P < 0.05$). The present findings suggest that the new technology (VC) contributes to improving the structure and development of the gastrointestinal tract in broiler chickens. The best results were obtained when DE was used as a carrier. Funding: National Center for Research and Development, No. 6/1.1.1/2020 SS Duże/MSP/JN 4

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-092** The effects of guanidinoacetic acid supplementation in a low AMEn diet on growth performances and mortality of broilers farmed under Indian conditionsC. Gayrard¹, M. Klünemann¹, Y. Patil²¹Evonik Operations GmbH, Hanau-Wolfgang, Germany, ²Evonik Pvt Ltd., Tamil Nadu, India

The objective of this experiment was to assess the effect of guanidinoacetic acid (GAA) supplementation in a low-AMEn diet, on growth performances and mortality in broiler chickens under Indian conditions. A total of 2,200 Ven Cobb 430 broilers were allocated randomly into three treatments with six (positive control, PC) to seven (Negative control NC and GAA groups) replicates of 110 chicks each. Broilers were fed corn-soybean meal-based diets low in metabolizable energy (2900, 3025 and 3150 kcal/kg for starter, grower and finisher diets respectively, 1) Negative control NC, or 2) NC with 600mg GAA/kg (GAA); and 3) a positive control diet (PC) higher in metabolizable energy (3000, 3125 and 3250 kcal/kg for starter, grower and finisher diets respectively). The low metabolizable energy diets (NC and GAA) were obtained by a 5.1 times lower incorporation of soybean oil compared to the PC diet. The trial lasted 42 days. The feed intake of broilers fed GAA increased in response to energy reduction when compared to PC (4.29 vs. 4.21 kg intake in average during the trial, $P < 0.01$), whereas the feed intake from NC (4.23kg) was not affected by the energy reduction and was similar to both GAA and PC groups ($P > 0.05$). The supplementation of GAA in the diet increased significantly the average daily weight gain (ADG, 61.1 vs. 57.7 and 58.1g/D, $P < 0.001$), the feed efficiency (1.65 vs. 1.72 and 1.69, $P < 0.01$) and the live weight ($P < 0.001$) of broilers compared to both NC and PC groups respectively. The final live weight of broilers fed GAA was 5.4% and 5% higher compared to NC and PC groups respectively. The lowest mortality rate was obtained in the GAA and PC groups (3.0% and 4.3% respectively) vs. 7.5% in NC ($P < 0.001$). It is concluded that the dietary supplementation of 600 mg/kg GAA improves growth performances and the mortality rate in low metabolizable energy diets under Indian conditions. The inclusion of 600 g of GAA mg/kg of feed can successfully compensate 100 kcal AMEn reduction per kg feed and in some cases confer additional benefits beyond energy compensation.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-093** The effects of sources of manganese, zinc, and copper during the rearing phase on growth performance, tibia traits, egg production and eggshell quality in Lohmann Brown birdsR. Akbari Moghaddam Kakhki¹, C. Alfonso-Carrillo¹, A. García-Ruiz¹¹Poultry R&D, Trouw Nutrition, El Viso de San Juan, Toledo, 45215, Spain

Though micronutrients such as manganese (Mn), zinc (Zn), and copper (Cu) have traditionally been supplemented in poultry diets as inorganic salts, other forms such as metal amino acid chelates or hydroxychloride (HC) bound have been developed and promoted, owing to better bioavailability and absorption. This study aimed to evaluate the effect of the substitution of Mn-oxide, Zn-oxide, and Cu-sulfate with organic or HC sources during the rearing phase on growth performance, tibia quality, egg production and eggshell quality in Lohmann brown hens up to 100 weeks. A total of 180-day-old birds were distributed to three dietary treatments, each comprised of six replications. Pullets were fed crumbled diets with 65 mg/ kg of Mn, 50 mg/ kg of Zn, and 5 mg/kg of Cu supplied by oxide/sulfate, organic, or HC sources. Sixteen birds were moved to individual cages at 16 weeks of age. After the onset of lay, all the birds were fed a mash diet supplied by inorganic sources of trace elements. The body weight (BW), feed intake and feed conversion ratio during the rearing phase were not affected by the sources of the trace elements. The average BW of the pullet was 1,661 g at 16 weeks of age. Tibia dry weight, ash content, ash percentage, and breaking strength were not influenced by the trace elements sources at 10, 16, 25, and 100 weeks ($P > 0.05$). After the onset of lay up to 50 weeks, daily feed intake was increased by 4.7 g in response to the substitution of oxide/sulfate sources with HC sources in the rearing diets ($P = 0.011$). In addition, the egg mass was higher by 2.02 g in birds fed with organic-supplemented diets compared to the oxide/sulfate group ($P = 0.018$). During 50 to 100 weeks, birds in the organic group had higher hen-day egg production compared to the rest of the treatments ($P = 0.002$). The BW, egg weight, and feed conversion ratio were not affected by the sources of the trace elements ($P > 0.05$). The substitution of the trace elements sources did not affect the eggshell breaking strength, elasticity, and eggshell thickness. In conclusion, the results showed that the substitution of oxide/sulfate with organic sources during the rearing phase had a long-lasting improvement in production performance by increasing feed intake, hen-day egg production and egg mass.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-094 The fate of different concentrations of dietary oat hulls with varying grinding levels in broilers**S. Ghimire¹, K. Itani¹, S. Kazcmarek², A. Smith³, B. Svihus¹*¹Department of Animal Sciences and Aquaculture Sciences, Norwegian University of Life Sciences (NMBU), Ås, Norway, ²Department of Animal Nutrition, Poznan University of Life Sciences (UPP), Poznan, Poland, ³DSM, Nutritional Products UK Ltd, Heanor Gate Industrial Estate, Heanor, Derbyshire, United Kingdom*

Six pelleted diets with 0, 6 or 11% of fine or coarsely hammer ground (2 or 6-mm) main ingredients including oat hulls (OH) were fed to broilers from day 11 to 32 to study the extent of selective retention and grinding of OH in gizzard. There were 13 replicate pens/treatment in a 2x3 factorial design, with 22 birds/pen with wood shavings as litter. Pellet durability and feed intake (FI) were not affected by grinding level but increasing OH level increased FI and increased gizzard relative weight as well. The hypothesis was that coarse OH would be selectively retained in gizzard to be ground down, but a high level of coarse OH would increasingly result in passage of unground OH. At day 28, gizzard content (GC) and small intestinal contents were quantitatively collected and analyzed for neutral detergent fibre (NDF) and wet-sieving particle size distribution (PSD). Litter in GC was visually identified and manually removed in a blinded manner. No significant OH x grinding level interaction was found for litter. However, adding OH and increasing coarseness of OH reduced litter amount in GC, confirming that presence of structural elements lowers consumption of litter in birds. Litter quality improved with increasing OH and excreta dry matter content increased as OH increased. There was no significant interaction and no effect of grinding level on NDF in GC, however adding OH increased the NDF concentration significantly ($p < 0.0001$). Increasing OH from 6 to 11% did not increase NDF, which may indicate that the gizzard has a maximum level of retention for OH. Further, NDF concentration in GC relative to diet showed a curvilinear relationship with OH suggesting that gizzard when reaching its maximum content either increases its grinding capacity or just passes OH unground. PSD of GC showed that the amount of larger particles (LP; > 1.6 mm) were significantly higher ($p < 0.0001$) for diets with added OH when ground coarsely. Both increasing OH and increasing coarseness increased LP amount in gizzard significantly ($p < 0.0001$), which may suggest that coarser OH are retained for a longer time in gizzard, assuming that most coarse particles are OH. Likewise, amount of LP in upper ileal content was also significantly higher ($p = 0.0004$) for diets with added OH when ground coarsely, while no such effect was seen for finely ground OH. Overall, these data seem to imply that passage of unground coarse LP from gizzard increases when it exceeds a maximum retention level.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-095 The impact of dietary supplementation with an *Aspergillus Oryzae*-derived postbiotic on productive performance of laying hens under commercial conditions**C. Ocasio Vega¹, F. Bargo¹*¹BioZyme Inc., St. Joseph Missouri, United States*

The impact of a postbiotic derived from *Aspergillus oryzae* (AOP) on eggshell quality, egg mass, and the productive life span of laying hens under commercial conditions were evaluated. Four validations were carried out in different countries, differing on the number of animals, production cycle weeks, and genetics (Validation 1 in Italy with 40.000 HyLine hens from 24-41 weeks of age; Validation 2 in Italy with 40.000 HyLine hens from 42-60 weeks of age; Validation 3 in Mexico 80.000 HyLine/Bovans hens from 14-45 weeks of age; and Validation 4 in Mexico with 70.000 HyLine/Bovans hens from 15-51 weeks of age). In all validations, enriched cages were used. On each validation, a minimum of two groups or barns of laying hens were fed either a commercial diet (CON) or the same diet supplemented with 50 g of the postbiotic per metric ton of feed (AOP). A total of 230 thousand laying hens were involved in these validations. Hen performance (egg production, egg weight, egg mass, feed intake, and feed conversion ratio), egg quality parameters (egg laid/hen, and sellable eggs), and mortality were recorded weekly. Weekly data were reduced to period means and their standard deviation. In all cases, the number of sellable eggs per week was standardized to 20 thousand animals per barn and 18 weeks of production. The inclusion of AOP in the nutritional program of the aforementioned operations improved hen performance, egg quality, and the productive life span of the flocks. Dietary supplementation with AOP resulted in 2% more egg mass (51,4g vs 52,4 g for the CON and the AOP group, respectively), in 3% higher egg production (83,2% vs 85,6% for the CON and the AOP group, respectively), and 3% more sellable egg per hen (2,09 vs 2,15 million eggs sold for the CON and the AOP group, respectively). In addition, feeding AOP reduced the mortality of the flock by 27% (7,32% vs 5,32% for the CON and the AOP group, respectively). Improving the survivability of the flock improves the productive life of laying hens because this is related to having more animals under production throughout the entire production cycle. It can be concluded that feeding 50 of AOP per metric ton of feed has a positive effect on eggshell quality, egg mass, and productive life span in laying hens. Research work aiming to document the MOA of AOP is ongoing, and results are in line with the postulated MOA of postbiotics in general.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-096 The influence of dietary cinnamaldehyde in combination with carvacrol or thymol on the mechanical properties of tibia in post-peak laying hens**

H. Zhang^{1,2}, Y. Wang¹, Y. Wang¹, L. Wang¹, X. Li³, G. Cui³, L. Ji³, Y. Huang¹, J. Michiels², W. Chen¹

¹College of Animal Science and Technology, Key Laboratory of Animal Biochemistry and Nutrition, Ministry of Agriculture, Henan Agricultural University, Zhengzhou, China, ²Laboratory for Animal Nutrition and Animal Product Quality, Department of Animal Sciences and Aquatic Ecology, Ghent University, Ghent, Belgium, ³Charoen Pokphand Group, Henan, China

Essential oils have been commonly practiced in animal feeding for their role as antibacterial, anti-inflammatory agent, and as digestive stimulant. Knowing the importance of the intestinal barrier in regulation of bone quality, the present study investigated the effect of dietary cinnamaldehyde with carvacrol or thymol essential oils on the gut and bone health in post-peak laying hens. After acclimation for 2 weeks, 52-week-old Hy-Line Brown laying hens were fed with a basal diet (Ctrl), a basal diet with 100 mg/kg essential oils consisted of 4.5% cinnamaldehyde with 13.5% carvacrol (CAR+CIN), or a basal diet with 100 mg/kg essential oils composed of 4.5% cinnamaldehyde with 13.5% thymol (THY+CIN) until 58 weeks. Each treatment groups had 8 replicate pens (16 birds/pen). One-way analysis of variance including post-hoc analysis (Tukey) or Kruskal-Wallis with Dunn's test for normally or non-normally distributed data, respectively, were used to evaluate the statistical differences of biological parameters. The stiffness and ultimate load of the tibiae from both CAR+CIN and THY+CIN group were higher than that of the Ctrl group ($P < 0.05$), along with comparable tibia ash, calcium, and phosphorus content among groups ($P > 0.05$). In addition, the supplementation with essential oils upregulated the transcription abundances of tight junction proteins and mucin-2 to varying degrees, whereas it did not significantly alter the abundance of most phyla of cecal microbiota. When compared to Ctrl group, birds fed the CAR+CIN and THY+CIN diet displayed decreased bone resorption marker and the pro-inflammatory factor interleukin-1 (IL-1) level, as well as increased the anti-inflammatory factor transforming growth factor beta (TGF- β) levels in serum. These findings suggest that cinnamaldehyde with carvacrol or thymol in feed of hens could improve the mechanical properties of tibia, which might involve suppression of inflammation-mediated bone resorption due to the positive role of dietary essential oils addition in enhancing intestinal barrier.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-097 The influence of varying inclusion levels of whole grain sorghum on performance and gut morphology of indigenous Boschveld chickens**

G. Mabunda¹, T.G. Manyelo¹, N. Sebola¹, M. Mabelebele¹

¹University of South Africa, Department of Agriculture and Animal Health, College of Agriculture and Environmental Sciences, Florida, 1710, South Africa

The aim of the study was to determine the influence of whole sorghum inclusion level on the performance and gut morphology of Boschveld chickens. A total of 224-day old Boschveld chickens were randomly assigned to a four- whole-grain sorghum inclusion levels in a complete randomized design having four replicates with 14 chickens per treatment. The level of inclusion was 0, 25, 50 and 75%. Diets were formulated to be isoenergetic and isonitrogenous. Body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) were assessed at days 42, 60 and 90, while visceral organs weight, length, pH, bones and meat characteristics were assessed at 60 and 90 days. Data on BWG, FI, FCR, visceral organs, meat characteristics and bones were analysed with GLM and means were separated with Duncan multiple test range. Whole grain sorghum (WGS) inclusion had significant effect ($p < 0.05$) on BWG, FI and FCR of indigenous Boschveld chickens aged 1 to 90 days. Whole grain sorghum inclusion had significant effect ($p < 0.05$) on the visceral organs weight, length and pH of indigenous Boschveld chickens aged 60 and 90 days. At the age of 60 days, birds fed 75% WGS diets had higher ($p < 0.05$) small intestine and gizzard weights compared to chickens fed 0, 25 and 50% WGS diets. Indigenous chickens fed diets with 75% WGS had a longer ($p < 0.05$) intestine compared to birds on other treatments. At the age of 90 days, Boschveld chickens fed diets with 75% WGS had the longest ($p < 0.05$) GIT and caeca than those that fed 0, 25 and 50% of WGS. Chickens offered control diets had heavy ($p < 0.05$) GIT, liver, gizzard, heart, spleen and crop weights than those fed diets having 25, 50 and 75% WGS. Whole grain sorghum (WGS) inclusion in diets had significant effect ($p < 0.05$) on small and large intestines, crops, gizzard and caecum of indigenous Boschveld chickens aged 60 and 90 days. The inclusion of varying levels of whole grain sorghum in the diets did not negatively affect the performance of the Boschveld chickens. Therefore, up to 75% whole sorghum grains can be included in chickens feed as it showed favour in most of affected parameters.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-098 The maternal effect of dietary mulberry-leaf flavonoids supplementation on the development of skeletal muscle in broiler offspring**Z. Lv¹, Z. Huang²

¹State Key Laboratory of Animal Nutrition, College of Animal Science and Technology, China Agricultural University, 2 Yuanmingyuan West Road, Beijing, 100193, China, ²State Key Laboratory of Animal Nutrition, Institute of Animal Sciences, Chinese Academy of Agricultural Sciences, Beijing 100193, China

The present study aims to clarify the mechanisms involved in dietary mulberry-leaf flavonoids (MF) supplementation regulating skeletal muscle development of breeder hen offspring from the perspective of maternal effect theory. Methods: A total of 270 Qiling broiler breeder hens (60-wk-old) were randomly assigned to 3 treatments with different supplemental dietary MF doses (0, 30, 60 mg/kg) for 8 weeks. 90 breeding eggs from each treatment were collected for incubation. 120 male offsprings (40 chicks from each group) were randomly selected and fed the same basal diet for 28 d. Another 90 eggs from three treatments were hatched for sample collection and statistics of development parameters. The results showed that maternal MF supplementation improved the skeletal muscle development of offspring, which significantly increased breast muscle weight and body weight of offspring during the embryo and chick stage ($P < 0.05$), following with the increased cross-sectional area of breast muscle fibers at 14 days of age ($P < 0.05$). Further detection revealed that the serum level of IGF1 and the number of muscle fibers at 1 day post hatching were increased after maternal MF treatment ($P = 0.092$). Furthermore, maternal MF supplementation significantly increased the mRNA expression of the myogenic regulatory factors Myf5 in the skeletal muscle at days 13, and 19 of embryonic age and 1 day after hatching ($P < 0.05$). Interestingly, maternal MF treatment significantly increased the relative expression of the downstream protein of BMPR2, Smad1 and p-Smad1/5/9 in the TGF β signaling pathway in the skeletal muscle of chicks at both embryonic and post-hatching stage ($P < 0.05$). Meanwhile, the increased expression of target protein p-mTOR in the breast muscle of offspring chicks is consistent with the improved breast and body growth rate. In conclusion, maternal MF supplementation may increase the number of muscle fibers of chick embryos by up-regulating the expression of Myf5. Maternal MF effect can activate the BMP/p-Smad1/5/9 axis, and continuously enhance the skeletal muscle protein metabolism of offspring chicks, which improves skeletal muscle development and growth performance. This study was supported by National Natural Science Foundation of China (No. 32202724) and Beijing Natural Science Foundation (No. 6222036).

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-099 The potentiality of using high crude protein sorghums in diets for broiler chickens**W.H.D.S.P. Macelline¹, I. Godwin², P. Chrystal³, M. Toghyani¹, D. Cantor⁴, M. Morshed⁴, P. Selle⁵, S. Liu⁵

¹School of Life and Environmental Sciences, Faculty of Science, The University of Sydney, Sydney, Australia, ²University of Queensland, QAAFI, Brisbane, Australia, ³Complete Feed Solutions, Howick, New Zealand, ⁴Australian Proteome Analysis Facility, Macquarie University, Sydney, Australia, ⁵Sydney School of Veterinary Science, Faculty of Science, The University of Sydney, Camden, Australia

Nutritionally equivalent diets based on three sorghum varieties selected for high crude protein (CP) concentrations (154.7 g/kg) were compared with diets based on seven standard sorghums (94.0 g/kg). Selected sorghum diets contained an average of 777 g/kg sorghum and 118 g/kg soybean meal as opposed to 620 g/kg and 279 g/kg, respectively, in the standard diets as all diets were formulated to 210 g/kg CP and 13.0 MJ/kg energy. Ten experimental diets were offered to 300 off-sex male Ross 308 birds from 14 to 35 days to determine growth performance, nutrient utilisation and ileal amino acid digestibility coefficients. Standard sorghum-diets generated higher weight gains by 2.46% (2328 versus 2272 g/bird; $P = 0.006$) and feed intakes by 2.49% (2922 versus 2851 g/bird; $P = 0.010$) than selected sorghum-based diets, but FCR were identical at 1.255 ($P = 0.996$). Selected sorghum-based diets supported superior energy utilisation by 0.24 MJ in AME (13.82 versus 13.58 MJ/kg; $P = 0.001$) and by 0.33 MJ in AMEn (12.46 versus 12.13 MJ/kg $P < 0.001$) than standard diets. There was effectively no difference in average ileal digestibility coefficients (0.839 versus 0.832) of 16 amino acids assessed in this comparison. The crucial advantage of high-CP sorghums, if feasible in practical broiler diets, is the 57.7% reduction in expensive, imported soybean meal inclusions. Kafirin is the dominant protein fraction in sorghum protein; therefore, kafirin concentrations and amino acid profiles were determined. The high-CP sorghums contained 98.3 g/kg kafirin as opposed to 53.5 g/kg in standard sorghums but the kafirin proportions were similar (63.6 versus 57.0; $P = 0.084$) in both sorghum types. There were significant differences in concentrations of five amino acids (His, Met, Phe, Val, Gly) in kafirin between the two sorghum types, but arguably they were not biologically influential given the amino acid digestibility outcomes. Increased dietary kafirin concentrations (39.6 versus 29.0 g/kg) have been shown to depress growth performance and energy utilisation significantly in broiler chickens in a previous study. In the present study dietary kafirin concentrations were substantially higher in the selected sorghum-based diets by a 2.3-fold factor (76.4 versus 33.2 g/kg), which did not compromise FCR and enhanced energy utilisation. This may suggest that the structure of the kafirin protein bodies in selected sorghums, and not kafirin amino acid profiles, was favourably modified.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-100** The supplementation of Glycine with a constant methionine-to-sulfur amino acids ratio improves performance of broiler chickens fed with low protein dietsD.I. Batonon-Alavo¹, T. Mahmood², Y. Mercier³¹Adisseo Canada, Montreal, Canada, ²Adisseo Animal Nutrition DMCC, Dubai, United Arab Emirates, ³CERN, Adisseo France S.A.S., Malicorne, France

Lowering dietary crude protein (CP) level in broiler diets is an efficient way of mitigating nitrogen excretion and improving animal production sustainability. Gly has often been suggested to be limiting in low protein diets, however, heterogenous findings have been reported in the literature. This inconsistency could be related to the interaction between Gly+Ser and sulfur amino acids levels in the diet. Therefore, we planned this study to evaluate the effect of different dGly+Ser levels at a constant dMet/dSAA ratio on the performance of broilers fed low protein diets. At day 11, Ross 308 male chicks, previously reared on a common starter diet, were allocated to 8 dietary treatments with 8 replicates of 20 birds each. Treatments were offered ad libitum until day 24 and were composed of a standard CP diet as the positive control (PC), formulated at 21% CP and 1.57% dGly+Ser, a low CP diet of 18% CP and 1.26% dGly+Ser as the negative control (NC). Five additional treatments were formulated with the constant addition of L-Cysteine to maintain the same dSAA level (0.87%) and dMet/dSAA (0.66%) as the PC and incremental Gly addition allowing to reach 1.25, 1.33, 1.41, 1.49, 1.57, and 1.65% dGly+Ser levels, respectively. All nutrients, and especially essential amino acids following ideal protein profile, matched or exceeded Aviagen (2019) nutrients recommendations. Performance parameters were recorded from 10 to 24-d and analyzed with a 1-way ANOVA. Means were compared using Tukey test. The body weight at d10 was used as a covariate for the subsequent statistical analyses. Feed intake, body weight, body weight gain and feed conversion ratio (FCR) were significantly affected by the experimental treatments ($p < 0.001$). The positive control treatment led to the best performance whereas the NC with a 3 percentage-points low CP impaired broiler performance. Among the low protein treatments, the supplementation of Gly did not significantly affect body weight ($p = 0.84$) or body weight gain ($p = 0.84$). However, the feed intake was significantly reduced with the increasing levels of dGly+Ser ($p = 0.02$), which resulted in a significant improvement of the FCR ($p < 0.001$). These results demonstrated that in low CP diets, Gly+Ser levels should be increased above the levels supplied by the NC. Therefore, it can be concluded that Gly supplementation allowed to improve broiler growth performance when fed with low protein diets.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-101** Total Replacement Technology™ (TRT) reduces mineral excretion, while improving eggshell strength and preserving bone healthJ. Estevinho¹, H. Walker², J. Taylor-Pickard³¹Alltech Portugal, Rio de Mouro, Portugal, ²Alltech UK, Stamford, United Kingdom, ³Alltech Ireland, Dunboyne, Ireland

This trial studied the effect of organic (OTM) and inorganic trace minerals (ITM) on mineral excretion, eggshell strength, tibia and keel bone traits, in brown layers. It was performed over five cage-free commercial farms. Each farm had a control and treatment group of the same breed and date of hatch. During the trial, the control and treatment birds received diets of the same specifications, except for Zinc (Zn), Copper (Cu), Manganese (Mn), Iron (Fe) and Selenium (Se): control diets were supplemented with standard levels of ITM; in treatment diets, ITM were replaced with lower levels of organic minerals (Total Replacement Technology™, TRT) for Zn, Cu, Mn and Fe (Bioplex®) and Se (Sel-Plex®). Before the trial there were no differences in shell strength between control and treatment (TRT); during the trial, TRT birds had improved shell strength ($p < 0.05$). The mineral content in the faeces of Zn, Mn, Cu, Ca, K and Na was lower ($p < 0.05$) in TRT. Tibia ash was greater in the control ($p = 0.034$), but tibia strength, Ca and P were unaffected. Keel width ($p = 0.001$), Ca (< 0.001) and P ($p = 0.005$) percentages in keel ash were greater in TRT birds, while keel height ($p = 0.024$), ash percentage ($p = 0.013$) and strength ($p = 0.002$) were lower. TRT birds had lower percentage of damaged keels (fractures and/or deviations) than the control in the cranial, middle and caudal portions, but with statistical significance ($p = 0.004$) only in the caudal. The results demonstrate that TRT significantly reduces mineral excretion in layers' faeces, namely Zn, Mn and Cu due to their higher bioavailability. Our hypothesis for the reduced excretion of Ca, K and Na is a consequence of the reduced antagonistic interaction when removing ITM from the diet, allowing for improved intestinal absorption. To our knowledge, this is the first report on the effect of lower levels of organic Zn, Mn, Cu, Fe and Se on the reduction of Ca, K and Na excretion. Albeit the reduced mineral supplementation, eggshell strength improved, tibia breaking strength was unaffected, Ca and P content in keel ash were greater, and there were fewer damaged keels in TRT birds. Keel damage was greater in the group with greater keel breaking strength, implying that other factors have a role in the prevention of keel damage. These novel findings demonstrate that TRT can simultaneously reduce mineral excretion, increase eggshell strength and reduce keel bone damage.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-102 Use of high-lauric oils in broiler starter diets and their influence on growth performance and fatty acid digestibility**

M. Saad¹, M. Espinosa de los Monteros Peñafiel¹, G. Verge Mèrida¹, M. Sadurní¹, M. Verdú², R. Sala¹, A.C. Barroeta¹, L. Castillejos¹

¹Animal Nutrition and Welfare Service, Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, Bellaterra 08193, Spain, Bellaterra, Spain, ²Department of Animal Nutrition and Feed Industry, bonÀrea Agrupa, Guissona 25210, Spain., Guissona, Spain

Palm kernel crude oil (PKO) is rich in medium chain fatty acids (MCFA), and particularly in lauric acid (C12:0 > 45%). During its physical refining, palm kernel fatty acid distillate (PKFAD) is obtained, a by-product rich in both MCFA and free fatty acids (FFA; 70-90%). The use of these fats in broiler feeding could contribute to improving the circular economy of the food chain. The aim of the present study was to evaluate the effects of the inclusion of high-lauric oils in broiler starter diets on performance and dry matter, organic matter and fatty acid digestibility of the diet. A total of 3,264 newly hatched mixed-sex broiler chickens (Ross 308) were randomly allocated to 24 pens and 3 dietary treatments (8 replicates per treatment). Animals were fed experimental diets (from 0 to 21 day-old) consisting of a basal diet (based in corn, wheat and soybean meal; crumble form) supplemented at 4% (as-fed basis) with 3 different fat sources: PKO (47% C12:0 and 3.2% FFA), PKFAD (41% C12:0 and 63% FFA) and soybean oil (SO: 0% C12:0 and 1% FFA) as a control. Silicate (1% as-fed basis) rich in HCl-insoluble ash was added as inert marker for digestibility assessment. Performance parameters as body weight (BW), average daily gain (ADG), and average daily feed intake (ADFI) were measured through experimental period, and feed conversion ratio (FCR) was calculated. At day 10, digesta from the lower ileum was collected. At day 21, broilers fed high-lauric palm kernel fat sources had higher BW (PKO: 833.1g and PKFAD: 863.9g vs. SO: 808.9g; P<0.01) and ADG (PKO: 37.6g/day and PKFAD: 39.1g/day vs. SO: 36.5 g/day; P<0.01) than those fed the SO diet. The lowest FCR was obtained for the PKFAD treatment (PKO: 1.362 g/g, PKFAD: 1.319 g/g, SO: 1.425 g/g; P<0.01). In relation to the ileal apparent digestibility, PKO and PKFAD diets had higher utilization of dry matter (PKO: 72.2% and PKFAD: 72.3% vs. SO: 64.7%; P<0.01) and organic matter (PKO: 73.6% and PKFAD: 73.5% vs. SO: 66.2%; P<0.01) than SO diet. Besides, both high-lauric diets had higher saturated fatty acid (PKO: 86.7% vs. PKFAD: 78.4% vs. SO: 72.9%; P<0.01) and MCFA digestibility (PKO: 94.1% and PKFAD: 90.8 % vs. SO: 75.5%; P<0.01) than SO diet. The results obtained indicate that PKO and PKFAD could be potentially interesting fat sources to be used at 4% in broiler starter diets (from 0 to 21 day-old) obtaining high growth performances and high digestibility of saturated and MCFA.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-103 Using vitamin B2 sourced from non-GMOs to determine the requirements in two breeds of laying hens**

W.D. Mansilla¹, A.I. García-Ruiz¹

¹Poultry Research Center, Trouw Nutrition, El Viso de San Juan, Spain

For organic production systems, regulations in the EU exclude the use of products obtained from genetically modified organisms (GMOs). In addition, the industry-suggested inclusion of vitamin B2 appears higher than those reported in the literature. This study aimed to determine the vitamin B2 requirement of laying hens when vitamin B2 was sourced from non-GMOs suitable for organic farming (OVB2). In total, 300 and 320 62-week-old laying hens (breeds A and B, respectively) were used. Laying hens were group-housed in cages of 10 hens each. A basal organic diet was formulated without a premix. Five premixes (1% of the final diet) were made with increasing concentrations of OVB2, adding 0, 0.6, 1.4, 2.4, and 5.0 ppm OVB2 to the experimental diets. Birds were fed the experimental diets for 18 weeks. Body weight (BW), egg weight, lay percentage, and feed intake were monitored during the trial. In weeks 4 and 18, 4 egg yolk samples were pooled per cage. Feed samples (triplicate) and egg yolk samples were analyzed for vitamin B2 content. Performance data were analyzed as repeated measures using SAS. Total vitamin B2 in the basal diet was low compared with the calculated value (0.57 ±0.13 SD vs. 1.59 ppm). The added OVB2, calculated as the vitamin B2 concentration difference between the experimental and basal diets, was on average 0.08 ppm from the expected value. By the end of the trial, the BW of hens fed 0 ppm OVB2 decreased compared with other treatments (-113 and -87 g for breeds A and B; P <0.001). From weeks 4 and 10 (for breeds A and B, respectively) until the end of the trial, the average egg weight was reduced in hens fed 0 ppm OVB2 (P <0.01). Daily feed intake was only decreased in breed A fed 0 ppm OVB2 compared with other treatments (P <0.05); there were no treatment differences in breed B (P >0.10). The concentration of vitamin B2 in the egg yolk increased in a dose-dependent manner (P <0.01). When fitting a curvilinear-plateau model to the egg yolk vitamin B2 concentration data, the plateau was 0.436 ±0.012 mg/100g egg yolk, and the breakpoint was at 2.90 ±0.35 ppm OVB2, with no differences between breeds. To cover the population vitamin B2 requirement (95% upper confidence limit), a minimum of 3.60 ppm OVB2 is needed. In conclusion, the vitamin B2 content in feed ingredients is variable and supplementation is necessary. To maintain BW, egg size, and concentration of vitamin B2 in the egg yolk, a minimum supplementation of 3.6 ppm OVB2 is required.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-104 Utilising a strain of probiotic *Bacillus licheniformis* to support high-producing layers**N. Ceylan¹, W. Van der Veken², V. Hautekiet²¹*Faculty of Agriculture / Ankara University, Ankara, Turkey,* ²*Huvepharma N.V., Antwerpen, Belgium*

Broiler applications dominate the probiotic research in literature. However, layers should not be neglected: high-producing laying hens must also be as efficient as possible, using their diet to the fullest whilst withstanding health challenges. From that perspective the importance of a proper functioning gastro-intestinal tract cannot be underestimated, indicating the value a probiotic supplementation can bring to a layer operation. A total of 250 Lohmann Brown layers were divided at random over a control and a probiotic group (25 replicates/treatment, 5 hens/replicate). The latter were supplemented with 1.6×10^9 CFU *Bacillus licheniformis* per kg of feed (strain DSM28710; B-Act®, Huvepharma) between 25 and 45 weeks of age and compared to a control fed a standard commercial diet. FCR and dirty egg percentage were recorded. Egg quality parameters were evaluated for 100 eggs per treatment, collected from each replicate biweekly (on the same day of the week) and analysed within 24 hours after collection. Moisture and protein levels in the manure were recorded at the start and at the end of the experiment, as an indication of how well the animal was using the respective diets. Supplementing *B. licheniformis* DSM28710 to these high-performing layers significantly improved FCR and egg mass ($P < 0.05$) compared to the control, with values of respectively 1.805 vs. 1.847 and 60.78 vs. 59.35 (g/hen/day). Egg quality parameters were also significantly improved in the probiotic group, including eggshell weight (6.83 vs 6.74 g) and shell thickness (0.393 vs. 0.389 mm; $P < 0.05$). Similarly, Haugh units significantly increased up to 82 in the probiotic group compared to the control's 80.6 ($P < 0.05$). Finally, the percentage of dirty eggs significantly reduced to 7.44 in the probiotic group compared to the control's 8.97%. These numbers could potentially be explained by the significant decrease in excreta moisture noted in the probiotic group (moisture reduction of 5.3% compared to the control's 4.5%; $P < 0.05$), as this could be seen as a better functioning of the gastrointestinal tract. The hypothesis is supported further as manure protein in the probiotic group was significantly lower compared to the control's (20.5 vs. 24.1, $P < 0.05$). In conclusion, the results here clearly show that *B. licheniformis* DSM28710 supports high-performing layers in utilising the provided nutrients from the diet as much as possible, in turn leading to improved FCR, egg quality and secondary feed efficiency parameters.

PS1 - Nutrition for sustainability in broiler, layer and turkey production**PS1-105 Zinc sources provide different effects on performance and on bacteria count in broiler**A. Corniaux¹, A. Rigo Monteiro², A. Romeo²¹*Cargill, Crevin, France,* ²*Animine, Annecy, France*

Zinc sulfate (ZnSO_4) is widely used in poultry nutrition and is considered the reference sources to assess bioavailability in poultry. In the latest decades, new sources emerged with the aim of providing more bioavailable Zn and additional benefits in comparison to sulfates. The objective of this study was to assess the efficacy of a different zinc sources versus the ZnSO_4 source in broiler diets. A total of 2 880 one-day-old broilers (Ross 308) were distributed into 4 experimental treatments (8 pens/ treatment and 90 birds of both sex/ pen): control diet (control), with 70 mg/kg of Zn from ZnSO_4 ; diet supplemented with 70 mg/kg Zn from a potentiated Zn source (PZ70; HiZox®; Animine, France); diet supplemented with 35 mg/kg Zn from potentiated Zn (PZ35); diet supplemented with 35 mg/kg from chelated zinc (CZ35). Broilers were fed experimental diets during the starter (1-19d) and grower (20-35d) periods. Performance was measured at days 1, 10, 19 and 35. At d 18, before the diet change, cloaca content was collected by using swab technique and analyzed for *E. coli* count. At the end of the trial, birds were slaughtered and the carcasses from 80 male broilers per treatment was used for breast yield assessment. Tibia bones were collected for bone strength analysis (left tibia) and mineral content (right tibia). In the first 10 d of the trial, there was a tendency ($P = 0.10$) for a higher BW for diets supplemented with 70 mg/kg Zn (average of 287 g); PZ35 had intermediated values (285 g) and CZ the lowest ones (279 g). Data for *E. coli* count at d 18 showed lower number of bacteria ($P = 0.08$) for diets supplemented with 70 mg/kg Zn and with PZ35, with higher values for CZ35 (around 89% superior than PZ35). At 35 d of the trial, no statistical differences for BW were observed, however, birds fed CZ35 presented better FCR (1.49) than the other treatments (average of 1.50 for PZ treatments and 1.54 for control). No differences on bone resistance (average of 242 N) nor on stiffness (average of 136 N/mm) were observed. Breast weight was higher ($P = 0.01$) for PZ diets and CZ35 (average of 475 g) than control diets (444 g). In summary, in the first 20 days of life, a potentiated Zn source provides a better control of bacteria growth and better performance than a chelated source. From 20d, no differences on performances and bone resistance were observed. In conclusion, a potentiated Zn source is a solution for chelated minerals with an advantage of controlling bacteria growth in the first days of life.

PS2 - Nutritional intervention for climate changes**PS2-01 Determination of the digestibility coefficient of canthaxanthin and apo-ester in broilers and layers**M. Umar-Faruk¹, F. Cisneros², V. Gigaud³¹DSM Nutritional Products, Village-Neuf, France, ²DSM Nutritional Products, Kaiseraugst, Switzerland, ³DSM Nutritional Products, La Garenne-Colombes, France

Egg yolk colour is an important criterion for consumers choice of eggs. It is used as a tool to assess the quality of eggs. Egg yolk colour is known to be a direct reflection of the concentration of pigments in the diets of laying hens. Pigmentation does not only depend on the total amount dietary content of pigment but also on the proportion of yellow and red carotenoids ingested and absorbed. Scarce knowledge on the digestibility of carotenoids is available. Therefore, the objective of this study was to determine the digestibility coefficient of canthaxanthin and apo-ester (Carophyll® Red and Yellow) in Broilers and Layers using a low xanthophyll diet (< 2 ppm/T of feed). Two trials were conducted in parallel. The first one involved 27 Hy-line Brown layers (45 weeks old) housed in individual cages split into 3 treatments. The trial was a dose response trial with 3, 6, and 9 ppm canthaxanthin and 3, 6 and 9 ppm of apo-ester respectively. The second one was conducted with 36 broilers (21 d old) with 6 chickens per cage. As for the layers one, 3 treatments were tested with 3, 6, and 9 ppm Canthaxanthin and 7, 14 and 21 ppm of apo-ester respectively. Feces were collected on day 21 prior to feeding the “carotenoids diets”, then 24h, 48h, 72h and 168h after continuous feeding. Feces will be immediately frozen under liquid nitrogen and sent to the laboratory for HPLC analyses to determine the amount of carotenoids in the feed and the excreta. Digestibility coefficient will then be calculated from these values. Both layers and broiler animals are capable of digesting carotenoids highly efficiently. Laying hens has a significantly ($P < 0.0001$) higher digestibility of apo-ester (95%) and canthaxanthin (92%) carotenoids compared to broiler chickens, 91% and 85% respectively. No significant dose effect on canthaxanthin digestibility was observed for both species. Apo-ester digestibility in layers was significantly ($p < 0.05$) higher with the highest dosage at 9 ppm of feed. The duration of feeding carotenoids has no significant impact on digestibility for both canthaxanthin or apo-ester in both broiler and layers. In conclusion, poultry are able to highly digest both yellow and red carotenoids, with layers being slightly efficient than broilers.

PS2 - Nutritional intervention for climate changes**PS2-02 Does a curcumin-based feed additive in broiler counteract heat stress consequences ?**M.M. Mustafa¹, F. Karadas², I.T. Tayeb¹, J.F. Gabarrou³¹Dep. Of Animal Sci.-Coll. Agric. Engine. Sci. University of Duhok, Duhok, Iraq, ²Yuzuncu Yil University, Faculty of Agriculture, Dep. of Animal Science. Van, Van, Turkey, ³Phodé, TERSSAC, France

Heat stress strongly reduce broiler performances in the world. Turmeric is well known to have an antioxidant property that could alleviate heat stress. As the main active of turmeric, curcumin is very fragile, the aim of this study was to investigate the effect of a specific protected curcumin (Force6, Phodé France) on broiler performances under heat stress. A total of 300 Ross 308-day old chicks were randomly assigned to 2 halls according to temperature: neutral temperature (34 to 24°C) or heat stressed (37 to 33°C). Each room contained 3 replicates of 25 birds per treatment. Treatments were: Control (CTRL): no plant extracts, plant extracts (PE50) at 50ppm. Feed intake (FI), Live Weight (LW), mortality and blood samples were collected at 35 days. Thyroid hormone T3, liver enzyme ALT, serum creatin kinase, uric acid and glucose were measured on 2 animals in each pen. Statistical analysis was monitored using a SAS GLM program followed by Duncan multiple range procedure, $P < 0.05$ was considered significant. Heat stress significantly reduced FI only by 2.7%, but live weight was reduced by 7.9% (1839±14 vs. 1697±9g) and feed conversion ratio (FCR) was highly degraded (1.60±0.01 vs. 1.72±0.02). Mortality also increased by 2.3 folds (4.0±0.6 vs. 9.3±1.3%). T3 serum content significantly decreased (2.01±0.1 vs. 1.53±0.1nmol/ml), ALT also significantly increased (5.1±0.1 vs. 7.2±0.2U/L), like creatine kinase (4326±189 vs. 6882±84U/L), uric acid (6.1±0.1 vs. 7.4±0.1U/L) and glucose (214±5 vs. 237±4mg/dl). PE50 had no effect on feed intake. In neutral temperature, LW was improved by 10.9% and FCR significantly reduced (1.60±0.01 vs. 1.48±0.02). Under heat stress, LW was improved by 14.4% (1697±9 vs. 1941±31g) and FCR was reduced (1.72±0.02 vs. 1.49±0.03). Mortality was also significantly reduced (9.3±1.3 vs. 4.0±0.1%). No significant difference was observed between control group in neutral temperature and PE50 under heat stress for T3, ALT, creatine kinase or glucose. Uric acid was also lower in PE50 under heat stress compared to control at neutral (6.1±0.1 vs. 4.9±0.1mg/dl). Heat stress decreased growth performance of broilers. PE50 allowed to counteract the heat stress effect by maintaining energy and protein metabolism closer to neutral situation. Further investigations need to be conducted to deeply understand the relation between antioxidant effect of this specific curcumin formulation and broiler's metabolism.

PS2 - Nutritional intervention for climate changes**PS2-03 Effect of a precision biotic on the growth performance, welfare indicators, and environmental footprint in broiler chickens**C. Bortoluzzi¹, P. Segobola¹, P. Fidiarakis¹, L. Tamassia¹, C. Saviani¹, J. Sorbara¹¹DSM Nutritional Products, Kaiseraugst, Switzerland

The objective of the present study was to evaluate the effect of a precision biotic (PB; SymphiomeTM, DSM Nutritional Products) on the growth performance, welfare indicators, and environmental footprint in broiler chickens. 1,560 one-day-old broiler chicks (males) were placed in a completely randomized block design with 2 treatments, 26 replicates/treatment, and 30 birds/replicate. The treatments consisted of feed supplemented or not with 1.14 kg/MT of PB (500 ppm of dried glycans). Feed was based on wheat and soybean meal formulated to meet or exceed the nutritional requirements by the primary breeder (Ross 308) and was supplied as crumble (starter) or pellet (grower and finisher). Phytase was added at 1,000 FYT/Kg. Growth performance was evaluated on d 14, 28, and 35. The feed conversion ratio (FCR) was mortality-adjusted then corrected to a common body weight (cFCR). Mortality was recorded during the entire experimental period. Additionally, litter pH, litter ammonia concentration, litter score, footpad lesion score, and gait score were evaluated. Environmental footprint was assessed by using SustellTM that considers aspects of carbon footprint, including, but not limited to animal and feed origins, feed formulation and feed additives, emissions, and measures, among others, terrestrial, marine, and freshwater eutrophication, and impact on climate change. The data were analyzed by one-way ANOVA ($P \leq 0.05$), and non-parametric data was analyzed by Wilcoxon's test by using JMP (16.0). The supplementation of PB improved ($P < 0.05$) the body weight gain (BWG) of the birds during the starter and grower phases and increased the final BWG by 2% ($P < 0.0001$). The cFCR was improved during all the phases, and by 6% from 1-42d ($P < 0.0001$). Mortality was reduced from 3.21% in the control vs 1.67 in the PB group as was litter pH ($P < 0.0001$), ammonia concentration ($P = 0.002$), and overall litter score ($P = 0.05$). Foot pad lesion score ($P = 0.001$) was reduced by 38% and gait score ($P = 0.03$) by 59% in PB supplemented birds. The SustellTM assessment showed that with the PB supplementation, the terrestrial eutrophication potential was reduced by 12.3%, and climate change by 2.2%, which corresponds to about 230 tons of CO₂ equivalent when considering a broiler operation that processes 1 million birds per day. In conclusion, PB improved the growth performance of broiler chickens, the welfare indicators, and reduced carbon footprint.

PS2 - Nutritional intervention for climate changes**PS2-04 Effect of different energy levels of low protein diets on the nitrogen retention and excretion of broiler chickens**P. Strifler¹, N.A. Such¹, V. Farkas¹, B. Horváth¹, K. Dublec¹, L. Pál¹¹Hungarian University of Agriculture and Life Sciences, Georgikon Campus, Keszthely, Hungary

The beneficial effects of feeding low-protein (LP) diets on the nitrogen excretion of broilers are well known, but less attention has been paid to the adequate energy supply of low-protein-fed birds. Therefore, this experiment was conducted to investigate the effect of LP diets with different AMEn content on the nitrogen retention of broilers and the concentration of excreted nitrogen forms. One-day-old male Ross 308 broiler chickens were randomly assigned to four experimental dietary treatments (6 pens of 24 birds in each). Besides the control diet (C) which met the breeder's nutrient recommendations, low-protein diets LP1, LP2 and LP3 were formulated with 1.5% crude protein reduction compared to the C diet. This change in crude protein level meant 6.5, 7.0, and 8.0% relative reductions in the case of starter, grower, and finisher diets, respectively. The diet LP1 was isocaloric with the C diet, while in the case of the LP2 and LP3 diets, the AMEn content was reduced by 1.5% and 3.0% compared to the C diet, respectively. In the case of six essential amino acids, the same SID concentration and ratio (levels of C diet) were set in each diet using crystalline amino acid supplementation. On day 35, 12 broilers per treatment (2 birds per pen) were randomly selected and transferred to metabolic cages where representative excreta samples using TiO₂ dietary marker were collected on days 40 and 41. The broilers in the isocaloric protein-reduced LP1 treatment group achieved significantly higher N retention (67.3% vs 56.4%) than the control birds ($P < 0.05$). There was no significant difference between the N retention values of the LP1 and LP2 groups. The LP2 treatment resulted in the highest N retention (68.7%) of broilers, which was significantly higher than the values of the animals in the C and LP3 groups. In the case of the N forms of the excreta, the same significance was observed for total N and uric acid N: the significantly lowest values were measured in the LP1 treatment group. Furthermore, the treatment LP2 also resulted in significantly lower total N and uric acid N excretion than treatments C and LP3. The dietary treatments did not influence the concentration of ammonium N in excreta. In conclusion, the 1.5 and 3.0% reduction of dietary AMEn of LP diets may cause significant differences in N retention of broilers and can negatively affect the nitrogen emission of birds. This research was supported by the Hungarian Ministry of Agriculture (AKGF/31/2022).

PS2 - Nutritional intervention for climate changes**PS2-05 Effect of temperature and feeding time on shell thickness**O. Blanco¹, N. Chaora¹, N. Tyler¹, M. Ciacciariello¹¹*Animal & Poultry Science. University of KwaZulu Natal, Pietermaritzburg, South Africa*

Broiler breeders are feed restricted, but ambient temperature can affect the time of day when the hen consumes feed, potentially affecting egg quality. The objective of this study was to assess the effect of ambient temperature (T) and feeding time (FT) on eggshell thickness (ST) and egg weight (EW) of broiler breeder hens. Thirty 44-week-old Ross 308 broiler breeder hens were randomly distributed into six environmentally controlled chambers and kept in individual cages. Three thermal treatments were applied: 20 °C (T1), cyclic 20-30 °C (30 °C between 1000 h and 1800 h) (T2), and 30 °C (T3). Birds received 180 g of commercial breeder food at 07:30 h (FT1) or 15:30 h (FT2). There were two replications per treatment and egg collection was performed for seven days. The eggs from the birds at T1 and T2 fed at 15:30 h (T1FT2 and T2FT2, respectively) were significantly heavier ($p < 0.05$) than those laid by hens at the same T when fed in the morning (T1FT1 and T2FT1); eggs from T1FT1 and T2FT1 were heavier ($p < 0.05$) than the eggs from T3, but there were no significant differences between them ($p > 0.05$). Both T and FT had significant effects on ST, but no significant interactions were found. Birds fed at 1530 h had the highest ST, whilst birds at T3 showed the lowest. Birds on T2 produced the thickest shells due to a higher ST in birds fed at 1530 h ($p < 0.05$). Birds fed at 1530 h consumed their food between 1800 h and 2030 h ($p < 0.05$), resulting in a higher dietary Ca2 + available during shell mineralization. The effect of FT and biphasic T treatments on ST in feed restricted broiler breeders should be interpreted considering the length of the high T phase to the actual food consumption time.

PS2 - Nutritional intervention for climate changes**PS2-06 Effects of dietary amino acid density on amino acid digestibility, performance, and breast meat composition in broilers reared under thermoneutral, heat stress, and pair-feeding conditions**J. Teyssier¹, P. Cozannet², S. Dridi¹, S.J. Rochell³¹*Center of Excellence for Poultry Science, University of Arkansas, Fayetteville, AR, United States*, ²*Adisseo France S.A.S., Commentry, France*, ³*Department of Poultry Science, Auburn University, Auburn, AL, United States*

Heat stress (HS) reduces broiler feed intake (FI) and alters bird metabolism. This study aimed to determine the effect of increasing dietary amino acids (AA) in the unbound form on performance, apparent ileal digestibility (AID) of AA, and total breast muscle (TBM) composition. Cobb male chicks ($n=1,536$) were allocated into 8 houses divided into 16 pens each (12 birds/pen) at 20 d post-hatch and reared until 42 d old. Four houses were set to a thermoneutral (TN) temperature of 24°C, while the remaining 4 houses were set to 35°C to induce chronic HS. Four diets were formulated with 100% of recommended AA levels (CTL) or 135% of recommended levels of either all 10 essential AA (AA+), Met, Arg, Thr (MRT), or Met, Arg, Thr, Ile, Val (MRTIV) and distributed to 4 pens per house. In each TN house, birds from 8 pens were pair-fed (PF) to equalize their FI to that of HS birds on the previous d, and birds from the remaining 8 pens were fed ad-libitum (AL). This resulted in a split-plot design of environment (whole-plot) × diet (sub-plot) with 12 treatments. Data were analyzed by ANOVA and Tukey's means separation. Performance was measured on d 20 and 41, while ileal digesta (pooled from 5 birds) and TBM (remaining birds) were collected on d 41 and 42, respectively, from 8 pens per treatment. The HS and PF groups had equal and lower (-20% , $P < 0.001$) FI than AL birds. Essential AA AID was reduced ($P=0.031$) under HS compared to PF conditions. For Met, AID was improved in HS birds with its supplementation in the AA+, MRT, and MRTIV diets but not in TN or PF birds, resulting in an environment × diet interaction ($P=0.007$). Similar trends ($P < 0.10$) were observed for Arg, Thr, Ile, and His. Supplementation of AA allowed for equal digestible intake of these AA among HS and PF birds fed AA-supplemented diets and AL birds fed the CTL diet. Regardless of dietary treatment, body weight gain and feed conversion ratio were best for AL birds, intermediate for PF birds, and worst for HS birds (respectively, -32% and $+20\%$, $P < 0.001$), indicating HS-specific effects. The TBM of birds fed the AA+ diet had higher ($P=0.013$) nitrogen content and lower ($P < 0.001$) energy and fat content than other dietary groups, regardless of environmental conditions. Overall, increasing AA in unbound form mitigated HS-induced reductions in digestible AA intake, but no combination of essential AA evaluated herein ameliorated the adverse effect of HS on performance or changes in TBM yield and composition.

PS2 - Nutritional intervention for climate changes**PS2-07 Effects of dietary supplementation with a plant extract combination in laying hens raised in hot conditions at the peak production phase**P. Sakkas¹, M. Panheleux¹, F. Robert¹¹DELTA VIT, CCPA Group, Janzé, France

Chronic exposure to heat stress penalises hen productivity and egg quality due to oxidative stress and ensuing inflammation, especially in the gastrointestinal tract. Certain phytochemicals may partially alleviate these effects. Herein, we investigated the effects of dietary supplementation of a plant extract combination of *Scutellaria baicalensis* and *Curcuma longa* (PHYTO) in laying hens raised in subtropical conditions. A total of 150, 24-week-old white pullets (BV 300) were allocated in 50 cages and offered a diet either containing 2 g/kg of PHYTO or not, for 16 weeks. The average daily in house temperature and relative humidity was 33 °C and 90%, respectively. Hens were weighed at the start and at the end of the trial and weekly hen day production (HDP), ADFI and egg weight (EW) were calculated. Egg quality traits (Egg shell breaking strength, yolk colour index, albumen height and Haugh units) were measured in 4 eggs per replicate cage at 4-week intervals. Furthermore, one hen per cage was randomly selected at the beginning of the trial for blood sampling at weeks 8 and 16 to assess serum biomarkers indicative of systemic oxidative stress (malonaldehyde; MDA), mucosal integrity (Zona occludens-1; ZO-1), hormonal milieu (corticosterone and triiodothyronine), resistance to stressors (Heterophil/Lymphocyte ratio; H/L) and thermal tolerance (HSP70). Effects were assessed by repeated measure analysis of variance of GLM with cage serving as the replicate for all analysis. Supplemented birds showed increased HDP ($P=0.007$) while ADFI or EW remained unaffected. Egg quality traits were unaffected other than yolk colour index, which was greater for the supplemented group at week 36 ($P=0.003$) and 40 ($P=0.001$). The concentration of MDA was unaffected by treatment. PHYTO supplementation reduced corticosterone ($P=0.018$), increased ZO-1 ($P=0.028$) and tended to increase triiodothyronine concentrations ($P=0.052$) at week 40. On the contrary H:L ratio was significantly reduced by PHYTO supplementation at week 32 ($P=0.004$). Importantly, PHYTO supplementation significantly reduced HSP70 ($P<0.05$) across sampling points. Differential effects over time may be related to the duration of PHYTO supplementation in conjunction with the stage of lay and the cumulative effect of HS. Our results demonstrate that PHYTO supplementation improvement of HDP was associated with an altered biomarker status suggestive of improved hen thermotolerance, effects being more prevalent at later stages of the experimental period.

PS2 - Nutritional intervention for climate changes**PS2-08 Effects of dietary supplementation with a plant extract combination on broiler performance and stress tolerance under hot ambient conditions**A.G. Mascarenhas¹, M.B. Café¹, A.S. do Carmo¹, H. Mello¹, J. Batista¹, F. Robert², M. Panheleux², P. Sakkas¹¹Federal University of Goiás, School of Veterinary and Animal science, Department of Animal Science, Goiás, Brazil, ²DELTA VIT, CCPA Group, Janzé, France

Broilers are continuously subjected to stressors, amongst which exposure to high temperatures. We hypothesised that combined dietary supplementation with *Curcuma longa* and *Scutellaria baicalensis* extracts (PHYTO), which act synergistically downregulating inflammatory pathways, would improve performance and modulate stress defences in sensitive tissues such as the liver and intestine, in broilers raised under hot ambient conditions. A total of 1404 day old male Cobb broiler chicks were randomly allocated to 36 pens and assigned to one of three treatments (14,5 broilers/m²), PHYTO supplemented (S; 0,2%), control non-supplemented (C) and in feed antibiotic supplemented (Avilamycin; A). Birds were raised in naturally elevated temperatures (24-34°C) and had ad libitum access to Starter (d1-7), Grower 1 (d8-21), Grower 2 (d22-33) and Finisher diets (d34-42). Performance parameters were evaluated at the end of each period, and Production efficiency index (PEF) for the overall growing period (d1-42). At d21 and d42, one bird per pen was euthanised to assess Heat shock protein 70 (HSP70) expression in intestinal and liver tissue determined by immunohistochemistry, as well as for the histomorphometrical evaluation of duodenal, jejunal and ileal villus length (VH), crypt depth (CD), their ratio (VH:CD) and goblet cell (GC) numbers. All data were analysed with the GLM and treatment means were compared by the Tukey's multiple comparison test. S birds tended to have reduced FCR ($P=0.07$) and had significantly improved PEF ($P<0.05$) in comparison to C birds for the overall production period, with A birds having intermediate values. At d21, S birds had greater VH than both C and A birds and at d42, S and A treatments had greater VH:CD and reduced CD in comparison to C birds ($P<0.001$). At d21 S birds had more GC in the jejunum ($P<0.05$) and ileum ($P<0.01$) compared to C birds, and at d42 both S and A birds had more GC in the jejunum ($P<0.001$). S birds had significantly reduced HSP70 expression in both the liver and intestinal tissue at both sampling points in comparison to the other groups ($P<0.05$). In conclusion, PHYTO supplementation improved broiler performance during the overall growing period and improved intestinal features, effects being superior to in feed antibiotics. Importantly, PHYTO supplementation downregulated HSP70 production in liver and intestinal tissue. Collectively, results are indicative of an improved stress response.

*PS2 - Nutritional intervention for climate changes***PS2-09** Effects of dietary α -tocopherol and ascorbic acid on growth performance and breast meat quality parameters in broiler chickens exposed to high ambient temperaturesM. Pečjak Pal¹, A. Levart¹, J. Leskovec¹, J. Salobir¹, V. Rezar¹¹University of Ljubljana, Biotechnical Faculty, Department of Animal Science, Jamnikarjeva 101, 1000 Ljubljana, Slovenia

Climatic factors, especially high ambient temperatures, present a great concern in chicken meat production worldwide. There are several strategies to mitigate production and economic losses, where feeding strategies are one of the most effective. This study was conducted to determine the effects of dietary α -tocopherol (α T) and ascorbic acid (AA) on growth performance and breast meat quality of broilers reared under high ambient temperatures between 23.5 and 31°C from day 26 to the end of the experiment. Sixty male, 1-d-old Ross 308 broilers were housed in 6 pens (10 chickens per pen, reared on deep litter with sawdust) and randomly divided into three experimental groups. Broilers were fed a basal diet according to Ross 308 nutritional recommendations without supplementation (cont) or the basal diet supplemented with either 200 IU α -tocopherol acetate/kg diet (+ α T) or 250 mg ascorbic acid/kg diet (+AA). Body weight (BW) and feed intake (FI) were recorded weekly for each pen. At the end of the experimental period (day 43), 12 birds per group were randomly selected, weighed, and slaughtered by cervical dislocation. At the slaughter line, breast muscle samples were collected from each bird and pH was measured 15 min post mortem. One half of the muscle was sliced and stored for further determination of oxidative stability (α - and γ -tocopherol and malondialdehyde (MDA) content), while measurements of physical characteristics of breast meat quality (pH, drip loss, color) were made on the other half 24 h post mortem. In addition, the color of the breast meat was measured 72 and 120 h post mortem. Data were statistically analyzed using the GLM procedure from SAS software ver. 9.4. No differences were observed in FI and feed conversion ratio (FCR). Body weight gain (BWG) from day 1 to 21 and BW at day 21 were significantly ($P < 0.05$) lower in the + α T group. The dietary supplements had no effect on drip loss, pH24h and meat color (L^* and b^* values), whereas a^* value was higher in the + α T group 24 h and 120 h post mortem, and pH15min was higher in the +AA group than in the control group. MDA content and γ -tocopherol concentration were not affected by the dietary AA and α T, while α T supplementation significantly increased α -tocopherol concentration in fresh breast meat. The results indicate that α T and AA supplementation had no negative effects on meat quality parameters and can be safely used at higher concentrations in broiler diets.

*PS2 - Nutritional intervention for climate changes***PS2-010** Environmental implications of using β -mannanase in broiler feeding programsF. Hickmann¹, I. Andretta¹, M. Kipper²¹Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, ²Elanco Animal Health, São Paulo, Brazil

Feeding is an important source of environmental impacts associated with poultry production systems. Thus, improving feeding practices may mitigate the environmental footprint of broiler production. The present study was therefore undertaken to assess the environmental implications of using β -mannanase (Hemicell™ HT, Elanco Animal Health) in broiler feeding programs. The functional unit considered was 1 kg of feed produced at a feed mill gate located in Concórdia, Santa Catarina, Brazil; simulated through a cradle-to-feed mill gate scope. Environmental impacts were evaluated according to life-cycle assessment standards using four interrelated steps: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and interpretation of the results. The major stages considered in the model were the production of feed ingredients from plant sources, the production of other feed ingredients, drying, processing, storage, and transportation. The simulation considered a scenario in which only grain from the Southern region was used to produce the following feeds: (i) without the enzyme based on the nutritional requirements of broilers or (ii) with a low-energy diet supplemented with β -mannanase (reduction of 45 kcal of metabolizable energy/kg of feed). Reduction of energy was achieved by replacing soybean oil by corn and soybean meal. Inputs and outputs were defined for each stage of the life cycle assessment and organized in a model using the SimaPro software (v. 8.0.3.14). The impact of climate change was estimated with the CML-IA baseline method. Producing feeds (1 kg at feed mill gate) in Southern Brazil using grain cultivated in the same region led to the emission of 816 to 910 g of CO₂-eq (climate change) and 4.62 to 4.97 g of PO₄-eq (eutrophication), depending on the broiler phase. A formulation procedure that considered the energy saved by β -mannanase mitigated the impact of climate change by 5.0 to 5.6% and eutrophication by 1.1%. Due to their high environmental impacts, feeding practices may be considered a prime target when developing mitigation strategies for the broiler production chain. In this context, the use of exogenous enzymes like β -mannanase may be an effective approach for improving the environmental sustainability of broiler production.

PS2 - Nutritional intervention for climate changes**PS2-011 Growth and slaughtering performance of a local chicken breed fed dried and live Black soldier fly larvae as environmental enrichment**

E. Fiorilla¹, M. Gariglio¹, V. Bongiorno¹, E.E. Cappone¹, V. Zambotto², F. Gai², J. Cortes³, C. Coudron⁴, I. Biasato⁵, A. Schiavone¹

¹Department of Veterinary Sciences, University of Turin, Grugliasco, Italy, ²Institute of Science of Food Production, National Research Council, Turin, Grugliasco, Italy, ³Entomo Agroindustrial, Murcia, Spain, ⁴Inagro vzw, Rumbeke-Beitem, Belgium, ⁵Department of Agricultural, Forest and Food Sciences, University of Turin, Grugliasco, Italy

Local chicken breeds could benefit from insect larvae to improve their welfare. This study aims at evaluating growth and slaughtering performance of a local chicken breed, Bianca di Saluzzo (BS), fed dried and live black soldier fly (BSF) larvae as environmental enrichment. A total of 144 male BS chickens (39d-old, average live weight, LW: 314.5±2.4 g) were allotted in 18 pens (6 replicates/treatment, 8 birds/pen) and assigned to 3 experimental treatments. The P group was fed a diet with the complete replacement of soybean meal with alternative ingredients (peas, beans)(metabolizable energy, ME: 2834 Kcal/kg; crude protein CP: 19.44% dry matter, DM), while the two experimental groups where fed the P diet supplemented with 4% (of expected daily feed intake (DFI)) dry matter of dried (DBSF) or live (LBSF) BSF larvae (corresponding to about 5% DBSF or 15% LBSF as fed). Nutrient composition of BSF larvae was: DM: 96.78, 33,63 % as fed; CP: 44.63, 42.79 % DM; Fat: 27.56, 28.43 % DM for dried and live larvae, respectively. The LW, average daily gain (ADG), DFI, and feed conversion ratio (FCR) were evaluated for the whole experimental period (39-147 d-old). Larvae consumption time was recorded 3 times a week for the whole trial using a stopwatch. At 147 d-old, 12 birds/treatments were selected and slaughtered. Hot and chilled carcass, and organs (spleen, liver, heart), breast and thigh muscles weights were recorded, and the corresponding yields (%LW) were calculated. Larvae consumption time was analyzed by a GLMM, while all the other data were analyzed using one-way ANOVA (SPSS, P≤0.05). Final LW, ADG and FCR were similar among groups, while DFI was lower for DBSF and LBSF when compared to P (P<0.05). The larvae consumption time was affected by the age of the birds (P<0.05), with the fastest time being observed between 60 and 101 d-old. No statistical difference in consumption time was observed between DBSF and LBSF groups (P>0.05). Hot and chilled carcasses, breast, and thigh yields were similar for P, DBSF and LBSF groups. No differences were found in organ weights and yields (P>0.05). Results were comparable between dried and live larvae. Moreover, birds didn't show any difference in terms of larvae consumption, suggesting no preference between the two larvae. Further research is needed to validate the possibility of using dried larvae instead of live larvae as environmental enrichment, which may be safer and easier to be preserved when compared to live ones.

PS2 - Nutritional intervention for climate changes**PS2-012 Plant-derived isoquinoline alkaloids enhance growth performance, gut integrity, and the gut microbiome in broiler chickens reared in summer of tropical climates area**

S. Khongthong^{1,2,3}, D. Faroongsarn^{1,3}, N. Roekngam^{1,3}, P. Piewngam⁴, W. Kraitavin⁵, A. Pastor⁶, T. Steiner⁶, Y. Theapparat^{7,3}

¹Department of Pharmaceutical Technology, Faculty of Pharmaceutical Sciences, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand, ²Faculty of Veterinary Science, Rajamangala University of Technology Srivijaya, Nakhon Si Thammarat, Thailand, ³Research Center of Microbiome Systemic Engineering, Prince of Songkla University, Hat Yai, Songkhla, 90110, Thailand, ⁴Allergy and Infectious Diseases, U.S. National Institutes of Health, Bethesda, MD, United States, ⁵Phytobiotics (Thailand) Co., Ltd., Huaykwang, Bangkok, Thailand, ⁶Phytobiotics Futterzusatzstoffe GmbH, 65343 Eltville, Germany, ⁷Center of Excellence in Functional Foods and Gastronomy, Faculty of Agro-Industry, Prince of Songkla University, Hat Yai, Songkhla, Thailand

Persistently hot and humid summertime in tropical climate induces heat stress, negatively affecting growth and gut health in broilers. The effect of isoquinoline alkaloids (IQ) on growth performance, gut microbiota composition, and gut integrity of broilers was assessed. 720 male broilers (Ross 308) were treated with IQ at null (control), 60 (IQ60), and 100 mg/kg (IQ100). They were reared in open production house during April-May in Southern Thailand with 33.0-38.0°C (average 35.0°C) and 75-80% relative humidity. It was found that IQ improved growth performance in broiler chickens; body weight (BW)/weight gain (BWG), and feed intake (FI) were significantly higher compared with control (p = <0.05) while feed conversion ratio (FCR) was considerably lower. IQ significantly reduced the relative expressions of the ileum inflammatory cytokines; nitric oxide synthase (iNOS), cytokines interferon gamma (IFN-γ), interleukin-4 (IL-4), tumor necrosis factor-alpha (TNF-α), nuclear factor κB (NF-κB). In IQ100, the expressions of jejunum tight junction proteins; occluding-1(OCLD-1), claudin-1(CLDN-1), tight junction proteins-1 (TJP-1), and mucin-2 (MUC-2) increased. IQ supported the ileum and cecal microbiota diversity yielding high alpha-diversity, ACE, OTUs, Chao1, and Shannon index (Kruskal-Wallis, p = < 0.05). In IQ60, day-14 ileum microbial population of Lactobacillus sp., (20%) Bacillus sp., (0.39%) and Turicibacter sp. (1.5%) increased while Escherichia sp. (0.69%) has a significantly lower than control (11%). Day-35 proportion of Lactobacillus sp., (13%), Alistipes sp. (10%) and Akkermansia sp. (3.1%) also increased (p = <0.05). In IQ100, day-35 beta-diversity (Unifrac) showed a significant difference (PERMANNOVA, p = <0.001) where cecal populations of Bacteroides sp. (22%) and Lactobacillus sp. (13%) were high. Functional profiles from PICRUSt2 analysis revealed that day-14 cecal phenylalanine metabolism (0.76%) in IQ60 increased whereas cortisol synthesis/secretion (0.018%) decreased (p = <0.001). IQ caused day-35 tryptophan metabolism (0.43%) related to serotonin synthesis pathway, glycine, serine, and threonine metabolisms (0.80%) to elevate (p = <0.001). Overall, isoquinoline alkaloid supplementation in broiler diet enhanced growth performance, improved gut integrity, and modulated beneficial microbiota diversity broiler reared in hot season of tropical climate.

PS2 - Nutritional intervention for climate changes**PS2-013 Supplemental methyl sulphonyl methane improves performance in grower phase and enhances tolerance to heat stress in the finisher phase of male broilers**

H. Zhang¹, M. Majdeddin¹, J. Degroote¹, E. Van Liefferinge¹, N. Van Noten¹, C. Van Kerschaver¹, M. Vandaele¹, J. Cesar De Paula Dorigam², J. Michiels¹

¹Laboratory for Animal Nutrition and Animal Product Quality, Department of Animal Sciences and Aquatic Ecology, Ghent University, Ghent, Belgium, ²Evonik Operations GmbH, Hanau-Wolfgang, Germany

Methyl sulphonyl methane (MSM) is available as a dietary supplement for human and has been associated with multiple health benefits such as reduction of oxidative stress. Heat stress (HS) is an environmental stressor challenging poultry production and known to inflict oxidative stress. We hypothesized that dietary MSM could attenuate HS-induced detrimental effects in broilers mediated by enhancement of antioxidant defences. A total of 792 1-d-old male Ross 308 broilers were allocated to 3 dietary treatments composed of corn-soybean meal diets with 0 (Ctrl), 1, or 2 g/kg MSM, with 12 replicates (22 birds each) per treatment for 39 d and subjected to a chronic cyclic HS model (temperature of 34 °C and 52% to 58% relative humidity for 6 h daily) from d 24 to 39. Differences among treatment groups were evaluated using one-way analysis of variance followed by Tukey's test or Kruskal-Wallis test for normally or non-normally distributed datasets, respectively. Orthogonal contrasts were applied to test for linear and quadratic effects upon incremental levels of MSM supplementation in the diet. $P < 0.05$ were considered statistically significant. MSM at 1 and 2 g/kg linearly increased daily gain and decreased feed-to-gain ratio compared with Ctrl in the grower phase (d 10-21, both $P < 0.05$). In the finisher phase (d 21-39) none of the performance and carcass indices were affected by treatment ($P > 0.05$). Nonetheless, data suggest reduced mortality by feeding MSM during HS. Also, during HS the diets with graded levels of MSM resulted in reduced rectal temperatures ($P < 0.05$) along with linearly decreased panting frequency on d 24 ($P < 0.05$). MSM supplemented birds showed a trend for linearly decreased thiobarbituric acid reactive substances of breast meat upon simulated retail display ($P = 0.078$). In addition, MSM administration linearly decreased lipid oxidation in plasma (d 25 and 39, $P < 0.05$) and breast muscle at d 23 ($P < 0.05$), concomitantly with linearly increased glutathione levels in erythrocytes (d 23 and 39, $P < 0.05$; d 25, $P < 0.1$) and breast muscle (d 23, $P < 0.05$; d 39, $P < 0.1$). In conclusion, MSM increased growth performance of broilers during grower phase and exhibited positive effects on heat tolerance mediated by improved antioxidant capacity in broilers resulting in lower mortality in finisher phase.

PS2 - Nutritional intervention for climate changes**PS2-014 Supplementation of a lignan-rich feed supplement derived from wood alleviates heat stress in fast-growing broilers**

Z. Idrus¹, S. Ahmad Hanafi¹, C. Potthast², A. Riemensperger², S. Hirtenlehner²

¹Institute of Tropical Agriculture & Food Security, Universiti Putra, Selangor, Malaysia, ²agromed Austria GmbH, Kremsmünster, Austria

One of the major environmental challenges for poultry production is heat stress (HS), which adversely affects well-being, productivity, and product quality. Broiler chickens are particularly susceptible to HS due to their rapid metabolic rate, increased basal metabolic heat production, and fast growth. This study tested the hypothesis that a wood-derived feed supplement can counteract HS-dependent production losses and health impairment of fast-growing broilers due to its anti-inflammatory properties. Two hundred sixty-four one-day-old male broilers (Cobb 500) were allocated randomly to 24 cages á 11 birds under climatically controlled conditions. Each cage was randomly assigned to one of two dietary groups receiving a standard diet with or without a commercial feed supplement at a dosage of 400 ppm (agromed®ROI; agromed Austria GmbH). Parallel to the 2-phase-feeding program, all birds were housed under thermoneutral conditions throughout a starter phase until day 21. During the finisher phase, between days 22 and 35, a HS regime was applied to half of the cages: The ambient temperature was increased to $34 \pm 1^\circ\text{C}$ for 6 hours a day at a relative humidity between 65 - 75%. Besides zootechnical performance, the expression of acute phase proteins and heat shock protein 70 (HSP70) was measured in broiler serum at the end of the trial. Significant differences were considered at $p < 0.05$. The HS regime significantly impacted all experimental parameters, proofing a successful challenge model. Including the feed supplement significantly reduced the mortality rate under thermoneutral conditions from 10% to 3% but only numerically reduced mortality under HS conditions. The supplementation significantly improved the feed conversion ratio of heat stressed birds from 1.56 to 1.49. Serum concentrations of the acute phase proteins were reduced significantly in heat-stressed birds fed a diet, including the lignan-containing supplement from 3.5 to 2.5 mg/ml for ceruloplasmin and from 102.8 to 54.4 mg/ml for alpha-1-acid glycoprotein. Both proteins are synthesized and secreted in the hepatocytes in response to tissue damage related to inflammatory and oxidative challenges. Unexpectedly, no change in HSP70 expression was measured. The feed supplement may be considered a beneficial tool for poultry production under suboptimum climatic conditions due to its alleviation of HS and improvement in viability, consequently contributing to farm productivity and animal welfare.

PS2 - Nutritional intervention for climate changes**PS2-015 The effects of different feed compositions on reducing the negative effects of heat stress in broilers on performance and meat quality**R. De Baets¹, E. Delezie¹, G. Antonissen², J. Michiels³

¹ILVO, Animal Sciences Unit, Melle, Belgium, ²Department of Pathobiology, Pharmacology and Zoological Medicine, Faculty of Veterinary Medicine, Ghent University, Merelbeke, Belgium, ³Laboratory for Animal Nutrition and Animal Product Quality, Department of Animal Sciences and Aquatic Ecology, Faculty of Bioscience Engineering, Ghent University, Ghent, Belgium

The use of different feed compositions is a promising strategy in reducing the negative effects of heat stress. Proteins have a higher heat increment than carbohydrates and lipids. Therefore, a reduced dietary protein content could be beneficial during heat stress. On the other hand, increasing dietary fat leads to extra metabolizable energy and a more efficient absorption of nutrients. Feed strategies such as reduced protein content, with or without combined increased fat content in heat stress conditions have been studied, however, discussion remains. Therefore, a trial to study the effect of different feed compositions on performance and meat quality was performed. 2400 male broilers (Ross 308) distributed over 4 dietary treatments (8 replicates/treatment, 30 birds/replicate), of which half of them were raised under thermoneutral or under heat stress conditions (32°C ± 2°C and RH 55-65% for 6h daily, d29-43). A three-phase feeding scheme was applied, and the dietary treatments were only provided during the finisher period (d26-d39). The control group (C) was fed a standard broiler diet formulated at 12.19 MJ/kg, 18.24% crude protein (CP) and 8% crude fat (CF), the low CP diet (LCP) had a reduced CP-level (CP 17.3%), The low CP and high CF diet (LCPHCF) had a reduced CP-level and increased CF-level (ME 12.63 MJ/kg; CP 17.3%; CF 9.66 %). Lastly, the high CF diet (HCF) consisted of an increased CF-level (ME 12.52 MJ/kg; CP 18.22%; CF 9.6%). Heat stress had negative effects on growth ($p < 0.01$), feed intake ($p < 0.01$), slaughter weight ($p < 0.01$), feed conversion ($p < 0.01$) and mortality ($p < 0.01$). In addition, the heat stress group had significantly higher slaughter yield ($p < 0.01$), upper thigh% ($p < 0.01$), drumstick% ($p < 0.01$) and breast muscle% ($p < 0.01$). Heat stress did not affect thawing or cooking loss. In contrast with our hypothesis, dietary treatments had no significant effects on the measured parameters. In conclusion, different feed compositions did not improve the broilers' performance during heat stress in this experimental design. Possibly, protein reductions were too restricted in this trial. Additionally, the lower feed intake during heat stress could be involved in the lack of dietary effects. Finally, the higher carcass and parts yield in the heat stress group is hypothesized to be related to the mortality of smaller, weaker birds during heat stress. This work was supported by Flanders Innovation & Entrepreneurship.

PS2 - Nutritional intervention for climate changes**PS2-016 The role of a natural antioxidant as a feed supplement in broilers**A. De Grande¹, S. Leleu¹, E. Delezie¹, T. Rijsselaere², K. Deschepper²

¹Institute for Agricultural, Fisheries and Food Research, 9090 Melle, Belgium, ²Impextraco NV Belgium, Heist-op-den-Berg, Belgium

Nutritional interventions, such as in-feed supplied antioxidants, might be able to alleviate negative effects of oxidative stress (OS) on broilers performance and meat quality. Polyphenolic compounds, vitamins and trace minerals are often supplemented to broiler diets because of their antioxidant capacities. As the amount of trace elements such as Zn and Cu is legally limited, and vitamins are an expensive source, the use of phenolic compounds has gained interest. Therefore, a broiler trial was conducted at ILVO, with a highly concentrated blend of polyphenols, which has antioxidant activity (AO, Elife®). In order to create a nutritional challenge at the intestinal level for the birds (mild dysbacteriosis), a wheat-rye base diet with a high level of non-starch polysaccharides without addition of NSP enzyme was fed to the birds. The trial consisted of 5 treatments: 900 Ross 308 male broilers were fed in 3 phase (starter d0-14, grower d14-28, finisher d28-d39) basal diet (T1, control diet), supplemented with 500 g/T AO in all periods (T2), 500 g/T AO in grower and finisher period (T3), 500 g/T AO in finisher period (T4), and 150 g/T AO in all periods (T5). Each dietary treatment consisted of 6 replicates (30 birds/replicate). Performance, meat yield and quality were assessed. At d39, body weight was higher for T3 and T5 as compared to T1 (2637 g (T1) vs. 2702 g (T3) and 2775 g (T5). This difference was significant for T5 ($P = 0.026$), which might be attributed to the significantly higher feed intake observed in T5 as compared to all other treatments ($P = 0.006$). Surprisingly, no significant effect on performance was observed for T2, which might be attributed to high variation for T2, this prospects for further research. Total slaughter yield was not influenced by dietary treatment, however a trend for an increased relative breast % was seen in T3 and T5 ($P = 0.053$). For T3 a lower drip loss (0.43%) was observed as compared to the other treatments ($P > 0.001$) with drip loss ranging from 2.47% to 2.61%. T3 and T4 showed lower cooking losses as compared to the other treatments ($P < 0.001$). A dose of 150 g/T was sufficient to enhance performance under the trial conditions, whereas supplying a higher dose during grower and/or finisher period also improves meat quality and might be necessary in more stressful conditions. To conclude, supplementation with natural antioxidants can contribute to an increased meat production, characterized by an increased meat quality.

PS3 - Nutrition and microbiome under challenging conditions**PS3-01 A microencapsulated blend of thymol and organic acids can support broilers during a necrotic enteritis challenge with *Clostridium perfringens***B. Tugnoli¹, A. Piva^{1,2}, E. Grilli^{2,3}¹Vetagro S.p.A., Reggio Emilia, Italy, ²University of Bologna, DIMEVET, Ozzano Emilia, BO, Italy, ³Vetagro Inc., Chicago, United States

The aim of the study was to evaluate the dietary supplementation with a microencapsulated blend of thymol and organic acids (mTOA) in broilers exposed to a necrotic enteritis (NE) challenge with *Eimeria* and *Clostridium perfringens* (CP). Two consecutive trials were conducted with day-old male chicks (Cobb500), vaccinated for coccidiosis (COCCIVAC®-B52), divided in floor pens (50 birds/pen) and assigned to dietary groups. In trial #1 (3,000 birds), groups were (12 pens each): unchallenged control (NEG), basal diet; positive control (POS), basal diet; and three groups fed basal diets supplemented with mTOA at either 100, 200 or 300 g/MT of feed (T100, T200, T300, respectively). In trial #2 (2,000 birds), groups were (10 pens each): CTR group, basal diet; BMD group, basal diet with 55 ppm of bacitracin; T200, basal diet supplemented with 200 g/MT of mTOA. All the animals except NEG group in trial #1 were orally challenged with *E. maxima* (5,000 oocysts) at day 14 and with a CP strain (field NE isolate, α and netB toxin positive, 108 CFU) at day 19, 20, 21. Both trials lasted 42 days with small intestine lesions scored at d21 (3 chicks/pen) and growth performance recorded throughout the studies. Data were analyzed with ANOVA and differences considered significant at $P < 0.05$. In trial #1, during the challenge (d14-28), FCR was higher in POS than NEG group (1.89 vs 1.62) while the product inclusion improved FCR in a dose-dependent manner (1.78, 1.73, 1.61 for T100, T200, T300, respectively; $P < 0.0001$). Overall (d0-42), the FCR value for POS group (1.75) was significantly higher than NEG group (1.61) and all the treated groups had FCR values comparable to NEG, unchallenged (1.66, 1.65, 1.63 for T100, T200, T300, respectively; $P < 0.0001$). Treated groups showed reduced small intestine lesion score and lower overall mortality due to NE compared to POS control ($P < 0.0001$). In trial #2, during the challenge (d14-28), BMD improved weight gain and FCR compared to CTR, while T200 showed intermediate improved values ($P < 0.01$). In the overall period, FCR was significantly reduced in BMD (1.68) and in T200 (1.77) compared to CTR (1.84), ($P < 0.0001$). Compared to CTR, total mortality, mortality due to NE and small intestine lesion scores were reduced by both BMD and T200 ($P < 0.01$). To conclude, the microencapsulated blend of thymol and organic acids used in this study can be a dietary tool to control NE in broilers by improving growth performance and reducing intestinal lesions.

PS3 - Nutrition and microbiome under challenging conditions**PS3-02 A microencapsulated thymol-based blend of botanicals can clear *Salmonella* Enteritidis in contrast to common in-feed antibiotics in broilers**G. Giovagnoni¹, B. Tugnoli², C. Johnson³, A. Piva^{1,2}, R. Arsenault⁴, C. Swaggerty³, E. Grilli^{1,5}¹DIMEVET, Dipartimento di Scienze Mediche Veterinarie, Università di Bologna, Ozzano dell'Emilia, Bologna, Italy, ²Vetagro S.p.A., Reggio Emilia, Italy, ³U.S. Department of Agriculture, Agricultural Research Service, Southern Plains Agricultural Research Center, College Station, TX, United States, ⁴Department of Animal and Food Sciences, University of Delaware, Newark, DE, United States, ⁵Vetagro Inc., Chicago, IL, United States

Salmonellosis is a foodborne disease frequently transmitted with poultry products that causes gastroenteritis in humans. Alternatives to antibiotics demand is growing worldwide in order to control diseases and fight the antibiotic resistance issue. The aim of the study was to compare the effect of a microencapsulated thymol-based blend of botanicals (TBB) with commonly used in-feed antibiotics in broilers during a *Salmonella* Enteritidis challenge. Prior to the in vivo study, the susceptibility of the inoculum strain to a panel of antibiotics was evaluated using Sensititre™ plates. Tylosin and neomycin were chosen as the strain was resistant to the former and susceptible to the latter. A total of 500 day-old straight chicks (Ross 308) were placed in floor pens (50 chicks/pen) and assigned to 5 groups with 2 replicates each. The groups were all fed with basal diets, without supplementations (CTR) or supplemented with: tylosin at 25 g/MT (TYL); neomycin sulfate at 100 g/MT (NEO); or TBB at inclusions of 500 g/MT (B500) and 1000 g/MT (B1000). All the pens were orally challenged at day 4 with the *S. Enteritidis* strain at 10^5 CFU/bird. At 7, 14, 21, and 35 days of life, ten animals from each pen were weighed and sacrificed in order to count *Salmonella* in ceca and determine its prevalence in the liver. Body weights and cecal counts were analyzed with ANOVA and differences considered significant at $p < 0.05$. Body weights remained stable until d35, when B1000 was significantly higher than all the other groups (+152 g compared to CTR). The trend of *Salmonella* counts in ceca for CTR, B500, and B1000 showed a peak at d14, followed by a progressive decrease until the bacteria at d35 were totally cleared. TYL had elevated counts throughout the experiment, concluding with the highest value among all groups (5.3 Log₁₀ CFU/g; $p < 0.0001$). NEO showed low counts during the first three necropsies reaching the peak at d35 and being statistically higher than CTR, B500, and B1000 (2.3 Log₁₀ CFU/g; $p \leq 0.0005$). The same trend was observed in the percentage of *Salmonella* prevalence in liver: at d35 the prevalence in CTR and TBB-fed groups was null, whereas in TYL and NEO was 90% and 40% respectively. To conclude, the thymol-based blend of botanicals at the highest dose had a positive effect on the final body weight. Furthermore, the blend at both doses was able to completely clear *S. Enteritidis* in broilers, while conventional antibiotics were not effective.

PS3 - Nutrition and microbiome under challenging conditions**PS3-03 A qPCR study of APEC and *C. perfringens* virulence gene prevalence in South African Poultry farms**J. Walker¹, Q. Wang¹, L. Mostert², A. Mereu³, K. Gibbs³, E. White³, J. McAuliffe¹¹Danisco Animal Nutrition & Health, Powder Mill Road PO Box 8352 Wilmington, DE 19803, United States, ²Chemuniqé (Pty) Ltd, 28 Eagle Lane, Lanseria Business Park, Lanseria, South Africa, ³Danisco Animal Nutrition & Health, Willem Einthovenstraat 4, 2342 BHG, Oegstgeest, Netherlands

Development of improved means for rapid analysis of Poultry microbiomes to identify intestinal health and performance risk factors is critical to more sustainable production. Existing methods based on live culture and end point PCR are cumbersome and slow. We have developed a qPCR method for direct analysis of Poultry intestinal swabs for two key microbial challenges, avian pathogenic *E. coli* (APEC) and *C. perfringens*, and validated such methodology in commercial poultry systems. In total, 352 ileal mucosal and 72 caecal mucosal intestinal swabs (Zymo Research) were collected from 352 commercial birds (broilers/breeders/layers) from 15 different commercial farms in South Africa. Furthermore, ileal mucosa segments were excised, homogenized, diluted and plated on selective media for *C. perfringens* and *E. coli*. Following incubation, CFU/g of mucosa were determined and representative colonies picked and preserved on FTA® cards (Whatman). These individual isolates from FTA® cards were subsequently analyzed by end-point PCR against a standard gene panel (five APEC genes and two *C. perfringens* virulence genes). Intestinal swabs were processed and subjected to qPCR analysis against an expanded gene panel (10 APEC virulence genes and 2 genes for *C. perfringens*). Data were processed in a custom python script and results plotted as absolute gene marker levels and ratios of marker genes to total bacteria, *E. coli* and *C. perfringens*. Differences were observed between farms with regard to total bacterial levels, levels of *E. coli* and APEC marker prevalence. Clostridial genes were mostly absent. The study revealed that cecal swabs gave superior results to swabs derived from ileal mucosa and that swabbing technique also had an influence. The qPCR method was able to identify farms with higher levels of APEC markers and showed modest to good correlation to traditional plate culture-based methods. In contrast to live isolate based methods, our qPCR-based method enables the determination of both absolute levels of virulence genes and their overall population abundance relative to total bacteria, *E. coli* and *C. perfringens*. We applied this method at 15 South African farms and identified factors that influence the results. This approach offers a simplified means for producers to monitor microbiome changes and in contrast to environmental sampling, provides insight into mid-gut health.

PS3 - Nutrition and microbiome under challenging conditions**PS3-04 Amino acid digestibility and tissue protein synthesis and degradation in broiler chickens on low protein diets during infection with *Eimeria* spp.**A.M. Ajao¹, G. Liu¹, J. Taylor², T. Applegate¹, R. Selvaraj¹, M. Ball², I. Kyriazakis^{2,3}, W.K. Kim¹, O.A. Olukosi¹¹Department of Poultry Science, University of Georgia, Athens, United States, ²Agri-Food & Biosciences Institute (AFBI), Belfast, BT9 5PX, United Kingdom, ³Institute for Global Food Security, Queen's University, Belfast, BT9 5DL, United Kingdom

We investigated the effect of supplementing Arg and branched-chain amino acids (BCAA) in diets of broilers receiving low protein diets and challenged with mixed *Eimeria* spp on amino acid (AA) digestibility, markers of protein synthesis and degradation in the pectoralis major. All birds received same starter (d 0-10) and finisher (d 28-35) diets that met Cobb 500 recommendations. Four grower diets were: positive control (PC) with adequate protein (185 g/kg); low protein (NC, 165 g/kg); or NC supplemented with Arg or BCAA. The AA were added at 50% above requirement, but the ratio of individual BCAA was kept the same in all diets. A total of 8 treatments (4 diets, with or without *Eimeria* challenge at d14) were used; each treatment had 8 replicates. Ileal digesta were collected from 5 birds per pen on d 21 and 28 (infection and recovery phases, respectively), and muscle tissue was collected from one bird per pen on d 21. There was no diet × *Eimeria* on AA digestibility in either phase. *Eimeria* challenge reduced ($P < 0.05$) AA digestibility during the infection phase (d 21). The birds receiving the PC diet had greater ($P < 0.05$) apparent digestibility of Ala, Asp, Cys, Glu, His, Phe, Ser, and Tyr during the infection phase. Birds receiving Arg or BCAA had greater ($P < 0.05$) apparent digestibility of the respective supplemental AA only. During the recovery phase, *Eimeria*-challenged birds had lower ($P < 0.05$) apparent digestibility of Met and Cys. Birds receiving Arg supplementation had greater ($P < 0.05$) apparent digestibility of His and Pro; and those receiving BCAA had greater ($P < 0.05$) apparent digestibility of Val and Tyr. A diet × *Eimeria* ($P < 0.05$) was observed during infection phase for the protein degradation genes (myogenin and myogenic regulatory factor 5); in non-challenged, the genes were downwardly expressed in all treatments compared with PC, but the reverse was observed in challenged treatments. *Eimeria*-challenged birds during infection phase (d 21) upwardly expressed ($P < 0.05$) eukaryotic elongation factor 2 (Eef2), but downwardly expressed ($P < 0.05$) S6 kinase 1, genes associated with protein synthesis. No effect of supplemental AA was observed with regard to protein synthesis and degradation genes during the infection phase. In conclusion, supplementing Arg and BCAA in the diets of *Eimeria*-challenged birds receiving low-protein diets selectively improved AA digestibility but had minimal effects on protein synthesis and degradation genes tested.

PS3 - Nutrition and microbiome under challenging conditions**PS3-05 Bacillus sp. PB6 improves performance and alters the microbiome of breeding pheasants under commercial conditions in Poland**K. Vermeulen¹, P. Bukowska¹, E. N'Guetta¹, A. Wealleans¹¹Kemin Europa, Herentals, Belgium

A 12 week field study was conducted at commercial pheasant breeding and rearing facilities in Poland. In accordance with the housing and feeding systems used on the farm, the reproductive flock was kept in cages (1 cock - 10 hens) using harem mating. Birds were assigned to two treatments: 1) 2870 hens and 291 roosters were assigned to a control house receiving commercial diets; and 2) 16007 hens and 1643 roosters were assigned to a treatment house, receiving diets supplemented with 1x10⁸ cfu PB6/kg feed. All birds were vaccinated against Egg Drop Syndrome, Swollen Head Syndrome, Marek's Disease and Newcastle Disease; birds were dewormed prior to study start. Six hens/treatment were sacrificed at the end of the laying period. DNA was extracted from ileal and caecal content and 16S rRNA amplicon sequencing methods were applied to all samples. Alpha and beta diversity measures were calculated, as were differences in relative abundance at the phylum and family level. Supplementation increased daily laying rate (+5.9%, P<0.05), speed to and height of peak lay, and reduced the decline from peak. Rooster mortality was substantially decreased. Ileal content of control birds contained relatively fewer Enterococcaceae, due to significantly lower Enterococcus (2.03% control, 8.05% PB6; P=0.01), as well as lower Staphylococcaceae (<0.04% control, 0.21% PB6; P=0.01), and Leuconostocaceae (<0.001% control, 0.09% PB6; P=0.002). In contrast, Peptococcaceae were significantly more abundant (0.43% control, 0.20% PB6; P=0.04). The caecal ratio of Firmicutes:Proteobacteria increased following supplementation (1.36 control, 2.35 PB6), which is associated with increased a reduction in opportunistic pathogen presence. A significantly higher percentage of Bacteroidaceae could be observed in the caeca of PB6-fed birds, driven by genus Bacteroides (10.17% control, 20.21% PB6; P=0.03). Supplementation also numerically increased relative abundances of Lachnospiraceae and Ruminococcaceae (explained by increased Faecalibacterium, which contains only a single species: F. prausnitzii, an abundant butyrate-producer), among others. Bacillus sp. PB6 supplementation to breeding pheasants improved performance, likely due to alterations in microbiome structure. The study also provided novel insight into the microbiome of laying pheasants.

PS3 - Nutrition and microbiome under challenging conditions**PS3-06 Butyric glycerides act directly and indirectly on chicken enterocytes to enhance resistance to pathogen colonization**A. Mellouk¹, N. Vieco-Saiz¹, V. Michel¹, O. Lemâle², T. Goossens³, J. Consuegra¹¹Adisseo France S.A.S. Center of Expertise and Research in Nutrition (CERN), Malicorne, France, ²Adisseo NL, Raamsdonksveer, Netherlands, ³Adisseo, Dedermonde, Belgium

Butyric acid supplementation to the feed is mainly used for its benefits on chickens' gut health. As a source of butyrate, mono-, di-, and triglycerides of butyric acid provide a better distribution of butyrate in the entire gastrointestinal tract. Here, we aim to study direct and indirect effects of these butyric glycerides' mixture on avian enterocytes' resistance to pathogen colonization. The Chic clone-8E11 immortalized chicken enterocytes (8E11) was used to conduct this study in vitro. First, we measured, by CellELISA, their resistance to C. jejuni and S. Typhimurium adhesion after a preincubation with sodium butyrate (SB) or butyric glycerides enriched with monobutylin (MB). At 2mM, MB significantly reduced the adhesion of C. jejuni and S. Typhimurium to 8E11 cells by 84 and 60 %, respectively. SB reduced only S. Typhimurium adhesion by 20% (n=3, p < 0.001). MB preincubation also protected 8E11 cells from the toxicity of C. perfringens α toxin measured by Resazurin cell survival test. MB maintained 8E11 survival levels at 80 % vs. 15 % and 20 % in the control and SB groups, respectively (n=3, p < 0.001). Next, we measured, by Seahorse®, the effects of the digested and non-digested butyric glycerides treatments on 8E11 cells mitochondrial activity. Only SB and butyrate released by lipase cleavage, but not MB, significantly increased, up to twice, the initial and maximal oxygen consumption rate (n = 8, p < 0.001). In mammals, this metabolic response is known to induce a shift in intestinal ecology to an anoxic profile favoring anaerobic microbiota and disfavoring aerobic pathogens growth. To further explore this shift, we are studying the microbiome of chickens fed with butyric glycerides mix supplementation (n = 6 / group). In summary, our results suggest that supplementing poultry feed with butyric glycerides mix, do not only ensure delivery of butyrate all along the gut but confers a triple antimicrobial effect. Besides the described antimicrobial effect of α -monoglycerides, we demonstrate that butyric glycerides act directly on enterocytes making them more resistant to pathogens adhesion and toxicity. In addition, butyric acid, when released by lipase, acts as a source of energy not only for mammalian but also avian enterocytes and can therefore indirectly drive a microbial shift towards a resistant profile to pathogen invasions. Altogether, we show in vitro how butyric glycerides can enhance animal resilience against pathogenic challenges.

PS3 - Nutrition and microbiome under challenging conditions**PS3-07 Changes in the gut microbial composition of broiler chicks fed non-antibiotic feed additives**

G.F.C. Sales¹, L.R. do Monte Pessoa Felix¹, M.R. Brito dos Santos¹, M. de Mesquita Souza Saraiva², W.J. de Araújo¹, P.E. Naves Givisiez¹, C.J. Bruno de Oliveira¹

¹Departament of Animal Science, College for Agricultural Sciences, Federal University of Paraíba (CCA/UFPB), Areia-PB, 58397-000, Brazil, ²Department of Pathology, Theriogenology and One Health, Laboratory of Ornithopathology, São Paulo State University (FCAV/Unesp), Jaboticabal-SP, 14884-900, Brazil

In order to investigate the microbial composition of the cecal contents of broiler chicks fed two non-antibiotic feed additives: a prebiotic-like fermented compound or a sanguinarine-based phytobiotic. One-day Cobb 500 chicks (n=72) were weighed individually and distributed in solid-floored pens (12 birds/pen) according to a completely randomized design with 3 treatments and 24 birds as replicates. The treatments consisted of feeding an initial phase diet (22.4% crude protein, 1.32% digestible lysine, 0.95% methionine+cysteine, 1.94% glycine+serine and 0.86% digestible threonine) as control (DCO), the same feed with a prebiotic-like fermented compound (Original XPC, Diamond V, USA) at 1.25 g/kg (PFC) or a sanguinarine-based phytobiotic (Sangrovit, Phytobiotics, Germany) at 1.5 g/kg (SAN). Cecal contents were collected from euthanized birds at 3 and 14 days (n=4 per treatment group/age). DNA was extracted, amplicon libraries targeting the V3-V4 region of the 16S rRNA gene were prepared and sequenced in Illumina Miseq. Demultiplexed sequences were processed by QIIME2 and de-replicated using VSEARCH. Chimeras were removed using UCHIME. Amplicon Sequence Variants (ASVs) were obtained by de novo clustering at 99% similarity. The number of sequences per sample was normalized and taxonomic classification was assigned using the Naïve Bayes method on the SILVA database. Alpha- and beta-diversity analyses were performed using Phyloseq and DESeq2 packages in R. Comparative analyzes of differential abundances were performed using STAMP. Higher alpha-diversity was observed in the microbiota of SAN-fed birds, as indicated by the Shannon diversity index that measures richness and evenness of taxa. Microbial composition in SAN showed higher dissimilarity compared with DCO and PFC. Both additives significantly (P<0.05) increased Lachnospiraceae and Sellimonas, while SAN decreased Bacteroidales compared with DCO and PFC-fed chicks. In conclusion, significant changes in gut microbial composition were observed in chicks fed SAN and PFC, both in terms of diversity and abundance of specific taxa. Further in-depth studies on the functional role of SAN and PFC in the gut of broiler chickens are warranted. Funding: Conselho Nacional de Pesquisa e Desenvolvimento (CNPq #313678/2020-0); Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, Finance code 001, Print 88881.311776/2018-01) and Fundação de Apoio à Pesquisa do estado de São Paulo (Fapesq # 3083/2021).

PS3 - Nutrition and microbiome under challenging conditions**PS3-08 Dietary supplementation with 3 strains of *Bacillus velezensis* improved performance and gut integrity in commercial broilers in Belgium**

J. Villatoro Hernandez¹, M. De Gussem², B. de Sloovere¹, S. van der Klein¹, K. Gibbs¹, C. Evans¹, B. Hillen¹

¹IFF Danisco Animal Nutrition & Health, Leiden, Netherlands, ²Poulpharm, Izegem, Belgium

Bacillus based feed additives have been available to support intestinal health in animal production for some time. The aim of this study was to assess the efficacy and value of a three *Bacillus velezensis* strain probiotic Belgian farms using a combination of nutraceutical-based parameters. Twenty farms in Belgium were selected randomly to participate in this study. A minimum of 2 houses per farm were used with comparable performance-one was used as the control and the other treated with 150000 cfu/g *B. velezensis* via top-dressing the feed for all feeding phases. Animals in both houses were of the same age and same genetics and had the same feed. For each house the following measurements were taken. Individual body weight of 200 birds (D14, D21, D28, D35), oocysts per gram (OPG) faeces counting and differentiation of *Eimeria* spp. (D21, D28, D35), Coccidiosis and bacterial enteritis lesion scoring on 5 birds (D21, D28, D35), Villi/Crypt ratio in the duodenum, Ovotransferrin (OTF) concentration in intestinal content for 5 birds (D28). Performance data were segmented based on the intestinal health challenge determined in the macroscopic lesion scoring. Farms were categorized as having a mild, moderate, or significant gut health challenge. The biggest improvements in flock performance as a result of *B. velezensis* supplementation occurred in flocks experiencing high intestinal health challenge. In these high challenge farms, supplementation resulted in a 60g additional bodyweight per bird at slaughter (D35) versus non-supplemented flocks (2140g vs 2080g; P<0.1). This correlated with the largest numerical reduction in intestinal OTF levels (control 8.9µg/100µg sample vs 5.24µg/100µg sample). While this was not statistically significant, it suggests OTF could be a useful tool to measure physiological challenge in birds. In farms with a mild intestinal challenge, bodyweight at slaughter was improved by an average of 40g per bird (2120g vs 2080g; P>0.1). Average VH/CD ratio was numerically improved in both mild and moderate challenge flocks. This study demonstrates that by using a combination of tools from gross macroscopic lesion evaluations, performance and chemical biomarker analysis the mode of action of probiotics and return of investment can be better assessed in field conditions. This work also highlights the importance in understanding and quantifying the starting level of challenge so best recommendations on intestinal health solutions can be made.

PS3 - Nutrition and microbiome under challenging conditions**PS3-09 Double Lactobacilli strain-based pro- and post-biotic influenced broiler caecal microbiota mainly under dietary challenging conditions**

S. Jansseune^{1,3,2}, F. Blanc², W. Hendriks³, J. van Baal³, A. Lammers³, A. Mahieu¹, M. Aoun¹, F. Calenge², M. Pinard van der Laan²

¹Idea, Sautron, France, ²INRAE, Jouy en Josas, France, ³Wageningen University, Wageningen, Netherlands

Microbiota play a key role in gut health of chickens. Its composition and functionality may be modulated by probiotics (Pro) and postbiotics (Post). This study aimed to assess the effects of *Lactobacillus rhamnosus* and *L. formosensis* coculture-based Pro and derived Post under 2 diets (standard [SD], challenge [CD]) on broiler caecal microbiota and metabolome. Following a 2x3 randomised block design, day-old Ross male broilers (n=1368) were fed 1 of 2 diets (SD or CD) and 1 of 3 additives (control, Pro or Post) from d1 to 42 with 6 pen replicates per treatment. SD and CD were formulated to contain identical levels of nutrients, with CD formulated to be richer than SD in non-starch polysaccharides. Caecal microbiota composition was assessed by 16S rRNA gene sequencing for 3-4 broilers/pen at d14 and 35, respectively. Variations in α - and β -diversity indexes were analysed by ANOVA and for contrasts. Operational taxonomic unit (OTU) abundances were compared by differential abundance analyses. P-values <0.05 were considered significant. At d14, Observed and Chao1 α -diversity indexes were higher for Pro compared to control in SD, and lower for Post compared to control in CD. At d35, no effects of additives were observed, while the latter indexes were lower for CD compared to SD. At d14, Bray and Jaccard β -diversity indexes showed a diet effect, no additive nor diet x additive effect, whereas at d35 these indexes showed an interaction and a diet effect, but no additive effect. At d14, 2 OTU were differentially abundant (DA) for Pro and Post compared to control for SD, whereas 6 and 17 OTU, respectively, were DA for Pro and Post compared to control for CD. At d35, Pro and Post had no DA OTU compared to control for SD. By contrast, for the CD, Pro and Post had 37 and 44 DA OTU compared to control, respectively. Four and 86 OTU were DA between the SD and CD controls at d14 and 35, respectively. In conclusion, Pro and Post modified broiler caecal microbiota in an age and diet dependent manner. In particular, their effects were more pronounced at d35 in the CD. Pro and Post effects on microbiota are in line with their effects observed for broiler growth, since Pro and Post increased body weight in CD without effects in SD. This highlights the importance of diet composition to assess Pro and Post effects on gut microbiota. Analyses to understand the potential functional effects of Pro and Post on the host microbiota, caecal metabolome and phenotypes, are pending.

PS3 - Nutrition and microbiome under challenging conditions**PS3-010 Effect of a precision biotic in broiler chickens fed corn or wheat-based diets**

C. Bortoluzzi¹, P. Segobola¹, M. Segura-Wang², C. Iaconis³, A. Leduc³, R. Aureli³, J. Sorbara¹

¹DSM Nutritional Products, Kaiseraugst, Switzerland, ²DSM Nutritional Products, Getzersdorf, Austria, ³DSM Nutritional Products, Village-Neuf, France

The objective of the present study was to evaluate the effect of a precision biotic (PB; SymphioMeTM, DSM Nutritional Products) on the growth performance, blood uric acid concentration, cecal short-chain fatty acids (SCFA) concentration, and ileal and cecal microbiome. One-day-old broiler chicks were placed in 4 treatments, 8 replicates/treatment, and 16 birds/replicate. The treatments were distributed in a 2 x 2 factorial arrangement: 2 types of diet (corn or wheat based) and with or without supplementation of 0.9 kg/MT of PB (400 ppm of dried glycan). All the birds were vaccinated against coccidiosis at the placement (Paracox 5). Growth performance was evaluated weekly, and at the end of the experiment. At day 35, blood was collected to determine uric acid concentration and cecal content for SCFA and microbiome analysis. The data were submitted to two-way ANOVA ($P \leq 0.05$), and LSMeans was used to separate the means. There was no significant interaction for any of the parameters evaluated. From d 1-15 ($P = 0.001$) and 15-28 ($P = 0.04$), wheat-based diets promoted higher body weight gain (BWG) vs corn-based diets. From d 28-36, the supplementation of PB improved the feed conversion ratio (FCR) by 4 points ($P = 0.06$). Considering the entire experimental period, PB supplemented to wheat-based diets numerically improved the corrected FCR by 4 points, and overall, by 2.6 points. The SCFA concentration in the ceca was not significantly affected by the treatments, but broilers fed a wheat-based diet had numerically higher concentration of acetate (10%; $P = 0.14$). PB supplemented to wheat-based diet increased butyrate concentration in the ceca by 20% ($P = 0.13$). There was a main effect of diet ($P = 0.02$) and supplementation of PB ($P = 0.02$) on the blood uric acid concentration, wherein wheat-based diet increased its concentration by 13%, and PB supplementation reduced its concentration by 14%. The microbiome analysis showed that the supplementation of PB to both corn or wheat-based diets led to a shift in the microbiome functional profile, modulating pathways related to amino acid, carbohydrate and vitamin metabolism, that play central role in energy metabolism, with a trend ($P = 0.09$) to increase the microbiome protein metabolism index (MPMI) in corn-based diets fed broilers. Overall, PB induces beneficial changes of the microbial metabolism that may explain the improvements in growth performance.

PS3 - Nutrition and microbiome under challenging conditions**PS3-011 Effect of a probiotic solution on intestinal health of broiler chickens co-challenged with salmonella and mycotoxins**

D. Preveraud¹, M. Ingberman², B. Castello Branco Beirão², N. Simarro-Fagundes³, T. Goossen¹, T. Quinteiro-Filho³

¹Adisseo France SAS, Antony, France, ²Imunova Análises Biológicas, Curitiba, Brazil, ³Adisseo Brasil, São Paulo, Brazil

The test comprises evaluating the immune parameter modulation by a commercial probiotic solution, *Bacillus Subtilis* DSM 29784 (Bs29784) in a mycotoxin-Salmonellosis experimental challenge. A total of 322 one-day-old Ross broilers from a commercial hatchery were placed in isolators and randomly assigned to 7 different experimental groups of 46 broilers each. The treatments consisted of a control group (CTRL), a mycotoxin (CM) and salmonella group (CS), a control group with Bs29784 (PRO), a co-infection mycotoxin-Salmonella group (CMS), a Salmonella group with Bs29784 (CS-PRO) and a mycotoxin-Salmonella group receiving Bs29784 (CMS-PRO). On d1, birds in CM, CMS and CMS-PRO groups started to receive the mycotoxins in their diet (mainly fumonisin, deoxynivalenol and T-2 toxin). On d4, each animal of CS, CMS, CS-PRO and CMS-MD groups received 1x10⁸ CFU *Salmonella* Heidelberg by oral delivery. Between d4 to d28, intestinal permeability was evaluated by serum FITC-dextran, ceca content was collected to assess *Salmonella* spp. counts by Most Probable Number (MPN) and microbiota composition was determined using S16 sequencing. In cecal tonsil, the cytokines gene expression was measured, histomorphology was assessed from jejunum and cecum tissues and liver samples were also collected for lipoperoxidation and histopathology evaluation. Finally, anti-salmonella IgA was quantified in feces. Statistical analysis was performed by two-way ANOVA with Tukey's post-hoc test ($P < 0.05$). Mycotoxin presence in the feed can significantly increase intestinal permeability ($P=0.0157$) and can numerically increase pro-inflammatory IL6 cytokine, leading to a higher passage of *Salmonella* across the epithelium and an activation of macrophages. The probiotic solution has shown significant effect on gut permeability (decrease FITC-d), salmonella prevalence in ceca (decrease MPN), redox status (decrease LPO), and inflammation (decrease IL6 and increase IL10). Bs29784 demonstrated a positive effect on liver histological integrity, and in a mycotoxin and Salmonellosis challenge, demonstrating a positive antioxidant effect. It seems to protect the intestinal layer in a mycotoxin-Salmonellosis challenge, reducing the bacterial counts and promoting microbiota's diversity.

PS3 - Nutrition and microbiome under challenging conditions**PS3-012 Effect of a stimbiotic and nutrient density in induced dysbacteriosis broiler chickens on performance, gut health, immune and microbiome modulation**

X. Rousseau¹, G.A. Gomes¹, N. Ahmad¹, S. Haldar², A.K. Dhara², S. Sihi Arora², T. Tedeschi dos Santos¹

¹AB Vista, Marlborough, United Kingdom, ²Agrivet Research and Advisory, Kolkata, India

This experiment study the effect of a stimbiotic (STB) in a 2x2x2 full factorial design comprising STB level [Signis, AB Vista, Marlborough, UK] at 0 or 100g/ton; sanitary conditions (without and with challenge); nutrient density (positive control [PC] and negative control [NC] which was reduced by 100kcal/kg vs PC). Day old Cobb 430 males were randomly distributed in 80 pens and fed a corn/wheat based diet till 42d of age. Performance, serum *E. coli* lipopolysaccharides (LPS) and tumour necrosis factor-alpha (TNF-alpha), short chain fatty acids (SCFAs) were evaluated. The challenge was set as oral gavage at d8 and d9 with *E. coli* following by a priming at d15 with *Eimeria* and oral injections of *C. perfringens* twice a day at d18-19 and 20. Data was submitted to a 3-way ANOVA with the effect of STB, challenge, nutrient density. Cecal droppings for SCFAs analysis were only collected from NC birds and analysed for a 2-way ANOVA. When interactions were found, means were separated using Student's T-test. Significance was accepted when $P \leq 0.05$, and trends discussed when $P < 0.10$. Feed intake from challenged birds was reduced from d15 onwards ($P < 0.05$) while an interaction between STB and challenge ($P < 0.05$) was observed from d1 to d14. FCR tended to be improved in the d15-d28 phase ($P < 0.10$) when supplemented with the STB whereas no effect of the challenge and nutrient density was observed ($P > 0.05$) that explains the overall period improvement of FCR with STB ($P < 0.05$). From d14, body weight was decreased by the NC vs PC ($P < 0.05$) while STB increased the body weight from d28 onwards ($P < 0.05$). *E. coli* LPS was increased for challenged birds ($P < 0.05$) and reduced with STB ($P < 0.05$). An interaction between STB and challenge ($P < 0.05$) was noticed for TNF-alpha. Challenge led to a TNF-alpha increase that was reduced when supplemented with STB ($P < 0.05$) while in non-challenge, no effect was observed. SCFAs analysed at d26 showed that STB tended to increase total SCFAs ($P < 0.10$) and butyric acid ($P < 0.10$) with a reduction of the ratio between branched chain and volatile fatty acids regardless the challenge. STB improves performance and caecal SCFAs profile irrespective of the challenge or dietary nutrient density. However, STB mitigated detrimental effects of the challenge by reducing inflammation and improving gut integrity and thereby performance.

PS3 - Nutrition and microbiome under challenging conditions**PS3-013 Effect of a triple-strain Bacillus-based probiotic on in vitro inhibition of Enterococcus cecorum isolated from broilers**A. Meuter¹, D. Sandvang¹, L. Skjoet-Rasmussen¹, L. Capern¹¹Chr. Hansen, A/S, Hørsholm, Denmark

Enterococcus cecorum is usually recognized as a harmless commensal of the gut of broiler chickens. However, dysbacteriosis conditions can allow this opportunistic pathogen to overgrow and benefit from loosening of tight junctions to translocate from a leaky gut to the bloodstream. E. cecorum can then be transported to specific tissues (e.g.: joints) or organs (e.g.: heart) where it can induce significant damages. The clinical picture of pathogenic E. cecorum infection in a flock is high mortality due to septicemia early in the growing period followed weeks later by lameness due to osteomyelitis of the femoral head. E. cecorum currently causes a lot of damage on the profitability of broiler operations worldwide with increased mortality, poor production, and increased condemnation. In this context, 12 isolates of E. cecorum were collected from broiler chickens raised in farms from Western Europe with the aim of evaluating the in vitro inhibition capability of a triple-strain Bacillus-based probiotic. A pathogen inhibition assay was conducted to assess the capacity of the supernatant of the probiotic to inhibit the growth of those different E. cecorum isolates. Growth of the 12 isolates was measured with and without the probiotic supernatant added and optical density was utilized to assess growth. All experiments were conducted in triplicates. Results revealed that the triple-strain Bacillus-based probiotic had a very high magnitude of inhibition against E. cecorum growth ranking from 80 to 95% for all 12 isolates. This strong in vitro capability for direct inhibition of clinical Enterococcus cecorum isolates can be explained by the ability of the different Bacillus strains in the probiotic to release specific inhibitory lipopeptides like surfactins and fengycins to its nearby surroundings. In vivo studies are planned to confirm the efficacy of this triple-strain Bacillus-based technology in commercial broilers challenged with E. cecorum.

PS3 - Nutrition and microbiome under challenging conditions**PS3-014 Effect of feeding diet containing coccidiostat and administration of antibiotics to turkeys in the first days after hatching on yolk sac resorption and maternal antibody levels**J. Jankowski¹, D. Mikulski¹, P. Konieczka¹, R. Smagiel², E. Cholewinska², A. Stepniowska², M. Krauze², K. Ognik²¹Department of Poultry Science and Apiculture, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland,²Department of Biochemistry and Toxicology, University of Life Sciences in Lublin, Lublin, Poland

The experiment verified the hypothesis that early administration of an antibiotic, especially when feeding diet containing coccidiostat, can reduce the rate of yolk sac absorption and decrease antibody levels, and consequently may impair the immune system function of growing turkeys. The experiment was conducted on 1152 one-day-old turkeys divided into 6 treatments: CM(-), EM(-), DM(-), CM(+), EM(+), DM(+). Turkeys in the M(-) groups did not receive monensin in the diet, while those in the M(+) groups received monensin at a dose of 90 mg/kg of feed. Turkeys in groups C, received no antibiotic supplement (control groups), while those in groups E received enrofloxacin at a dose of 10 mg/kg BW for the first 5 days of life, and those in groups D received doxycycline at a dose of 50 mg/kg BW for the first 5 days of life. The birds were vaccinated against APV and NDV on day 1 of life and against ORT on day 28 of life. On days 1, 3, 5, 7 and 56, blood was collected from 21 birds in the group to evaluate anti-APV, anti-NDV, anti-ORT antibody titers and IgY and IgM levels. A two-way ANOVA analysis showed no interaction between the antibiotic and monensin ($P > 0.05$). A reduction in IgM levels ($P = 0.006$) in yolk sac and serum of 3-day-old turkeys was observed during doxycycline administration. A reduction in IgM ($P < 0.001$) in the serum of 3-day-old turkeys was also noted when monensin was administered. In addition, a reduction in anti-ORT ($P = 0.002$) and anti-APV ($P = 0.025$) titers was observed in the blood serum of 5-day-old turkeys receiving monensin. At day 7 of life, i.e., after the end of doxycycline administration, there was an increase in serum IgM and IgY levels ($P = 0.005$, both), and at a time more distant from the administration of both doxycycline and enrofloxacin, i.e., at day 56, there was a decrease in IgY levels ($P < 0.001$). There was also a reduction in serum anti-NDV titers ($P = 0.05$) in 56-day-old turkeys under the influence of monensin administration. It has been established that early administration of antibiotics does not affect the rate of resorption of turkey yolk sacs, but there is a real risk of inducing an immunosuppressive reaction if doxycycline is administered in the first days of turkey life or if monensin is used for a longer life period. This work was supported by the National Science Centre in Poland, Grant No. 2020/39/B/NZ9/00765

PS3 - Nutrition and microbiome under challenging conditions**PS3-015 Effect of low-oil distillers dried grains with solubles on broilers challenged with *C. perfringens* and *Eimeria* spp.**B. Singh¹, E. Chadwick¹, J. Krehling¹, K. Macklin²¹Auburn University, Department of Poultry Science, Auburn, United States, ²Mississippi State University, Department of Poultry Science, Starkville, United States

Necrotic enteritis (NE) is a disease of substantial economic importance. Distillers dried grains with solubles (DDGS) inclusion in diets has been studied extensively; however, there is less knowledge of low-oil DDGS (L-DDGS). Nutrition can serve as a strategy to control NE; however, a better understanding must be gained of how nutrition impacts the microbiome and shifts during NE development. Mixed sex Ross 708 birds were used to determine the effects of feeding L-DDGS (4.3% crude fat) on growth performance, intestinal microbiome, and NE development. The experiment consisted of a 2(diet) × 2(challenge) factorial arrangement of treatments. Each treatment was replicated in battery cages with 9 pens (10 birds/pen) and was fed a two-phase feeding program, from 0 to 27 d of age. The control diet consisted of a commercial corn-soy diet lacking L-DDGS. The L-DDGS diet consisted of the commercial diet with 5.0% inclusion in the starter and 7.5% in the grower. Both diets were formulated to provide a ME of 2264 kcal/kg. Inoculation with *Eimeria* spp. occurred on d 18, followed by inoculation of *C. perfringens* on d 21-23. Feed intake (FI) and body weight (BW) were measured on d 0, 14 and 27. On d 27, 5 birds per pen were selected, necropsied, jejunum tissue collected for 16S rRNA gene sequencing and intestine scored for NE lesions. Data were analyzed using GLM procedure, if significant ($P < 0.05$) means were separated using Tukey's post hoc analysis. Results imply that dietary L-DDGS reduces NE incidence, severity and average lesion scores. However, L-DDGS resulted in a significant reduction in BWG at 14-27 d of age ($P = 0.013$) and worsened mortality-adjusted FCR at 14-27 d ($P = 0.010$) and 0 to 27 d of age ($P = 0.003$). This reduction was not due to palatability as diet did not significantly affect FI during any period ($P > 0.05$). An increased need for energy was noticed, as FI was slightly greater in the L-DDGS diet fed birds than the control diet fed birds. The oil extraction process, likely caused an increase in the fiber content and proportion of protein, thereby impacting the digestibility of the L-DDGS diet. With the microbiome, L-DDGS had significant richness ($P = 0.027$) and diversity ($P = 0.015$) in unchallenged birds, compared to unchallenged birds consuming a corn-soy based diet. The indirect effect of lactate and butyrate producing bacteria should be further studied, as these bacteria together may largely affect *C. perfringens* colonization and disease induction.

PS3 - Nutrition and microbiome under challenging conditions**PS3-016 Effect of muramidase in combination with different fiber type diets and different anticoccidial programs on broiler performance**I. Eising¹, P. Segobola¹, S. van der Vaart², E. van Eerden²¹DSM ANH EMEA, Basel, Switzerland, ²Schothorst Feed Research, Lelystad, Netherlands

Muramidase (Mur) is an enzyme that cleaves peptidoglycans (PGNs) of dead bacteria. PGNs are part of bacterial cell walls and are recognized by the immune system. Mur has shown to reduce inflammation, created by PGNs of dead bacterial cell debris. Thereby, Mur can give an added benefit for birds with an immune challenge or when dietary antibacterial ingredients increase PGN levels in the gut. Fermentable fibers (FF) increase digesta viscosity thereby creating a higher intestinal challenge than inert fibers (IF). Ionophore anticoccidials have an antibacterial activity while an anticoccidial vaccine impacts the immune system. Three hypotheses were tested: 1. Mur has a more pronounced effect in diets containing FF vs IF. 2. Mur can mitigate a drop in performance due to anticoccidial vaccination. 3. Mur supports performance in different anticoccidial strategies in combination with different fiber sources. The trial had a factorial design, factors were fiber source (8% soyhulls (FF) vs 8% oat hulls (IF)), anticoccidial strategy (none vs. vaccine vs. ionophore coccidiostat) and Mur supplementation (0 vs 35.000 LSU(F)/kg feed). There were 12 treatments with 8 replicates of 23 male Ross 308 broilers. A starter diet was fed from D0-14, a grower diet from D14-28 and a finisher diet from D28-36. Birds and feed were weighed on D7, D14, D28 and D36. Performance measurements were feed intake, body weight gain (BWG) and feed conversion ratio (FCR). Supplementation of Mur vs no Mur gave overall the best results (2463g vs 2413g BWG and 1.467 vs. 1.485 FCR; $p < 0.01$). FF increased viscosity and decreased the nutrient absorption (data not shown) in the starter diets. Mur vs. no Mur addition to FF plus an ionophore coccidiostat had a positive effect on FCR (1.244 vs. 1.338) in the starter phase. Birds vaccinated against coccidiosis showed a drop in performance vs birds fed with an ionophore coccidiostat, regardless of fiber source or Mur addition. Mur vs. no Mur addition to IF had a positive effect on FCR (1.375 vs. 1.439) in the grower phase in vaccinated birds. This trial showed an overall positive effect of Mur addition on broiler performance, unrelated to fiber source or anticoccidial strategy. Mur is also able to maintain good performance in mildly challenged conditions (FF diets). And this trial showed that Mur can counteract the negative effects of an anticoccidial vaccine on performance, resulting in comparable performance vs when an ionophore is added to the diet.

PS3 - Nutrition and microbiome under challenging conditions**PS3-017 Effects of the dietary inclusion of insect meal and live larvae on microbiota modulation in Muscovy duck**M. Gariglio¹, I. Ferrocino², I. Biasato², L. Gasco², A. Schiavone¹¹Department of Veterinary Sciences, University of Turin, Grugliasco (TO), Italy, ²Department of Agricultural, Forest and Food Sciences, University of Turin, Grugliasco (TO), Italy

The aim of this work was to investigate microbiota shift in Muscovy ducks (*Cairina moschata domestica*) fed insect meal and live larvae. Two trials were performed. In the first trial (Exp 1), 192 female Muscovy ducks were assigned to 4 dietary treatments (6 replicates/treatment) with increasing inclusion levels of black soldier fly (BSF, *Hermetia illucens*) larva meal: 0, 3, 6 and 9% (BSF0, BSF3, BSF6 and BSF9, respectively). In the second trial (Exp 2), 126 female Muscovy ducks were assigned to 3 experimental treatments (6 replicates/treatment): C (control) fed a commercial feed, while BSF and yellow mealworm (YMW, *Tenebrio molitor*) groups were fed a commercial feed supplemented with BSF and YMW live larvae (provided as 5% of expected daily feed intake), respectively. At the end of both trials (50 and 55d of age for Exp 1 and Exp 2, respectively), 12 birds/treatments were slaughtered and cecal samples were collected for microbiota analysis. A 16S rRNA based metataxonomic approach was then used to assess differences in the cecal microbiota as a function of the dietary treatment. In Exp 1, alpha diversity index (ADI) showed a significant increase in BSF3 group, while a decrease was observed in BSF6 and BSF9 groups ($P < 0.05$). Cluster analysis showed that BSF0 and BSF6 were found to be similar, while BSF3 and BSF9 were well separated. The BSF0 group showed higher frequency of Coriobacteriaceae and Parabacteroides, while in BSF9 group a reduction was observed ($P < 0.05$). In Exp 2, no significant differences in ADI were observed among the experimental treatments ($P > 0.05$). However, the minor operational taxonomic units (OTUs) fraction was differentially associated with the dietary inclusion of insect live larvae ($P < 0.05$). Indeed, C birds were characterized by the presence of Coriobacteriaceae and Phascolarctobacterium, while BSF and YMW showed the highest presence of Helicobacter, Elusimicrobium and Succinatimonas. It is well known that nutrition directly affects the intestinal microbiota in poultry species and the results obtained for Exp 1 support this thesis. On the contrary, in Exp 2 this effect is not particularly evident, probably due to the lower nutrients amount supplied by the live insect larvae administration. The little modifications in terms of microbiota population in Exp 1 had no adverse effects on birds' performance and health. Moreover, the highest ADI observed for BSF3 group could be useful in the maintenance of intestinal microbiota stability.

PS3 - Nutrition and microbiome under challenging conditions**PS3-018 Encapsulated branched-chain amino acids: a novel strategy to mitigate the effects of coccidiosis in chickens**T. Chalvon-Demersay¹, W. Lambert¹¹METEX ANIMAL NUTRITION, Paris, France

The use of anticoccidial drug is under scrutiny. In this context, it is important to develop nutritional solutions to help chickens coping with coccidiosis challenge. The objective of this study was to evaluate the efficacy of encapsulated branched-chain amino acids (BCAA) administered from day 1 until day 22 as an aid in the prevention of coccidiosis caused by *Eimeria* spp. in broiler chickens kept under battery cage conditions. Ninety Ross 308 chickens (18 cages of 5 animals) were allocated to three treatment groups : an infected untreated control (IUC), an uninfected untreated control (UUC), and infected untreated supplemented with 2 kg/Ton encapsulated BCAA (30% of BCAA, Leucine:Valine:Isoleucine = 1:1:1, IUC+BCAA). In the IUC and IUC+BCAA groups, birds were infected with a coccidiosis inoculum at 15 days of age. The French inoculum contained per dose 47,200 *E. acervulina*, 6,000 *E. tenella* and 800 *E. maxima* sporulated oocysts. The efficacy of this treatment was assessed by following intestinal lesion scoring on day 22 and body weight gain, feed intake and feed conversion ratio from day 13 to day 22. Coccidiosis challenge increased *Eimeria tenella* (1.241 ± 0.256 vs. 0.100 ± 0.056 , $P = 0.001$), *Eimeria maxima* (0.414 ± 0.117 vs. 0.033 ± 0.033 , $P = 0.022$), *Eimeria acervulina* (2.345 ± 0.114 vs. 0.467 ± 0.142 , $P < 0.001$) and total lesion scores (3.867 ± 0.335 vs. 0.600 ± 0.141 , $P < 0.001$). The supplementation of encapsulated BCAA did not alter these scores ($P > 0.05$). During the post-challenge period, the challenge significantly decreased body weight gain (521.7 ± 23.2 g vs. 597.0 ± 14.4 g, $P = 0.039$) without any effect on feed intake (824.2 ± 22.4 g vs. 849.4 ± 17.1 g, $P > 0.05$) which translated into a significant increase in feed conversion ratio gain (1.588 ± 0.044 vs. 1.424 ± 0.010 , $P = 0.003$). The supplementation of encapsulated BCAA tended to improve body weight gain (587.1 ± 20.1 g vs. 521.7 ± 23.2 g, $P = 0.077$) and reversed significantly the negative effect of coccidiosis on feed conversion ratio (1.478 ± 0.022 vs. 1.588 ± 0.044 , $P = 0.044$). In conclusion, this study shows some promising benefits of encapsulated branched-chain amino acids to mitigate the negative effects of coccidiosis in chickens. The mode of action does not rely on a reduction of lesion scores and still remains to be elucidated.

PS3 - Nutrition and microbiome under challenging conditions**PS3-019** Evaluation of formic and propionic acid blends supplemented via feed or drinking water for control of colonization of *C. jejuni* in broiler chickensG. Wischer¹, C. Hofacre², M. Jones², R. Berghaus³, A. Sokale¹¹BASF SE, Ludwigshafen, Germany, ²Southern Poultry Research Group, Inc., Watkinsville, GA, United States, ³Department of Population Health, College of Veterinary Medicine, University of Georgia, Athens, GA, United States

One of the major global public health concerns are foodborne diseases like campylobacteriosis. Nearly one third of all cases in humans are related to direct contact with raw chicken meat. Beside a safe handling of chicken meat and good kitchen hygiene a reduction of *C. jejuni* concentration in the gut would be a rational strategy. Organic acids are used for feed hygiene and preservation. Thus, the objective of this study was to evaluate two liquid formic and propionic acid blends to control *C. jejuni* in broiler at processing age. Broiler diets based on wheat, corn and soybean were formulated for starter, grower (G) and finisher (F) phase and were equal across all treatments. Sodium formate (FA) and a mixture of propionic acid and sodium formate (PFA) were tested in application via feed or drinking water (DW, supplemented to set pH 4) as follows: challenge control (T1) 6kg FA per mt of feed in G and F (T2), 8kg FA per mt of feed in F (T3), FA in DW for the last 7d (T4), PFA in DW for the last 7d (T5), FA for the last 3d (T6), with six replicates per treatment with 25 male Ross 708 broiler. All birds were orally gavaged with *C. jejuni* on DOT 14 (6.0 x 10⁵ CFU/bird). Ceca samples were collected on DOT 35 and 42/43. Log-transformed CFUs were analyzed using linear mixed models with a random pen effect. Pairwise comparisons between treatments were performed using the Bonferroni procedure (STATA, StataCorp LLC, College Station, TX). All testing assumed a two-sided alternative hypothesis, and $P < 0.05$ was considered statistically significant. No differences were observed in broiler performance. Mean crop pH of birds at DOT 42 was significantly reduced in T3 compared to T1 and addition via drinking water in T4 and T5. The challenge of *C. jejuni* was confirmed by boot socks swabs and equal across all treatments on DOT 21. In ceca, the CFU in T1 on DOT 35 and 42/43 (6.68 and 6.50 log₁₀ CFU/g) was unexpectedly low and numerically lower compared the untreated periods of T3 to T6 (avg. on DOT 35: 7.53, 42/43: 6.55 log₁₀ CFU/g). For T2, the CFU on DOT 35 and 42/43 was 6.89 and 6.41 log₁₀ CFU/g. The CFU on DOT 42/43 for T3 to T6 were 6.60, 6.55, 6.60 and 6.46 log₁₀ CFU/g. In conclusion, the organic acid addition resulted in an average numerical decrease in *C. jejuni* of approximately 1 log₁₀ CFU/g in ceca, which equals a 90% reduction. Numerical improvements suggest that statistical differences might be achieved with greater replication.

PS3 - Nutrition and microbiome under challenging conditions**PS3-020** Evaluation of monoglycerides of short and medium chain fatty acids on performance of broiler chickens in a bacterial enteritis challenge modelS. Vermaut¹, A. Holthausen¹, L. Barnard¹, J. Millecam², E. Labeeuw², M. De Gussem²¹Animal Nutrition BU, Eastman Chemical Company, Zwiinaarde, Belgium, ²Poulpharm, Izegem, Belgium

Butyrins supplemented to feed has been found to positively impact the performance of broilers, through its effect on gut integrity and oxidative stress status. However, the effects are less known when combining different monoglycerides of short chain (SCFA) with medium chain fatty acids (MCFA). A 35-day broiler trial was conducted to evaluate the efficacy of monoglycerides of SCFA and MCFA on performance parameters in a bacterial enteritis challenge model. A total of 1080 one-day-old broiler chicks (Ross 308, sexed males) were randomly allocated to 5 dietary treatments based on their initial body weight (BW). Broilers were housed pairwise in 60 pens with 18 broilers per pen. The birds were fed a typical European grain-soybean meal-based pelleted diet according to the CVB nutrient requirements of broilers. Feed was given in 3 phases (starter d1-14; grower d15-28 and finisher d29-35) and was available ad libitum. Birds were exposed to a bacterial (d21-23) and coccidial challenge (d22), developed by Poulpharm. The treatments were (T1) an uninfected, untreated group (UUC), (T2) an infected, untreated group as a negative control (IUC), (T3) an infected group treated with Bacitracin as a positive control (PC), (T4) an infected group fed with a combination of monoglycerides of SCFA and MCFA (C8-C10) (1 kg/MT), and (T5) treatment 4 with additional monoglycerides of caprylic and capric (C8-C10) and lauric acid (C12) on top. Body weight and feed intake were recorded weekly. Average daily gain (ADG) and feed conversion ratio (FCR) were calculated for the starter (d1-14), grower (d15-28), finisher (d29-35), and total period (d1-35). Data were analysed using JMP 16.0 to identify differences between treatments. There was a significant effect of treatment on FCR d1-35 ($P = 0.006$). All treatments were significantly different from the IUC negative control. Supplementation with SCFA and MCFA (T4; 1.420) resulted in a similar FCR to the Bacitracin-treated group (T3; 1.419) and the unchallenged control (T1; 1.412). The best effects were observed when supplementing with the additional C8, C10 and C12 versus T4 (T5; 1.378; $P = 0.06$). Specifically, in the final week (d28-35), there was a numerically higher ADG for both treatments T4 and T5 compared to the IUC negative control (T2) (112.6 and 113.9 versus 107.8 g/day). In conclusion, an intelligent combination of specific short chain and medium chain monoglycerides may contribute to improved feed conversion of broilers.

PS3 - Nutrition and microbiome under challenging conditions**PS3-021** How a novel probiotic affects the gut microbiome - Initial insights

J. Maertens¹, N. Smeets¹, A. Luis Gonzalez Sanchez¹, K. Vermeulen¹, E. Arévalo Sureda², A. Abdelqader³, R. Rodriguez¹, V. Van Hoeck¹

¹Kemin Europa NV, Herentals, Belgium, ²Department of Biosystems, KU Leuven, Leuven, Belgium, ³Department of Animal Production, School of Agriculture, the University of Jordan, Amman, Jordan

For the long-term sustainability of human health, animal health and meat production, it is imperative that we reduce antibiotics use to an absolute minimum. Probiotics have already shown their use in antibiotic reduction and improvement of animal health. Spore-forming *Bacillus* spp. are often used since they have a measurable positive effect as a probiotic as well as other beneficial properties such as surviving the pelleting process and long shelf life. During the development process of a new triple-strain probiotic (*Bacillus* spp. ATCC PTA-6737; ATCC PTA-127114; ATCC PTA-127113), the effects of the probiotic on the gut microbiome were tested in two broiler trials. In the first trial, a total of 390 male day-old Ross 308 broilers were housed in floor pens of 15 broilers each and divided over two treatments (13 replicates): T1: negative control; T2: triple-strain probiotic, 3.0x10⁸ CFU/kg feed. In a second trial, 520 female day-old Ross 308 broilers were housed in floor pens of 20 broilers each and divided over two treatments (13 replicates): T1: negative control; T2: triple-strain probiotic, 3.0x10⁸ CFU/kg feed. DNA was extracted from the ileal and cecal content of both treatments (for trial 1 only on day 35; for trial 2 on day 14 and 35) and 16S rRNA amplicon sequencing methods were applied to all samples. Alpha diversity was calculated, as well as differences in relative abundance at several taxonomic levels. In the first trial, the probiotic treatment significantly improved body weight and average daily gain compared to the control. At the ileal level, probiotic treatment decreased the relative abundance of *Staphylococcaceae* while increasing the *Lactobacillaceae*. At the cecal level, probiotic treatment significantly increased the alpha diversity and increased the abundance of *Lachnospiraceae*, a family known for their butyrate production. In the second trial, the probiotic treatment groups significantly improved body weight, average daily gain and feed conversion ratio compared to the control. At 14 days of age, the diversity in the cecum was significantly increased and the relative abundances of *Firmicutes* and *Lachnospiraceae* increased as well. In conclusion, these trials show that the dietary use of this triple-strain probiotic can improve the performance of birds in non-challenged conditions. Furthermore, the use of this probiotic can increase diversity and alter the composition of the gut microbiome.

PS3 - Nutrition and microbiome under challenging conditions**PS3-022** Impact of a blend of microencapsulated organic acids and botanicals on the microbiota of commercial broilers under clinical necrotic enteritis

D. Dittoe¹, C. Swaggerty², C. Johnson², S. Ricke¹, A. Piva^{3,4}, E. Grilli^{3,5}

¹University of Wisconsin, Madison, WI, United States, ²USDA/ARS, College Station, TX, United States, ³University of Bologna, Bologna, Italy, ⁴Vetagro S.p.A, Reggio Emilia, Italy, ⁵Vetagro Inc., Chicago, IL, United States

Recently, supplementation of a microencapsulated blend of organic acids (25% citric; 16.7% sorbic) and botanicals (1.7% thymol; 1% vanillin), AviPlus® P (Vetagro S.p.A., Reggio Emilia, Italy), has demonstrated improved broiler health and performance under non-challenged conditions. In continuation of those efforts, the objective of this study was to determine the effect of the microencapsulated blend on mitigating dysbiosis and necrotic enteritis (NE) among broiler chickens. On day of hatch, male broiler chicks were assigned to non-challenge and challenge groups and placed into floor pens. A basal diet supplemented with 0 or 500 g/MT of the microencapsulated blend and water were supplied ad libitum. On d 14, challenge groups were given a 2' coccidiosis vaccine and on d 17-19 administered four *Clostridium perfringens* strains (107 CFU/mL). On d 20-21, the jejunum/ileum were collected for microbiome sequencing (n = 10; V4 region of the 16S rRNA gene) on an Illumina MiSeq. The experiment was repeated three independent times with data analyzed in QIIME2 and R. Alpha and beta diversity, core microbiome, and compositional differences determined with significance set at a P and Q ≤ 0.05. There was no difference between the richness and evenness of those fed diets containing 0 and 500 g/MT microencapsulated blends, but differences were seen between the non-challenged and challenged groups. Beta diversity of the 0 and 500 g/MT non-challenged groups were different but there were no differences between the NE challenged groups. The core microbiome of those fed diets containing 500 g/MT similarly consisted of *Lactobacillus* and *Clostridiaceae*. As well, challenged birds fed diets containing 500 g/MT of the microencapsulated blend had a higher abundance of significant different phyla, *Actinobacteriota*, *Bacteroidota*, and *Verrucomicrobiota*, then the 0 g/MT challenged group. In conclusion, the supplementation of a microencapsulated blend shifted the microbiome by supporting beneficial and core taxa; however, due to the clinical NE, these shifts were not drastic in nature. Funding: This research was supported by Vetagro (CLIS Agreement number 58-3091-8-005 and the USDA/ARS (3091-32000-035-00D).

PS3 - Nutrition and microbiome under challenging conditions**PS3-023** Phytogenic feed additive ameliorates carcass traits, cecal pathogen load and blood markers of broilers kept under challenging conditionsA. Möddel¹, I. Kröger¹, S. Haldar², A. Dhara², B. Eckel¹¹Dr. Eckel Animal Nutrition GmbH & Co KG, Niederzissen, Germany, ²Agrivet Research and Advisory Pvt. Ltd., Kolkata, India

Heat stress and poor hygiene conditions have a devastating effect on intestinal health, well-being and performance. Therefore, feeding strategies are needed that counteract such challenging conditions in broiler farming. The present study investigated the effect of a phytogenic feed additive on performance, cecal pathogens and stress related blood parameters. During the trial broilers were exposed to cyclic thermal stress and were kept under poor hygienic conditions. A feeding trial was conducted with 200 male broiler chickens (Cobb 500) from day 1 - 42. Two groups with 10 replicates were randomly allocated to two treatments. The negative control group (NC) was fed without phytogenic additive. The second group received the NC diet and additionally 200 g/t Anta®Phyt MO (APMO, Dr. Eckel Animal Nutrition) from day 1 - 42. APMO consists of a combination of natural plants and their extracts with hops as the primary ingredient. The birds were fed with a 3-phase feeding system. Diets and drinking water were offered ad libitum. To create challenging conditions, birds were exposed to cyclic heat stress (30 - 36°C) during the day (3rd to 6th week of age). In addition, broilers were challenged by previously used bedding material. Carcass traits, cecal and blood parameters were determined from 10 birds per group at day 42. Cecal samples were analyzed on *Clostridium perfringens*, *Salmonella* and *Escherichia coli* counts. Blood samples were taken from the brachial vein and analysed on stress-associated parameters corticosterone, catalase and glutathione peroxidase. All data were subjected to one-way analysis of variance with the dietary treatments as the grouping factor, applying Tukey's B-test. Results showed that carcass yield in the APMO group was 64 g higher than in the NC group ($p = 0.05$). Additionally, the thighs yield was improved by 1,6 % ($p < 0.05$). The cecal *Clostridium perfringens* and *Escherichia coli* load in the APMO group was reduced by 4,5 and 3,6 % respectively ($p < 0.05$). Furthermore, feeding APMO resulted in lower corticosterone (-28,1%), catalase (-51,3%) and glutathione peroxidase (-47,5%) as compared to the NC feeding ($p < 0.05$). Data showed that APMO has positive effects on performance, intestinal pathogen load and stress related blood parameters, even under challenging conditions. Therefore, supplementation of Anta®Phyt MO can be used as a tool to sustain performance and gut health in commercially reared broiler chickens.

PS3 - Nutrition and microbiome under challenging conditions**PS3-024** Positive impact of early-probiotic administration on performance parameters and gut microbiota composition in chickensM. Hussain^{1,2}, A. Pérez de Rozas³, O. Aizpurua⁴, M. Guivernau⁵, A. Jofré⁶, A. Alberdi⁴, E. Rodríguez-Gallego², M.H. Kogut⁷, J. Tarradas¹¹Animal Nutrition, IRTA, Constantí, Spain, ²Department of Biochemistry and Biotechnology, MoBioFood Research Group, Universitat Rovira i Virgili, Tarragona, Spain, ³Animal Health Research Center (CRESA), IRTA, Cerdanyola del Valles, Spain, ⁴Center for Evolutionary Hologenomics, Globe Institute, University of Copenhagen, Copenhagen, Denmark, ⁵Sustainability in Biosystems Programme, IRTA, Caldes de Montbui, Spain, ⁶Food Safety and Functionality Programme, IRTA, Monells, Spain, ⁷Southern Plains Agricultural Research Center, USDA-ARS, College Station, TX, United States

Reducing antibiotic use in animal production is essential to avoid the emergence of antimicrobial resistances, but alternative products are needed to maintain productivity and animal health. Three probiotic strains (*Enterococcus faecalis* [EntF], *Bacteroides fragilis* [BacF] and *Ligilactobacillus salivarius* [LigS]) with capacity to reduce *Salmonella* spp. colonization were tested in two in vivo trials with broilers. Randomized block designs were used. Trial 1 (individual probiotic effects) had 4 treatments (TR): TR1=Basal diet (BD), TR2= BD+EntF, TR3= BD+BacF, and TR4= BD+LigS (TR 2-4 with $5 \cdot 10^7$ CFU/bird-day); 6 pens/TR and 36 birds/pen. Trial 2 (probiotic synergies): 4 TR [TR1= BD, TR2= BD+Zn Bacitracin (55ppm), TR3= BD+(EntF+BacF+LigS) ($1.6+1.6+0.1 \cdot 10^8$ CFU/bird-day (0-10d), respectively), and TR4= TR3 0-35d]; 13 pens/TR and 20 birds/pen. Wheat-soybean-rye based diets (starter 0-7d, grower 7-21d, and finisher 21-35d) without exogenous enzymes were used to induce intestinal low-grade inflammation. In the Trial 2, birds were challenged with $2 \cdot 10^6$ CFU *Salmonella* Typhimurium at 6d (4 seeder birds/pen). Performance was monitored, and jejunum tissue and ileum and caecum contents were sampled to analyse immune biomarkers and microbiota (16S rRNA-Illumina MiSeq). Trial 1: TR2 and TR3 improved performance at 7d ($p < 0.01$), but not at 35d. TR4 reduced BW at 35d (viscosity was increased due to its biofilm formation capacity) ($p = 0.03$). TR2 and TR3 reduced IL1b expression (14d) ($p = 0.02$), and tend to increase IL10 (21 and 7d, respectively) in jejunum, controlling dietary induced inflammation. Microbiota diversity increased with time ($p < 0.05$), but it was not affected by TR. However, the microbial composition of TR2 group was different from T1 at 7d (14% explained by TR). Trial 2: Compared to TR1, TR3 and TR4 improved FCR (0-35) to the same extent as TR2 (Zn Bacitracin) ($p < 0.01$). At 7d, microbiota diversity and composition of TR3 and TR4 were similar but they differed from TR1 and TR2 ($p = 0.01$; 33% explained by TR). TR3 and TR4 also reduced *Salmonella* counts ($p < 0.01$). The administration of probiotic mixtures, specifically during the first days post-hatch, is crucial to modify microbiota populations in the chickens' gut, and positively impact in animal conversion at 35d. Therefore, the administration of probiotics may not be necessary during the entire productive life. Funding: Spanish Government (RTI2018-098090-A-I00) and EU Marie Skłodowska-Curie (945413).

PS3 - Nutrition and microbiome under challenging conditions**PS3-025 Probiotic supplementation influences performance and apparent ileal digestibility in male and female broilers fed with different protein levels under necrotic enteritis challenge condition**K. Gharib-Naseri¹, H. Nguyen¹, N. Yacoubi², A. Kumar¹, S. Wu¹¹*School of Environmental and Rural Science, University of New England, Armidale, Australia, ²Evonik Operations GmbH, Nutrition & Care, Hanau-Wolfgang, Germany*

Necrotic enteritis (NE) is a major threat to the broiler production during post antibiotic era. Additionally, high protein diets have been often considered to compromise gut health and cause environmental concerns due to nitrogen pollution. Moreover, the application of probiotics has become a promising approach to restore the lost performance and control infectious diseases in the flocks. The effectiveness of probiotic addition to control NE challenge has been controversial and its use with the consideration of protein level and bird sex has not been investigated. It is, therefore, hypothesised that the probiotic supplementation will produce different effects on the performance and nutrient utilisation at different dietary protein levels and/or in different sexes under NE challenge. A total of 1536 day old Cobb 500 broilers were sexed, and males and females were allocated separately to 16 treatment groups in a 2 × 2 × 2 × 2 factorial arrangement, with 6 replicate pens of 16 birds each. The factors were: (1) challenge (No or Yes); (2) crude protein (CP) level (Standard - SCP or Reduced at 2% - RCP); (3) probiotic (0 or 500 g/t, *B. subtilis* DSM 32315 strain at 2 × 10⁹ cfu/g) and (4) sex (Male or Female). Birds were challenged with *Eimeria* spp. on day 9 and *Clostridium perfringens* (NE 18 strain) on day 14 and 15. Digesta samples were taken on day 35 for ileal digestibility evaluation. Results showed that from day 0-35, NE challenge and RCP diets severely impaired performance ($P < 0.05$). NE challenge reduced the apparent ileal digestibility of CP and all amino acids (AAs) ($P < 0.05$) whereas the reverse was true upon RCP application, except for glycine. Improved performance and higher AA digestion were also observed in probiotic-supplemented-birds ($P < 0.05$). Probiotic addition lowered FCR and increased digestibility of CP and most AAs under challenge condition ($P < 0.01$) whilst improved all performance criteria in birds fed with RCP diets ($P < 0.05$). In addition, female birds had improved digestibility of CP and all AAs ($P < 0.05$) when fed with RCP diets but not male birds. Notably, probiotic enhanced WG and reduced FCR in challenged birds fed RCP diets ($P < 0.05$) while no effects were found in remaining groups. Consequently, the results demonstrated that the addition of probiotic in diet is beneficial, and it is important to consider disease conditions dietary CP level and sex of the birds upon the addition of the probiotic in broiler diets.

PS3 - Nutrition and microbiome under challenging conditions**PS3-026 Provision of a synergetic solution of functional amino acids and polyphenols improves performance of broilers facing mild coccidiosis challenge under commercial conditions**S. Fontaine¹, C. Manceaux², R. Bouvet², W. Lambert¹¹*METEX ANIMAL NUTRITION, Paris, France, ²Zootests, Ploufragan, France*

Over past years, the concept of functional amino acids (AA) has received an ever-growing interest. Amino acids are no longer considered as nutrients directed only towards muscle deposition, but also towards other metabolic functions related to animal health and immunity. Previously, synergizing some of these AA (Thr, Gln, Arg) with polyphenols has been shown to positively affect health and performance of challenged broilers. The aim of the trial was to assess whether supplementation of Inneus[®] solution, composed with L-Arg, L-Thr, L-Gln combined with grape polyphenols, also showed improved performance of broiler chickens facing a mild coccidiosis challenge in commercial conditions. Therefore, 3,600 Ross 308 mixed broiler chickens were distributed in 12 pens of 300 birds for 42 days, with 3 pens composed of males and 3 pens with females for each treatment. Birds received standard, corn - soybean meal-based diets, with the same crude protein and energy levels. Amino acid balance was respected according to assumed animal requirements. There were two treatments: animals receiving treatment 1 (T1) were provided the control diet without inneus[®] and treatment 2 (T2) animals were provided with Inneus[®] at 1 kg/T. All animals were fed without anticoccidial drugs and were challenged with coccidiosis via usage of reused litter taken from neighbouring farms with high coccidiosis pressure. Oocysts count and lesion scoring were measured at 21 and 28 days of age, transcriptomics of ileal tissues were assessed at 42d, and performance parameters were measured at d12, d28 and d42. Oocysts counts and lesion scorings at d21 and d28 showed presence of a mild coccidiosis challenge, without significant difference between treatments. There was no effect of inneus[®] on feed intake, but birds fed with Inneus[®] showed significantly higher final body weight. Final body weight was affected by sex ($p < 0.001$) and interaction between treatment and sex was significant ($p < 0.001$). Males from T2 were significantly heavier than T1 by 86 g and females from T2 were 29 g heavier than those from T1. Inneus[®] improved corrected whole life feed conversion ratio (-5pts, $p < 0.05$) compared to T1 as well as European Production Index (+ 13 for males, + 18 for females, $p < 0.001$). Transcriptomics results will be available for ESPN congress. Compiled data allows hypothesizing on the product's mode of action. Results confirm efficacy of Inneus[®] at 1 kg/T in commercial settings with a mild coccidiosis challenge.

PS3 - Nutrition and microbiome under challenging conditions**PS3-027 Real-time energy metabolism evaluation of growing broiler chickens under health challenge**

R. de Souza Camargos¹, R. Riveros Lizana¹, M. Macari¹, K. Cardoso Bícigo¹, B. Balbino Leme¹, N. Kazue Sakomura¹

¹Animal Science Department, School of Agricultural and Veterinarian Sciences (FCAV), São Paulo State University (UNESP), Jaboticabal, Brazil

The objective was to describe the real-time variation in the energy utilization of broiler chickens under health challenges. Ninety-four 14-day-old male Ross 308 chicks were randomly distributed into three treatments (C: challenge group, PF: unchallenged birds pair-feeding equal to challenge group, and AL: non-challenge birds fed ad libitum). Each treatment had four replicated with eight birds each. At d 14, the C treatment was inoculated with 1 ml of *Eimeria maxima* (8x10³ oocysts) and from d 18 to 20, with *Clostridium perfringens* (2.5x10⁶ CFUs). The birds were housed in open-circuit respirometric chambers from d 14 to 22. During this period, oxygen consumption and carbon dioxide production were measured, and heat production (HP) was calculated. The body weight, feed intake, and excreta production were recorded daily. Additionally, the energy and nitrogen balance trial was conducted to determine the metabolizable energy (ME) and nitrogen retention (NR) for further calculations. The total energy retention (ER) was obtained from the difference between ME intake and HP. The ER was fractioned as protein and fat. The energy partitioning results of treatment C and PF were expressed in function to the AL (referential group). The data was subject to two-way ANOVA, considering the treatment effect and the time (after inoculation) as a longitudinal factor. When the interaction treatment*time was shown, a contrast analysis was performed between C vs PF. The results evidenced that time had a significant effect, and interaction was shown for all measurements. The birds under challenge conditions presented lower ME intake (P=0.013), HP (P<0.007), and ERpt (P=0.034), meanwhile the ER (P=0.101) and ER as fat (P=0.265) were not affected. At d 19 and 20, the challenged birds had a significant decline in the ER as protein (P<0.05), and at d 20, the drop was for ER as fat (P<0.05). In conclusion, the health challenge affects energy utilization in broilers, with the reduction of protein and fat retention in a short time after inoculation and not recovering on the rate of energy retention of the tissue and energy expenditure. Financial support: Fapesp 2019/26575-6 and 2021/08142-5.

PS3 - Nutrition and microbiome under challenging conditions**PS3-028 Reduction of chondronecrosis with osteomyelitis lameness in broilers fed metal amino acid complexes using two challenge models**

A. Alrubaye^{1,2}, R. Burin³, M. Rebollo³, C. Torres³, D. Neves³, A. Aljamal³, S. Ekesi¹, A. Hasan^{1,4}, D. Rhoads^{1,5}

¹Cell and Molecular Biology Program, University of Arkansas, Fayetteville, United States, ²Department of Poultry Science, University of Arkansas, Fayetteville, United States, ³Zinpro Corporation, Eden Prairie, United States, ⁴Department of Veterinary Public Health, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq, ⁵Department of Biological Sciences, University of Arkansas, Fayetteville, United States

Bacterial Chondronecrosis with Osteomyelitis (BCO) lameness is one of the top economic and animal welfare issues facing the poultry industry today. BCO is caused by a bacterial infection that leads to necrosis of rapidly growing long bones like femoral and tibial heads subjected to repeated mechanical stress. BCO lameness in heavy broilers has increased by over 1% in the past two decades. However, the underlying bacterial infections are substantially bigger, becoming a product quality and animal welfare concern. Feed additives, including amino acid-bound minerals, could be used as a prophylactic strategy for reducing BCO lameness, given its ability to enhance epithelial integrity, gut health, and immune function and contribute to cartilage and bone development. It was hypothesized that in-feed supplementation of the metal-amino-acid-complexes zinc, manganese, and copper (Zinpro®Availa®ZMC) reduce lameness in broilers under two different BCO-challenge models. In the first model, chicks were placed on suspended wire flooring to induce lameness triggered by mechanical stress. In the pathogen exposure model, all chicks were raised on litter, but chicks in source pens were challenged with *Staphylococcus agnetis* strain 908 in the drinking water using a 105cfu/ml concentration. Both models were evaluated for 56 days. The dietary treatments consisted of a control group receiving inorganic sources of zinc, manganese, and copper; a second group in which the inorganic sources were partially replaced with normal levels of AvailaZMC; and a third group receiving a replacement with higher levels of AvailaZMC. For both wire and litter flooring models, all birds were checked for cumulative lameness. Any bird that was reticent to move and continued to be unwilling or unable to walk were diagnosed as clinically lame and further confirmed through necropsy. The two dietary treatments containing AvailaZMC effectively reduced lameness by 20% in the wire flooring model and 25% in the litter flooring model. The reduced lameness was attributed to the improved intestinal barrier integrity and efficacious immune response mediated by increased expression of tight junction proteins, immunomodulatory cytokines, and stimulation of bactericidal killing of adherent peripheral blood monocytes obtained from the birds treated with AvailaZMC. In conclusion, AvailaZMC has the potential to provide a reasonably effective alternative to antibiotics for reducing BCO lameness in broiler chickens.

PS3 - Nutrition and microbiome under challenging conditions**PS3-029 Screening and Characterization of *Pediococcus acidilactici* LC-9-1 Toward the Selection as a Potential Probiotic for Poultry with Antibacterial and Antioxidative Properties**C. Li^{1,2}, S. Wang¹, S. Chen³, G. Liu¹, Y. Beckers², H. Cai¹

¹Key Laboratory for Feed Biotechnology of the Ministry of Agriculture and Rural Affairs, Institute of Feed Research, Chinese Academy of Agriculture Sciences, Beijing, China, ²Precision Livestock and Nutrition Laboratory, Teaching and Research Centre (TERRA), Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium, ³Department of Molecular Cell Biology, Samsung Medical Center, Sungkyunkwan University School of Medicine, Suwon, Korea, Republic of

Growing interest has focused on lactic acid bacteria as alternatives of antimicrobial growth promoters, which are characterized by producing various functional metabolites, including antioxidants and antimicrobial compounds. The present study was undertaken to characterize a bacteria LC-9-1, screened from the intestines of healthy animals. Morphological, biochemical, and molecular characterization of LC-9-1 revealed it to be *Pediococcus acidilactici*. The strain has excellent properties including acid-production efficiency, antibacterial performance and antioxidant activity. Initially confirmed the safety of the strain in vitro. Subsequently, 120 newly hatched male Arbor Acres broiler chickens were randomly allocated into 2 groups with 6 replicates of 10 birds. The control (CON) group were fed a corn-soybean-based, and the (PA) group were fed a basal diet containing *P. acidilactici* LC-9-1 that the final concentration was 2.5×10^9 CFU/g. In the 42 days experiment dietary LC-9-1 supplementation improved the growth performance and decreased the abdominal fat, moreover, enhanced antioxidant capability and the intestinal innate immunity of broilers. Analysis of intestinal microbiota showed that the Chao1 index of OTU level was not significantly different between the groups, while the Shannon index of OTU level was significantly higher in the PA broilers ($P < 0.05$). The results of PCA and PCoA showed that samples in CON and PA group were with different community composition and structure. Adopting the Kruskal-Wallis rank sum test, we found that Cyanobacteria and Actinobacteriota at the Phylum level were more abundant ($P < 0.05$) in the PA group than in the CON group, while the abundance of Proteobacteria was significantly decreased ($P < 0.05$). At the genus level, the relative abundance of *Escherichia-Shigella*, *Romboutsia* and *Macrococcus* were notably decreased in the PA group ($P < 0.05$), while the other species of bacteria such as *Chloroplast*, *Rothia* and *Ruminococcus* were significantly elevated ($P < 0.05$). Importantly, we also found a significant increase in the relative abundance of *Pediococcus* in the PA group ($P < 0.01$). Collectively, such in-depth characterization and the available data will guide future efforts to develop next generation probiotics, and LC-9-1 could be considered as a potential strain for further utilization in direct-fed microbial or starter culture for fermentation.

PS3 - Nutrition and microbiome under challenging conditions**PS3-030 Soybean bioactive compounds improve the intestinal and reproductive tract microbiomes of broiler breeders**M. Gao^{1,2}, Z. Lv^{1,2}, Y. Guo^{1,2}

¹Agricultural University, Haidian District, Beijing 100193, China, ²State Key Laboratory of Animal Nutrition, College of Animal Science & Technology, Beijing, China

Recent work characterized the chicken gut microbiome traveling the entire reproductive tract (oviduct) length. Daidzein and soybean saponin are soy-derived bioactive compounds, which could regulate immune function through the gut microbiome. However, their effect on the reproductive tract microbiome has not been addressed yet. Here we characterized the microbiome composition along the oviduct (magnum and cloaca) as well as in the cecum, and determined the role of soybean bioactive compounds on them. A total of 720 WOD 188 white-feathered broiler breeder hens were fed a basal diet(CON) or a 40 mg/kg daidzein-supplemented diet(DA), or a 200 mg/kg soybean saponin-supplemented diet(SS) for 7 weeks. The results showed that with 40 mg/kg DA supplementation, the egg production rate and feed conversion ratio (FCR) were improved. 200 mg/kg SS supplementation increased the egg production rate and improved the eggshell quality. Using 16S rRNA gene sequencing, we demonstrated there was a large overlap in the composition of the gut and oviduct microbiomes. Furthermore, we identified a strong correlation between the relative abundance of OTUs in the cloaca and their probability to be found in the magnum. This is possibly the result of chicken physiology which includes the cloaca, a cavity to which both the intestinal and reproductive tracts open into. Additionally, dietary 40 mg/kg DA improved the cecum microbiome by up-regulating the relative abundance of *Bacteroides* and *Oscillospiraceae*, driving the cloaca microbiome composition closer to that of the cecum. Dietary 200 mg/kg SS improved the magnum microbiome by up-regulating the relative abundance of *Stenotrophomonas* and *Rhodococcus*, driving the cloaca microbiome composition closer to that of the magnum. The intestinal-reproductive tract system allowed an integrative assessment of broiler breeder microbiome assembly. Moreover, whereas a vertical transmission route from the breeder to the chick has been suggested, our work starts laying a mechanistic foundation to this route, by describing different soybean bioactive compounds' effect on the movement of gut bacteria to the oviduct, where they may be enclosed in the embryo. Our findings illuminated that DA and SS supplementation altered the movement of intestinal material throughout the oviduct, which suggested plant extracts have a much more direct effect on reproduction and egg formation. Funding acknowledgment: This study was supported by National Natural Science Foundation of China (No. 32202724), and Beijing Natural Science Foundation (No. 6222036).

PS3 - Nutrition and microbiome under challenging conditions**PS3-031** Supplementation with a probiotic mixture in the diet of Guinea fowls (*Numida meleagris*) may introduce beneficial changes in gut microbiota

L. Galosi¹, A. Roncarati¹, P. Robino², A. Bellato², I. Ferrocino³, P. Nebbia², L. Biagini¹, L. Filoni¹, A.R. Attili¹, G. Rossi¹

¹School of Biosciences and Veterinary Medicine, University of Camerino, Matelica, Italy, ²Department of Veterinary Sciences, University of Torino, Grugliasco, Italy, ³Department of Agriculture, Forestry and Food Science, University of Torino, Grugliasco, Italy

Intestinal microbial communities assume a near-stable state within a week which leaves a very small window for permanent microbiota remodeling. First colonizers determine the fate of microbial community, and after the microbiota has matured the likelihood of permanent change is very small, as the stable community resists change. We assessed the microbiota diversity of caecal samples from healthy Guinea fowls (*Numida meleagris*) supplemented or not with probiotics. At 10 days of age, 40 unsexed healthy birds were randomly assigned to 2 groups: the control group (C) received water without any additive, while the treated group (P) received water supplemented with a multistrain probiotic (SLAB51, SivoMixx®, Mendes SA, Swiss), at the dosage of 2x10¹¹ UFC/liter, until the end of the cycle. Both groups were housed in similar environment, fed ad libitum with a two phases commercial feed, and slaughtered at 120 days of age. Caecal samples were used to assess the microbiota by 16S amplicon based sequencing on the Illumina MiSeq platform. Treatment with probiotic considerably varied the intestinal flora of the birds, with α -diversity showing that the level of complexity was higher in P group samples than in the C group samples ($P < 0.05$). Comparing the relative abundance of the main OTUs among the samples, we observed that microbial diversity, richness (Shannon, $P = 0.0003$) and relative abundance of Firmicutes were higher in the P group. Differences were further demonstrated by Principal Component Analysis, based on the relative abundance of the main OTUs, showing that the samples from the C group samples were well separated from those with a probiotic-supplemented diet. The caecal microbiome in the P samples showed an enrichment of Bacteroidales (that favour the breakdown of protein and carbohydrate), some Clostridiales as *Prevotella*, and important members of Lachnospiraceae family, as *Coprococcus*. An increase of *Faecalibacteria* and *Coprococcus*, strong butyrate producers, is associated with a healthy gastrointestinal barrier status, while *Prevotella* increases the rate of fatty acids production, creating a good intestinal environment for Lacto- and Bifidobacteria colonization. Although no statistically significant changes were observed in the percentage of Bifid and *Lactobacillus* (main components of the probiotic) between two groups, the different bacterial species present in the probiotic lead to a remodeling of the microbiota, as the changing OTUs are influenced by the presence of the probiotic.

PS3 - Nutrition and microbiome under challenging conditions**PS3-032** The effect of a postbiotic on the growth performance and gastrointestinal microbiota of broilers infected with subacute necrotic enteritis

T. Duong¹, B. Lumpkins², T. Timoharju³, T. Rinttilä³, S. Llamas-Moya¹

¹Animal Performance Solutions, Kerry, Naas, Co. Kildare, Ireland, ²Southern Poultry Feed & Research, Inc., Athens, Georgia, United States, ³Alimetrics Diagnostics, Espoo, Finland

Necrotic enteritis (NE) is a multifactorial disease characterized typically by an over-growth of *Clostridium perfringens* and is estimated to have an annual cost to the poultry industry of 6 billion USD worldwide. Although traditionally managed using antibiotics, consumer preferences and regulatory pressures to reduce their use has increased the need to develop interventions to mitigate effects of NE in poultry production. Postbiotics, preparations of inanimate microorganisms and/or their components that confer health benefits on the host, may be potentially important alternatives to antibiotics in managing NE because of their beneficial health effects. The aim of this study was to evaluate the effect of a postbiotic preparation (PT) derived from whey cultured using a Lactic Acid Bacterium on the growth performance and gastrointestinal (GI) microbiota of broilers in a subacute co-infection model of NE. Day-old male broiler chicks ($n = 1,950$) were allocated randomly to 3 treatment groups with 13 replicate pens of 50 birds arranged as a randomised complete block design. Broilers were fed untreated (UNT) feed or feed treated with either bacitracin methylene disalicylate (BMD, 55 g/metric ton) or PT (75 g/metric ton), and NE was induced experimentally using co-infection with *Eimeria* spp. and *C. perfringens*. Growth performance was evaluated through 42 d post-hatch. Ileal and cecal contents (3 birds/pen) were collected at 21 d post-hatch for quantification of short chain fatty acids (SCFA) and specific populations of GI microbiota using gas chromatography and quantitative PCR, respectively. Data were analysed using ANOVA. Body weight gain and feed conversion ratio through 42 d were improved significantly by BMD and PT when compared to the UNT group ($P < 0.001$). Administration of BMD reduced total SCFA concentration in the ileum ($P < 0.05$), whereas PT tended to increase SCFA, primarily lactate, relative to the UNT and BMD treatments. Ileal *Lactobacillus* spp. were highest in the PT group, with BMD reducing the *Lactobacillus* spp. in the ileum ($P < 0.001$). Additionally, PT tended to reduce *C. perfringens* ($P = 0.058$) in the cecum of broilers when compared with the UNT and BMD-treated groups. These results suggest administration of the postbiotic described in this study may be used to mitigate gut microbiota changes induced by necrotic enteritis in broiler chickens.

PS3 - Nutrition and microbiome under challenging conditions**PS3-033 The effect of *Bacillus amyloliquefaciens* CECT 5940 on animal performance and microbiota maturation of broilers fed alternative ingredients**N. Yacoubi¹, M. Klunemann¹, C. Adams², c. Stefanello²¹*Evonik Operations GmbH, Hanau- Wolfgang, Germany*, ²*Federal University of Santa Maria (UFSM), Santa Maria, Brazil*

Fluctuating prices and availability of common feed ingredients resulted in the use of alternative ingredients in animal production. These ingredients are often characterized by a high amount of soluble fiber resulting in lower performance and intestinal health issues that limits their inclusion rate in the diet. The probiotic *Bacillus amyloliquefaciens* CECT 5940 (Ba) can produce various metabolites and enzymes relieving these negative effects and therefore allows a higher inclusion rate of these ingredients resulting in better economic success. An experiment was conducted to evaluate the effects of 2 alternative ingredients (rye and rice bran) in interaction with the Ba in diets for broilers until day 35 of age. The effect on growth performance and intestinal microbiota were investigated. A total of 672 one-day-old male Cobb 500 slow feathering broilers were used. Dietary treatments were distributed in a 2 x 2 factorial design, 6 pens of 28 broilers. A corn-soy basal diet was formulated with an inclusion rate of 10, 15, and 20% in starter, grower, and finisher diets of rye or defatted rice bran with and without supplementation of the Ba (1,000 g/ton). No interaction was observed between the ingredient and the probiotic. Birds fed the diet with rice bran had a higher BW (+4%) and FCR (-5.5%) compared to rye, Ba supplementation improved BWG (+ 3.4%) and FCR (-5.2%) compared to non-supplemented groups ($P < 0.05$). Cecal microbiota composition was determined at days 7, 14, 21 and 35 using 16S amplicon sequencing. Species richness was positively correlated with age and with Ba supplementation. The relative abundance of the *Alistipes* genus had a positive correlation with time having an abundance between 0.65 and 1.4% when broilers were fed diets without or with Ba, respectively, and reaching 20.05 and 27.75% on day 35, respectively. On day 7, it was observed that groups with Ba had a comparable microbiota composition to the group without Ba in day 14, indicating that the probiotic may have accelerated the maturation of the microbiota during the early stages. In conclusion, these results confirmed that the probiotic *Bacillus amyloliquefaciens* CECT 5940 resulted in improved growth performance of broilers fed alternative ingredients such as rye and rice bran. Furthermore, maturation of the cecal microbiota in broilers is mainly driven by time and then affected by the feed ingredients and the probiotic.

PS3 - Nutrition and microbiome under challenging conditions**PS3-034 The effects of amino acid supplementation of low protein diet on the immune responses and short chain fatty acid profile in broiler chickens challenged with *Eimeria* spp.**G. Liu¹, A. Ajao¹, J. Taylor², T. Applegate¹, R. Selvaraj¹, E. Ball², I. Kyriazakis^{3,2}, O. Olukosi¹, W.K. Kim¹¹*Department of Poultry Science, University of Georgia, Athens, United States*, ²*Agri-Food & Biosciences Institute (AFBI), Belfast, United Kingdom*, ³*Institute for Global Food Security, Queen's University, Belfast, United Kingdom*

We aimed to investigate the effects of supplementing arginine (Arg) and branched chain amino acids: leucine, isoleucine, and valine (BCAA) in low protein diet fed broilers challenged with *Eimeria* spp. All birds were fed the same starter diet (d 0-10) that met Cobb 500 nutrient requirements. Four grower diets were formulated: positive control (PC); low protein (NC) with 18.5% or 16.5% crude protein respectively; or NC supplemented with Arg or BCAA at 50% above requirement. Requirements for all essential amino acids were met by crystalline amino acid supplementations in the four diets. A 4x2 factorial arrangement (4 diets, each with or without *Eimeria* challenge) was used in the study. The challenged and non-challenged birds were orally gavaged with mixed *Eimeria* spp. or distilled water respectively on d 14. Significant interaction effects ($P < 0.01$) were found in macrophage nitric oxide production (NO) on d21 and 28: in non-challenged birds, NO was higher in Arg than in the other groups. While in challenged birds, NO was higher in both Arg and BCAA. *Eimeria* challenge increased ($P < 0.01$) the ratio of cytotoxic T cells to T helper cells (CD8: CD4) on d21 and regulatory T cells (Treg) on d28 in cecal tonsils (CT). On d21, the interaction effect ($P < 0.01$) for Treg was due to the higher numbers in challenged birds than non-challenged ones only in PC and NC. On d28, an interaction effect ($P < 0.01$) for CD8: CD4 in CT was found that *Eimeria* challenge increased the ratios in all groups except Arg, and BCAA had a higher ratio than Arg only in challenged birds. *Eimeria* challenge increased ($P < 0.01$) bile anti-coccidial immunoglobulin A (IgA) on d21 and 28. On d21, an interaction effect ($P < 0.05$) was found for IgA which was significantly increased by challenge only in PC and Arg, and IgA was higher in NC than in PC and BCAA only in challenged birds. *Eimeria* challenge increased ($P < 0.05$) expression of IL-10 on d21, TGF β -1 on d28, and IL-4 on d21 and 28 while decreased ($P < 0.01$) IFN- γ on d21 and IL-1 β on d28. *Eimeria* challenge decreased ($P < 0.01$) short chain fatty acid concentrations on d21 and 28, except isobutyrate and isovalerate on d21 whose concentrations were increased ($P < 0.05$) by the challenge. In conclusion, Arg and BCAA supplementation could be beneficial to broilers in fighting against *Eimeria* infection. Immune responses seemed downregulated in Arg in the recovery phase, which could favor the birds in reducing metabolic costs of immune systems.

PS3 - Nutrition and microbiome under challenging conditions**PS3-035 The laying hen's age impact on cholecalciferol (vitamin D3) level of enriched or per se eggs**G.M. Cornescu¹, T. Panaite¹, A. Cismileanu¹, M.I. Munțiu Rusu¹¹*The National Research-Development Institute for Animal Biology and Nutrition (INCDBNA-IBNA Balotești) (IBNA), Balotești, Ilfov, , Romania*

Vitamin D, especially within COVID-19 context is playing an important part of the immune system. It is very difficult to establish certain vitamin D levels to prevent insufficiency or deficiency, both in human and poultry. Vitamin D fortification of eggs by feed supplementation is already possible but only within some limits. It is known that 80 µg 25(OH)D3/kg feed assures 1 µg 25(OH)D3/60 g egg or 5 µg total vitamin D. The vitamin D status depends also on the laying hens' age. Therefore, we assumed that the level of vitamin D dietary inclusion will vary considerably along with the productive cycle of hen. The present study reviewed the scientific literature using PubMed and Google Scholar, without a determined requested time interval to find studies involving vitamin D enriched or per se eggs and its correlation with laying hen age. Results, discussions and opinions on perspectives, strategies to alleviate, when appropriate, where taken into consideration. In our review we observed that vitamin D egg content varies highly, in relation to the source utilized, natural vs. synthetic vitamin, to limits legislation that establish dietary level inclusion (from 2,200 IU up to 102,000 IU/kg of diet) and also to poultry's age from day of hatch to the end of the productive cycle. The results and conclusions about the vitamin D3 efficiency transfer from feed to egg, also about the safety vs. toxicity of the maximum vitamin D3 inclusion level presented contradictory data within literature. Therefore, more studies about how poultry's age affects vitamin D3 status in eggs (enriched or per se), about its absorption, transportation, excretion, tissue distribution related to different factors as life cycle and dietary feed supplementation are recommended.

PS3 - Nutrition and microbiome under challenging conditions**PS3-036 The potential of a pre-starter feeding strategy to ameliorate the adverse impact of health challenges on growth performance in broilers**R. Franco-Rosselló¹, C. Alfonso-Carrillo¹, J. Polo², D. Solà-Oriol³, A.I. García-Ruiz¹¹*Poultry R&D, Trouw Nutrition, 45215 El Viso de San Juan (Toledo), Spain, ²APC Europe, S.L. , 08403 Granollers, Spain, ³Servei de Nutrició i Benestar Animal (SNIiBA), Departament de Ciència Animal i dels Aliments, Universitat Autònoma de Barcelona (UAB), 08193 Bellaterra, Spain*

In the last few years, there has been many concerns about bacterial resistance to antibiotics, mainly used for therapeutic purposes or as growth promoters in poultry. Therefore, there is a clear need to look for alternatives, such as early nutrition strategies, which have been reported to improve the overall growth of the bird. The current study aimed to evaluate the potential effect of a pre-starter diet (0-4d), based on the use of spray dried porcine plasma and a low Ca strategy (ChickCare®; CC), on growth performance and bacterial diversity from caecum samples (n=16; 16S rRNA gene sequencing) at 4 and 10d of age. A total of 1056 male day-old Ross 308 were randomly allocated over 48 collective pens in 2 rooms. The study followed a factorial design of 3 contrasting 0-4d pre-starter diets, standard (S), standard+antibiotic (S+A), or CC by 2 scenarios (challenging conditions [reused litter + 5x Eimeria vaccination] or no challenge). After the pre-starter phase, all birds received a common 3-phase feeding program (4-10d, 10-28d and 28-35d). Birds fed the S+A received tylosin phosphate throughout the cycle (0-35d). The use of CC improved (P<0.001) BW and FCR at 4d compared to S and S+A diets. Considering the whole cycle (0-35d), CC and S+A groups improved BW compared to S group and only S+A improved FCR (P<0.001). Higher richness and diversity were observed in challenged birds compared to non-challenged birds. Under challenging conditions, birds of CC group had a higher relative abundance of SCFA-producing bacteria (e.g., Subdoligranulum, Lachnospira, or Ruminococcaceae UCG-005), bacteria with anti-inflammatory properties (Alistipes), high productivity-associated bacteria (Bifidobacteria), or considered ideal probiotics (Anaerostipes or Butyrivibrio pullicaecorum) compared to S+A (P<0.05) during the pre-starter phase. At 10d, chicks fed on CC had higher relative abundance than the S+A of Akkermansia, a biomarker of a healthy gut and Lactobacillus salivarius, an ideal probiotic. In conclusion, fed animals with a special pre-starter diet (CC) could offset the adverse impact of challenging conditions in broilers, standing out as a successful alternative feeding strategy toward the goal of reducing antibiotic use, especially broad-spectrum antibiotics. The beneficial effect of this strategy might have resulted from an improvement in gut microbiome, such as SCFA-producing bacteria regulating intestinal homeostasis, intestinal barrier function, or probiotics bacteria.

PS3 - Nutrition and microbiome under challenging conditions**PS3-037 Unraveling the probiotic potential of two novel *Bacillus* spp.**

K. Venkatasubramanian¹, J. Maertens², A. Luis Gonzalez Sanchez², K. Vermeulen², N. Smeets²

¹Kemin Industries South Asia Pvt. Ltd., Chennai, India, ²Kemin Europa NV, Herentals, Belgium

Extensive use of antibiotic growth promoters (AGP) in livestock industry has led to the development of resistant strains of pathogenic microbes. Probiotics are becoming the most relevant alternative to AGP's for supporting intestinal health and performance. The present study aimed to explore the probiotic attributes of new isolates of *Bacillus subtilis* (FXA, ATCC PTA 127114) and *Bacillus licheniformis* (G3, ATCC PTA 127113) which exhibited in vitro antimicrobial efficacy against common pathogens in preliminary studies. The strains were tested for their tolerance to gastric pH and bile in the intestinal simulation condition, their susceptibility to antibiotics, cytotoxicity in animal cell lines and compatibility to coccidiostats. The adhesion capability of the strains was tested by in vitro auto-aggregation, co-aggregation with gram negative bacteria and cell surface hydrophobicity which was measured by microbial adhesion to hydrocarbon method. Additionally, the presence of antibiotic resistance and toxigenic genes were investigated by whole genome sequence analysis. Both the *Bacillus* spp. showed good tolerance to gastric pH 3 and bile salt at 0.2%, ensuring their survivability in poultry intestinal environment. The strains were susceptible to the antibiotics of human and veterinary importance as listed by the European Food Safety Authority and showed no cytotoxicity to Vero cells. The strains were compatible with coccidiostats amprolium, monensin and diclazuril and compatibility analysis with additional coccidiostats is in progress. The auto aggregation of *Bacillus subtilis* FXA and *Bacillus licheniformis* G3 were 90% and 80% respectively and the cell surface hydrophobicity was 90% for each strain. Both strains had a co-aggregation capacity against *E. coli* ATCC 25922 and *Salmonella enterica* ATCC 13076 in the range of 55-60%. The whole genome analysis revealed that both the *Bacillus* spp. had no antibiotic resistance and toxigenic gene/plasmids. In conclusion, both *Bacillus subtilis* FXA and *Bacillus licheniformis* G3 exhibited functional probiotic potential at the tested conditions and can be considered safe for commercial application in animals.

PS3 - Nutrition and microbiome under challenging conditions**PS3-038 Yeast cell wall improves immune modulation response in aflatoxin challenge broilers**

M. Bonato¹, M. Ingbergman², B. Beirão³, F. Souza¹

¹ICC Brazil, São Paulo, Brazil, ²Imunova Análises Biológicas, Curitiba, Brazil, ³Universidade Federal do Paraná, Curitiba, Brazil

The objective of this study was to evaluate the effect of a yeast cell wall (source of β -glucans and MOS) to modulate the immune responses in aflatoxin-challenged broilers. 152 one-day-old male chicks were randomly distributed in 4 treatments: NC (negative control, basal diet without contamination), AFB (positive control, basal diet with 2.5 ppm of aflatoxin in diet administration), YCW (basal diet with 0.5 kg/MT from *Saccharomyces cerevisiae*'s cell wall - ImmunoWall®) and YCW+AFB (yeast cell wall diet with 2.5 ppm contamination of aflatoxin). The study design considered a bird as a replicate per analysis/parameter because the performance was not measured. The experimental period was 35 days with the diets, and on the 14th day was administrated the Newcastle vaccine. On days 1 and 14, blood samples were collected with anticoagulants for ELISA antibodies against Newcastle Disease (NDV) to determine maternal titer (10 birds/treat). ELISA for antibodies against NDV was assessed in blood samples at days 28 and 35 (8 birds/treat). The blood collection samples with anticoagulant for determination of cell profile by flow cytometry, the phagocytic capacity of peripheral blood lymphocytes, and the assessment of intestinal permeability (using Dextran-FITC, 3-5 kD) were performed at days 7, 28, and 35 (8 birds/treat). The data from each analysis were submitted to the D'Agostino-Pearson omnibus K2 normality test. However, the data that failed this test were submitted to non-parametric analyses, the Kruskal-Wallis test (GraphPad Software). The challenge with aflatoxin was verified and resulted in 2.24 ± 0.28 ppm in the challenged groups. The Aflatoxin challenge promoted the depletion of cytotoxic T lymphocytes on day 14. The YCW+AFB promoted an increase ($P < 0.05$) in diverse populations of immune cells, including total lymphocytes, T and B lymphocytes, in addition to phagocytic macrophages and heterophils (at day 28). Even without an aflatoxin challenge, animals treated with YCW showed higher production of NDV antibodies ($P < 0.05$) at day 35. No differences between the treatments were found in intestinal permeability. The YCW supplementation in broilers challenged with 2.5 ppm of aflatoxin showed an immune modulation effect; in non-challenged birds, it was observed an impact in higher production of antibodies, probably through the trained immunity mechanism (cytotoxic T lymphocytes).

PS3 - Nutrition and microbiome under challenging conditions**PS3-039** Yolk color assessment of eggs obtained under heat stress conditions using different dietary phyto-additivesG.M. Cornescu¹, T. Panaite¹, A. Cismileanu¹, C. Matache¹, M.I. Munțiu Rusu¹¹The National Research-Development Institute for Animal Biology and Nutrition (INCDBNA-IBNA Balotești) (IBNA), Balotești, Ilfov, , Romania

The objective of the study was to assess the color parameters (L^* , a^* , b^* , ΔL^* , Δa^* , Δb^* , ΔE^*_{ab}) of eggs obtained of 47-week-old laying hens ($n=120$) divided into six groups: control diet (CON), E1 (CON+1% yeast), E2 (CON+2% parsley), E3 (CON+2% inulin), E4 (CON+1% yeast+2% parsley), E5 (CON+1% yeast+ 2% inulin). The experiments were conducted under heat stress conditions ($34\pm 1^\circ\text{C}$). Egg samples were collected at the end of the experiment (18 eggs/group) and yolk color was measured by a portable color spectrophotometer, using the Commission Internationale de l'Eclairage system. All measurements were performed in triplicate. The spectrophotometry results showed that the yolk color changes were highly significant ($p < 0.0001$) for lightness L^* parameter on E1 and E5 groups compared to E2, E3, E4 groups. The saturation index in green/red intensity a^* parameter registered highly significant values ($p < 0.0001$) on E2, E4, E5 groups compared to C group; E1, E3 groups compared to E2 and E4; and E3, E4, E2 compared to E5 group. The saturation index in blue/yellow intensity b^* parameter was highly significant ($p < 0.0001$) on E1, E2, E3, E4, E5 groups compared to C group; E2 and E4 compared to E1 group; E3 and E5 groups compared to E2 and E4. The b^* increases values showed a tendency to bluish color. The color parameter variation (ΔL^*) had negative values and registered highly significant values ($p < 0.0001$) on E2, E3, E4, E5 compared to C and E1 groups; E2, E3, E4 groups compared to E5 group. Also, the color parameters variation Δa^* and Δb^* registered similar highly significant values ($p < 0.0001$) on E2, E3, E4, E5 compared to C and E1 groups, E3 group registered significant values compared to E4 and E5 ($p < 0.005$), and highly significant values ($p < 0.0001$) in E4 compared to E5 group. The global color change (ΔE^*_{ab}) registered highly significant values ($p < 0.0001$) on E2, E3, E4, E5 compared to C and E1 groups and on E3 compared to E4 group. This study showed significantly yolk color changes within all groups compared to C group, within heat stress conditions, when different levels of individually or mixed natural feed additives were added into laying hens' diets. Key words: yolk, color, hen, parsley, yeast, inulin, heat stress

PS3 - Nutrition and microbiome under challenging conditions**PS3-040** Yucca schidigera improves performance and lowers oocyst counts in eimeria challenged broilersK. Kozłowski¹, P. Vervenne-Zetteler², P. Konieczka¹, Ł. Szymanski¹, A. van Vilsteren²¹Department of Poultry Science and Apiculture, Faculty of Animal Bioengineering, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland, ²Jadis Additiva BV, Schiedam, Netherlands

In this trial, a 100% Yucca schidigera powder was tested for effectiveness against coccidiosis against a positive and negative control as well as an anticoccidial in Eimeria-challenged broilers. A total of 504 unsexed Ross 308 one day old chicks were divided over 4 treatments at random while ensuring the same starter weights between treatments. Every treatment consisted of 7 pens (7 replicates) with 18 birds each, resulting in 126 birds per treatment. We tested Yucca schidigera powder (500 g/T) as a natural alternative in broilers challenged with several Eimeria strains. This treatment was compared to three other treatments: an unchallenged control, a challenged control, and a challenged anticoccidial (625 g/T) treatment with focus on performance, oocyst per gram counts (OPG), and lesion scores. The 3 groups that were challenged received a 40 times overdose of Evalon vaccine, containing Eimeria acervulina, Eimeria brunetti, Eimeria maxima, Eimeria necatrix, and Eimeria tenella strains, into the crop on day 14 and 21 of the trial. A two-phase feeding scheme was applied (day 0-21 starter period and day 22-35 grower period) and the birds received feed and water ad libitum. Both the anticoccidial and the Yucca schidigera group showed significant improvement in body weight (2,150 and 2,058 vs. 1,998 and 1,971 kg), growth (60,2 and 57,6 vs. 55,8 and 55,1 g/d) and feed-conversion ratio (1,46 and 1,51 vs. 1,53 and 1,58), compared to both the challenged and unchallenged control groups. No significant differences were found between the treatments on OPG collection days 18 and 25. On day 35, lowest OPG counts were found in the unchallenged group (93), followed by the Yucca schidigera group (114), the anticoccidial group (243), and the challenged group (650). No significant differences were found for lesion scores, but the anticoccidial group had numerically the highest total lesion scores. Numerically, only the unchallenged birds differ from the other treatments. In conclusion, adding Yucca schidigera abolished the effect of the challenge resulting in comparable (FCR) or better (ADG) performance results compared to the unchallenged birds. Yucca schidigera consistently showed lower numbers for OPG counts compared to the anticoccidial and challenged group. Therefore, Yucca schidigera can be considered as an effective alternative for anticoccidial treatment in broilers.

PS3 - Nutrition and microbiome under challenging conditions**PS3-041 Zn acid complex reduces salmonella typhimurium shedding and prevalence by inducing the immune response of Cobb500 broilers**R. Burin¹, A. Aljamal¹, D. Neves¹, C. Torres¹, M. Rebollo¹, S. Carlson²¹Zinpro Corporation, Eden Prairie, United States, ²Iowa State University, Ames, United States

The use of alternative pre-harvest interventions to reduce the incoming loads of Salmonella at the processing plant becomes essential when efforts are being made to reduce the use of antibiotics in the poultry production. Therefore, searching for an intervention that stimulates birds to perform at their best and fight against bacterial challenges, has been the focus of this research. Dietary supplementation of highly available mineral sources, such as those from amino-acid-complexes, has been proven to improve epithelial tissue structure and function, as well as immunity. This study investigated whether supplementation of Zinc-amino-acid-complex (Zinpro® Availa®Zn) induces intestinal immunity and thereby impact cecal recovery and fecal shedding of Salmonella Typhimurium in broilers. One hundred Cobb500-day-old-chicks were tested for the absence of Salmonella and then randomly assigned to 4 treatments: T1) Control, with no added Zn; T2) AvailaZn at 60 ppm; T3) Zn sulfate at 80 ppm and T4) AvailaZn at 80 ppm. Birds received an oral challenge on D3, 6, 10, 13, and 16 with S. Typhimurium DT104 at 1x10⁸ CFUs/bird. Dietary treatments were offered from D22 to 42. Fecal samples were individually collected using rectal swabs on D23, 30, 37, and 40. On D42, birds were weighed, euthanized and cecal content and tissue samples were collected for Salmonella recovery and intestinal gene expression analysis, respectively. When compared to the control (Avg. 4.51 log₁₀CFU/g) and sulfate (Avg. 4.38 log₁₀CFU/g) groups, birds fed with AvailaZn 60 showed statistically significant lower Salmonella excretion in feces at D30 (1.53 log₁₀CFU/g), D37 (1.29 log₁₀CFU/g) and D40 (0.86 log₁₀CFU/g). Birds fed AvailaZn 80 also showed significantly lower Salmonella fecal shedding at D30 (1.00 log₁₀CFU/g), D37 (0.46 log₁₀CFU/g), D40 (0.43 log₁₀CFU/g), and lower loads of Salmonella in cecal content at D42 (1.49 log₁₀CFU/g) when compared to control (3.66 log₁₀CFU/g) and sulfate (3.64 log₁₀CFU/g) groups. Such Salmonella reduction observed in birds fed with AvailaZn 80 may be explained by the significantly higher expression of genes encoding intestinal cytokines (IL-6, IL-10, IL-18), acute phase protein (CPR), chemokines (CCL20, CCL4, CXCL14) and tight junction proteins (Claudin and PATJ). In conclusion, AvailaZn 80 induces intestinal immunity, contributes to the reduction of Salmonella in broilers and thereby could be used as a nutritional strategy for Salmonella prophylactic programs.

PS4 - Solution to improve the nutritional value of feed**PS4-001 A bacterial xylanase improves growth performance and intestinal integrity in broiler chickens**M. Lemos de Moraes¹, M. de Souza Vieira¹, H. Vieira Rios¹, Y. Katagiri Dalmoro², C. Boudry³, R. Sanz Garcia³, L. Lahaye¹, T. Bastos Stefanello¹, C. Stefanello²¹Jejo Nutrition, Saint-Hyacinthe, Canada, ²Federal University of Santa Maria, Santa Maria, Brazil, ³Belfeed NV, Andenne, Belgium

Bacterial xylanases are known to present high affinity to the insoluble portion of arabinoxylans, that represents approximately 90% of corn arabinoxylans. However, not much attention has been given to the effects of xylanase on intestinal health, which can be potentially improved due to arabinoxylan-oligosaccharides (AXOS) production. Therefore, a study was conducted to evaluate the effects of a *Bacillus subtilis* xylanase on intestinal integrity and growth performance of broiler chickens. A total of 900 one-day-old male broiler chicks were randomly allocated into 3 treatments with 10 replicates each for a 42-day trial. Diets were corn-soy-based, and treatments were as following: T1: Control (standard diet); T2: energy reduction diet (ER); and T3: ER + 100 g/t of a bacterial origin xylanase. A four-phased dietary program was used. Metabolizable energy reductions of ER diets were calculated according to the content of arabinoxylans of each diet, being: 80.1 kcal/kg reduction for Pre-starter; 81.8 kcal/kg reduction for Starter; 86.7 kcal/kg reduction for Grower, and 91.8 kcal/kg reduction for Finisher. All birds were challenged with *Eimeria* spp. at day 1 and with *Clostridium perfringens* (108 CFU/bird) at 11, 12 and 13 days. Feed intake (FI), body weight gain (BWG) and feed conversion ratio (FCR) were evaluated. At 17 d, intestinal permeability was evaluated by the FITC-d (fluorescein isothiocyanate-dextran) test. FITC-d is a molecule with high molecular weight that is inoculated via oral gavage and can be detected in the blood when the intestinal mucosa is damaged, presenting a higher permeability. Data was submitted to ANOVA and means were compared by Fisher test at 5% and 10%. At 42 d, birds from ER + Xylanase treatment presented 5% higher (P<0.05) BWG when compared to those from ER treatment, however they did not differ from those from Control treatment. Similarly, FCR was 4.1% lower (P<0.10) for ER + Xylanase when compared to ER, not differing from the Control group. The lowest FITC-d concentration was observed for the ER + Xylanase treatment (P<0.05), which indicates a lower intestinal permeability and lower chances of bacterial translocation. In conclusion, animals fed diets with energy reduction supplemented with xylanase were able to compensate the effects of energy reduction on performance. Additionally, the supplementation of xylanase promoted better integrity of the intestinal mucosa, possibly due to the prebiotic effect of AXOS which are products of xylanase action.

PS4 - Solution to improve the nutritional value of feed**PS4-002 A bacterial xylanase improves nutrient digestibility and growth performance of pullets**

M. Lemos de Moraes¹, M. de Souza Vieira¹, H. Vieira Rios¹, C. Boudry², R. Sanz Garcia², L. Lahaye¹, T. Bastos Stefanello¹, R. Santamaría Brito³, D. Purón Hernández³

¹*Jefo Nutrition, Saint-Hyacinthe, Canada*, ²*Belfeed NV, Andenne, Belgium*, ³*Centro de Investigación Animal Aplicada, Chablekal, Mexico*

Bacterial xylanase presents high affinity to insoluble arabinoxylans and therefore offers novel nutrition strategies to degrade arabinoxylans on corn-soy-based diets. The aim of this study was to evaluate the effects of a xylanase from *Bacillus subtilis* supplemented in pullets' corn/soy-based diets on nutrient digestibility and growth performance. A total of 600 six-week-old Bovans White pullets was randomly allocated in 60 cages, distributed in three treatments with 20 replicates and 10 animals/replicate until they completed 16w. Treatments were as follows: T1: Control (standard diet based on Bovans guidelines); T2: Energy reduction (ER); and T3: ER + Xylanase at 100 g/t. Reductions in metabolizable energy (ME) were calculated based on the arabinoxylans content of diets, being 91.9 kcal/kg in grower (6w-10w) diet and 100 kcal/kg in developer (11w-16w) diet. Feed intake, body weight gain (BWG) and feed conversion ratio (FCR) were evaluated weekly. At 10w, total excreta were collected to evaluate the total-tract retention of dry matter (DM), crude protein (CP), ether extract (EE), and ME. Data were subjected to one-way ANOVA and means were compared by Fisher test at a level of 5% of significance (XLSTAT software). Pullets fed ER + Xylanase diet presented similar BWG to Control and 3.2% higher than pullets fed ER diet with no xylanase ($P < 0.05$). The highest FCR was observed for pullets fed the ER diet (5.091), while pullets fed ER + Xylanase had similar FCR (4.937) to Control (4.966) ($P < 0.05$). The supplementation of xylanase in pullets' diets increased ME utilization and EE digestibility when compared ER treatment by 95 kcal (3,154 kcal/kg vs 3,059 kcal/kg) and 4.1% (86.3% vs 82.8%) respectively ($P < 0.05$). No difference was observed for CP and DM digestibility among treatments. In conclusion, the supplementation of bacterial xylanase on corn/soy-based diets with reduced metabolizable energy improved nutrient digestibility and growth performance of pullets.

PS4 - Solution to improve the nutritional value of feed**PS4-003 Addition of nutritional emulsifiers in decreased nutrient diets**

W. Smink¹, C. van der Eijk²

¹*Feed Innovation Services, Wageningen, Netherlands*, ²*Denuco, Berlaar, Belgium*

Feed of farm animals requires high amounts of energy and other nutrients. The consequence is that relatively high amounts of fat are needed in diets. The real metabolic energy contribution that fat brings to the diet is determined by the fat source, total fat level, age of the animals and the other ingredients in the diet. Young broiler chickens lack the right quantity of bile to digest the amount of fat that they consume. In addition, suboptimal circumstances often have a large impact on fat digestibility. Bile acids might also be deconjugated causing a lower energy value. If fat is less or slowly digested, it might also inhibit the digestion of other components in the diet, like proteins and carbohydrates. To aid the digestion of fats in the animal, nutritional emulsifiers can be used. These emulsifiers can be highly water soluble (high hydrophilic-lipophilic balance; HLB) which aids the bile acid activity to increase the surface area of the fat. In addition nutritional emulsifiers can be based on lysolecithin to improve the fat digestion. The aim of the study was to determine the effect of nutritional emulsifiers in a broiler diet with decreased energy and amino acids. Male Ross 308 broilers were used in the two trials with the same set up and given diets formulated with adequate (positive control) and 3.5% lower energy and 2% lower amino acid levels (negative control). Eleven replicates of four birds per treatment group were used in both trials. Several nutritional emulsifiers were added to the negative control diets. The negative control diet resulted in a statistical significant lower performance in comparison with the positive control. The gain and feed conversion efficiency were inferior. Supplementation of the emulsifiers with high HLB an lysolecithins improved gain from 2790 into 2900 g/bird or more and at least the same level as the positive control (2907 g) in trial 1. In trial 2, feeding of the positive control improved significant the feed conversion from 1.49 into 1.44. The nutritional emulsifier with a high HLB tended to improve feed conversion (1.46). There was no significant difference between the emulsifier groups and the positive control. The results of the trials indicate that the addition of nutritional emulsifiers allows energy and amino acid reduction in broiler chicken diets.

PS4 - Solution to improve the nutritional value of feed**PS4-004 Apparent metabolizable energy and soluble fibre utilisation in broiler chickens fed wheat diets with supplemental carbohydrases and organic acid**E. Kim¹, L. Hall², A. Fickler², G. Pasquali², M. Choct¹¹University of New England, Armidale, Australia, ²BASF SE, Lampertheim, Germany

Wheat has variable apparent metabolizable energy (AME) values, which have a direct influence on bird performance and economic profit for producers. The variation in wheat AME values is mostly associated with the presence of non-starch polysaccharides (NSP). NSP-rich wheat often contains low AME and may result in wet litter, growth depression and poor feed efficiency in broiler chickens. However, birds do not efficiently utilise NSP that have complex physicochemical characteristics due to the lack of endogenous enzymes for NSP digestion. In this respect, the present study investigated the effects of three commercial feed additives and their combination on AME and soluble NSP retention in broiler chickens. A total of 576 Cobb 500 mixed-sex broilers were reared in floor pens and allocated to 6 dietary treatments (8 replicates/treatment; 12 birds/replicate). Treatments were control (no additives), β -xylanase/ β -glucanase (XG), β -mannanase (M), buffered formic acid (FA) and their combinations (XG+M or XG+M+FA). On d 15, 24 birds per treatment were transferred to cages (6 replicates/treatment; 4 birds/cage), and excreta were taken between d 17 and 20 for AME and soluble NSP retention measurement. The male percentage of each pen or cage was used as a covariate during the statistical analyses for all measurements. All the feed additives either numerically or significantly improved the final body weight at d 35, with a more pronounced improvement found when the feed additives were used in concert. XG+M and XG+M+FA improved the final body weight by 4.6% (2,401 g) and 3.9% (2,384 g), respectively, compared to the control (2,295 g). Hence, XG+M and XG+M+FA improved AME by 1.3% and 1.5% (3,339 and 3,345 kcal/kg; $P = 0.019$), respectively, in comparison to the control diet (3,295 kcal/kg). Total tract soluble NSP retention at d 21 was improved ($P < 0.001$) by supplements FA (36%), XG+M (40%) and XG+M+FA (34%) compared to the control (0.1%). It is evident from the present study that an appropriate combination of carbohydrases and organic acid could exert a synergistic impact on bird growth by effectively targeting soluble NSP present in wheat diets and enhancing energy utilisation. However, the increased soluble NSP retention by FA supplementation did not lead to improvement in growth performance, suggesting that mechanisms other than soluble NSP degradation may come into play when a cohort of additives are used in concert to elicit positive performance response in birds.

PS4 - Solution to improve the nutritional value of feed**PS4-005 Application of methionine source concept in commercial broiler production**A. Lemme¹, K. Fenske², H. Westendarp², M. Guhe³, E. Rother¹¹EVONIK Operations GmbH, Hanau, Germany, ²University of Applied Sciences Osnabrueck, Osnabrueck, Germany, ³RAIFFEISEN Ems-Vechte, Klein-Berßen, Germany

Both, DL-methionine (DLM) and its hydroxyanalogue free acid (MHA-FA) are common feed additives in commercial feed production for optimizing methionine+cysteine supply of broilers. This project was conducted to validate the concept that MHA-FA is 65% as effective as DLM as methionine source. A broiler complex with 10 houses containing each 42,000 mixed sex broilers (Ross 308) was used. Chicken harvesting took place at days 29 (24% of birds), 34 (15%) and 41. In a 4-phase feeding program diet changes were at day 10, day 19 and day 25. Five houses received standard feeds supplemented with MHA-FA whereas five houses received exactly the same feed except that MHA-FA (2,95 kg/t on average across all phases) was replaced by DLM at only 65% of the quantity (1,92 kg/t). Specified amino acid levels as well as supplementation levels were confirmed by analysis of a total of 110 produced feed batches. Feed consumption was recorded per house and phase. Final body weights of broilers per harvest and house were received from the slaughterhouse. Body weights (hopper scales), feed and water consumption were also recorded in each house on daily basis with respective devices. The slaughterhouse also reported footpad dermatitis (FPD) scoring for all delivered birds according to a 4-grade scoring scheme. Nitrogen utilization and excretion were calculated based on N-analysis and the assumption of 30g N/kg broiler liveweight. Data were analysed by t-test ($p < 0.05$). Results indicated that quantitative replacement of MHA-FA by DLM at a ratio of 65% had no detrimental effect on any performance parameter. Average final body weight was 2.43 kg/bird with MHA-FA and 2.42 kg/bird while respective FCR was 1.50 kg/kg and 1.50 kg/kg. At no point in time treatments differed in terms of body weight, feed and water consumption. FPD scoring reported that 94.9% (MHA-FA) and 94.6% (DLM) of delivered birds had best score (no lesions). Nitrogen excretion and respective N-utilization were 313 and 314 g/place/year and 62.4 and 62.2% for MHA-FA and DLM fed broilers, respectively. Economic assessment revealed savings of supplementation cost by 19%. It is concluded that the concept of 65% relative bioavailability of MHA-FA compared to DLM is applicable under commercial condition without any negative impact on broiler performance, welfare (FPD scoring) and environment (N-excretion). However, savings on feed cost can be realized.

PS4 - Solution to improve the nutritional value of feed**PS4-006 Bacillus licheniformis and phytase mixture affect growth performance, nutrient digestibility, and cecal microbiome of broiler chickens**J. Trela¹, B. Kierończyk², M. Rawski³, J. Mazurkiewicz³, D. Józefiak²¹Huvepharma Poland Sp. z o.o., Warsaw, Poland, ²Poznań University of Life Sciences, Department of Animal Nutrition, Poznań, Poland, ³Poznań University of Life Sciences, Department of Zoology, Laboratory of Inland Fisheries and Aquaculture, Poznań, Poland

This study aims to evaluate the effects of *Bacillus licheniformis* and 6-phytase added alone or in combination to broiler chicken diets on the growth performance, apparent ileal digestibility coefficient (AID) of nutrients, microbial activity, and cecal bacterial communities. In total, 400 one-day-old female Ross 308 chicks were randomly assigned to 4 dietary treatments (10 replicate pens, 10 birds each). The following groups were defined: NC (negative control), a basal diet without any feed additive supplementation; NC+Pro, a basal diet with the addition of the *B. licheniformis* preparation (500 g/t of diet); NC+Phy, a basal diet with the addition of phytase (200 g/t of diet); and NC+Pro+Phy, basal diet combined with both studied additives. The addition of *B. licheniformis* positively affected ($P < 0.05$) the feed intake (FI) and feed conversion ratio (FCR) in the first 10 d of bird rearing. Moreover, phytase supplementation elevated the FCR from 21 to 35 d. In the entire experiment, an interaction between phytase and probiotic was observed only in terms of decreasing the bird FI ($P = 0.005$) without a negative effect on the FCR ($P > 0.05$). Furthermore, the AID of ether extract was improved by phytase supplementation. In terms of the cecal microecology, both separately administered factors promoted Lactobacillaceae in the ceca. Interactions between probiotic preparation and phytase were noted that indicated a decreased Clostridiales population and favored Ruminococcaceae proliferation. For the first time in the available literature, favorable interactions between *B. licheniformis* and phytase were observed regarding improved performance and cecal microbiota changes in broilers. This work was supported by statutory funding No. 506.533.04.00 of the Faculty of Veterinary Medicine and Animal Science Poznań University of Life Sciences, Poland; Department of Animal Nutrition.

PS4 - Solution to improve the nutritional value of feed**PS4-007 Benefit of full matrix application for a novel consensus bacterial 6-phytase variant alone or in combination with xylanase and beta-glucanase**R. Durán¹, A. Bello², S. Gilani³, B. Hillen³, K. Venter⁴, P. Plumstead⁴¹Danisco Animal Nutrition & Health, IFF, Madrid, Spain, ²Danisco Animal Nutrition & Health, IFF, Wilmington, 19803, Wilmington, United States, ³Danisco Animal Nutrition & Health, IFF, 2342 BH Oegstgeest, Oegstgeest, Netherlands, ⁴Chemuniqu International (PTY) Ltd, Lanseria, South Africa

With current high ingredients cost, application of full matrix for phytase including digestible phosphorus (P), calcium (Ca), sodium (Na), digestible AA and metabolizable energy (ME) is an important strategy to reduce feed cost. This study validated the application of full matrix for a novel consensus [was derived by the alignment of 23 bacterial phytase sequences (including *Buttiauxella* sp. phytase)] bacterial 6-phytase variant (PhyG) alone or with a xylanase+beta-glucanase (XB) mix in broilers. Ross 308 as-hatched broilers were randomly assigned to 5 dietary treatments with 8 pens of 55 birds/pen per treatment. The diets were based on corn, wheat, SBM, sunflower meal and rapeseed meal, in pelleted form in 3 phases (starter, 1-10 d; grower, 10-21 d and finisher, 21-32 d). The treatments included 1) a nutrient and energy adequate positive control (PC); 2) PC reduced in Ca by 0.24 - 0.21% point (p), digestible P by 0.20 - 0.18% p, Na by 0.05% p, dig AA by up to 0.04% p and ME up to 79 kcal/kg across the 3 phases (NC1); 3) NC1 supplemented with PhyG at 2,000, 1,500, and 1,000 FTU/kg (NC1+PhyG) in starter, grower and finisher phase, respectively; 4) the NC1 with additional reduction in dig AA by up to 0.02% p and ME by 78 kcal/kg (NC2) and 5) NC2 supplemented with PhyG (at the same dose as 3) and XB (xylanase at 1200 XU/kg, beta-glucanase at 152 U/kg) in all dietary phases (NC2+PhyG+XB). Data was analyzed with a one-way ANOVA and means separated by Tukey test ($P < 0.05$ as significant). The nutrient and energy reduction in NC1 and NC2 reduced ($P < 0.05$) 32 d body weight (BW) and 1-32 d feed conversion ratio (FCR) vs PC. Both NC1+PhyG and NC2+PhyG+XB maintained 32d BW and overall FCR vs PC ($P > 0.05$). Similarly, NC1 and NC2 reduced bone ash content at d 10 and 32, carcass, breast, thigh, and leg meat weights vs PC and both NC1+PhyG and NC2+PhyG+XB maintained these parameters. The estimated overall feed cost (€/kg body weight gain (BWG)) was reduced by 7.2 and 9.8% and carbon footprint (g CO₂ eq/kg BWG) was 12 and 17% lower with NC1+PhyG and NC2+PhyG+XB respectively vs PC ($P < 0.05$). In conclusion, supplementation of the novel phytase alone or with a xylanase+beta-glucanase mixture with full matrix application maintained broiler growth performance, bone ash, carcass characteristics and resulting economic benefit and could contribute to sustainable broiler production.

PS4 - Solution to improve the nutritional value of feed**PS4-008 Corn nutrient composition, energy value, and digestibility of amino acids according to the country of origin and year of harvest: The value of Near-Infrared Reflectance Spectroscopy**E.O. Oviedo-Rondón¹, A. Toscan², N.S. Fagundes², J.K. Vidal², J. Barbi², P. Thiery³¹Prestage Department of Poultry Science, North Carolina State University, Raleigh, NC, United States, ²Adisseo Latin America, São Paulo, SP, Brazil, ³Adisseo France, Antony, France

Corn is the most common grain used as a feedstuff for poultry with international trade. There is significant variability in corn nutrient, energy value, and amino acid (AA) digestibility (dig) due to origin and agronomic conditions per harvest. However, analytical variability among labs can also affect comparisons. Near-infrared reflectance spectroscopy (NIRS) can reduce this analytical variability. This study evaluated the effects of origin and year of harvest on corn nutrient, AME, AMEn, and AA content and AA dig coefficients estimated with NIRS. The database contained 84,331 corn samples scanned in Argentina, Brazil, Indonesia, the Philippines, and the United States between 2018 and 2021. The database was collected using the PNE system (Adisseo®). The PNE has a unique NIRS curve based on direct calibration generated with in vivo data of standard poultry AME and AA dig methods. A two-way ANOVA was conducted to evaluate the effects of country of origin and year of harvest on nutrient composition, AME, AMEn, and AA dig in DM. A 5 x 4 factorial design was used with five countries and four years of harvest. Significant interaction effects ($P < 0.001$) were observed for all parameters evaluated. Corn varied by country of origin, but values depend on the harvest year. In general, and across years, Indonesian and Philippine corn had higher nutrient content, total AAs, and AA dig than Argentinian and American corn. Philippine corn had the highest fat (4.64%), AME, and AMEn (3,792 kcal/kg) contents. Indonesian corn had the highest CP (9.64%), ash, and fiber. Brazilian corn had the second-highest AME and AMEn. Argentinian corn had the lowest CP content (8.27%). American corn had the lowest fat, AME, and AMEn (3,719 kcal/kg) content across the years. Indonesian corn had the highest content of all AAs except for Met. Corn produced in the Philippines had the highest Met content (0.20%). The lowest Cys, Thr, Trp, Ile, and Phe contents were observed in Argentinian corn. The lowest Lys, Met (0.18%), Val, and Arg contents were in corn harvested in the USA. Generally, across the years, Indonesian corn had the highest AA dig of all AAs except for Met, Leu (Philippine corn), and His (Brazilian corn). The lowest dig of Lys (77.48%), Trp, Ile, Leu, Phe, and His were observed in Argentinian corn. In conclusion, the NIRS PNE system was able to detect the variability caused by the interaction of country of origin and year of harvest in corn nutrient and energy content and AA dig.

PS4 - Solution to improve the nutritional value of feed**PS4-009 Determination of the standardized ileal digestible calcium requirement of fast-growing male broilers from day 29 to 44 post-hatch**C. Walk¹, P. Jenn², C. Chatelle², R. Aureli²¹DSM Nutritional Products, Kaiseraugst, Switzerland, ²DSM Nutritional Products, Village-Neuf, France

An experiment was conducted to determine the standardized ileal digestible (SID) Ca requirement of broilers from d 29 to 44 post-hatch. Ross 308 male broilers were obtained at d of hatch and allocated to floor pens. From hatch to d 29, all birds were fed a nutrient adequate diet, including digestible P (dgP) and SID Ca, containing wheat, soybean meal and rapeseed meal. On d 29, 480 birds were weighed and randomly allocated to the 48 floor pens at 10 birds/pen and 12 pens/diet. Birds were fed one of four experimental diets until day 44. The diets were formulated using published ingredient SID Ca values, to contain 0.40, 0.30, 0.20, or 0.10% SID Ca. Digestible P was maintained in all experimental diets at 0.32%, including 0.18% dgP from 2,000 FYT/kg of phytase. Data were analyzed using JMP. Means were separated using orthogonal contrasts. The SID Ca requirement was estimated at 95% of the maximum response using analyzed SID Ca and quadratic models in the fit curve platform. Analyzed total Ca content in the diet agreed with expected values. Average initial body weight (BW) at the start of the experiment (d 29) was $1,698 \pm 28$ g and this was 97% of breed guidelines. Final (d 44) average BW was $3,320 \pm 50$ g and this was equivalent to breed guidelines. There was no effect of SID Ca concentration on BW gain ($P = 0.1334$), feed intake ($P = 0.4747$), or mortality corrected feed conversion ratio ($P = 0.3653$). Tibia ash percent, weight, P or Ca linearly ($P < 0.05$) increased as the SID Ca content in the diet increased. Apparent ileal digestibility (AID) of P and apparent ileal digested P linearly ($P < 0.05$) decreased as the SID Ca concentration in the diet increased from 0.10 to 0.40%. The AID of Ca was greatest in birds fed 0.10 or 0.20% SID Ca and decreased (quadratic, $P < 0.05$) as the SID Ca concentration in the diet increased to 0.40%; whereas ileal digested Ca linearly ($P < 0.05$) increased as the SID Ca concentration of the diet increased and was in agreement ($r = 0.958$) with the analyzed SID Ca concentrations in the diet. In conclusion, the SID Ca requirement of fast-growing broilers from d 29 to 44 post-hatch was estimated at 0.402% using the analyzed SID Ca concentrations in the diets, 95% of the maximum response, and tibia ash percent and weight, and tibia Ca and P weight. This corresponds to a SID Ca to dgP ratio of 1.26. These results are similar to previous work suggesting the SID Ca requirement of broilers from d 25 to 42 was 0.37% when using tibia ash.

PS4 - Solution to improve the nutritional value of feed**PS4-010 Dietary supplementation of lysolecithin compared to a combination of lysolecithin, synthetic emulsifier and monoglycerides, on laying performance and egg quality of laying hens**A. Wealleans¹, A. Desbruslais¹, D. Gonzalez-Sanchez¹¹KEMIN Animal Nutrition & Health EMENA

The positive effect of lysolecithin supplementation to broiler diets on growth performance, energy availability, lipid and protein digestibility has been previously documented. The addition of monoglycerides and synthetic emulsifiers in combination with lysolecithins, could further improve digestion and absorption of nutrients of poultry diets. The present study investigates the efficacy of supplementing lysolecithin alone compared to a combination of lysolecithin, synthetic emulsifier and monoglycerides to diets of laying hens on laying performance and selected egg quality parameters. A total of 384 Hy-line brown laying hens were randomly assigned to three dietary treatments for 12 weeks: T1, control wheat-maize-soybean diet; T2, control + 500 ppm of lysolecithin (LECI); T3, control + 500 ppm of a combination of lysolecithin, synthetic emulsifier and monoglycerides (LEX). Each treatment consisted of 32 cages/replicates of 4 birds each. Bird weights were measured at the start and end of trial. Egg number, weight, and condition (cracked, dirty, soft shells) were recorded daily. Egg mass and feed intake were measured weekly. Every 4 weeks throughout the study, 1 egg per pen (in total 96 eggs per treatment) was assessed, using the EggAnalyzer®, for egg weight, yolk colour (DSM Yolk Colour Fan), albumin height and Haugh unit. Results indicate that layers fed diets supplemented with LEX compared to control showed a tendency to improve laying rate from 0 to 4 weeks (97.08 vs. 97.03 %; p=0.0755) and from 0 to 12 weeks (97.02 vs. 94.11; p=0.0574) and a better feed efficiency (FCR) from 8 to 12 weeks (2.306 vs. 2.448; p=0.0188) and from 0 to 12 weeks (2.316 vs. 2.419; p=0.0291). Daily egg mass also tended to be increased versus control from 0 to 4 weeks (59.2 vs. 57.08 g/hen; p=0.0749) and 4 to 8 weeks (61.52 vs. 59.09 g/hen; p=0.0551), which became significant from 8 to 12 weeks (63.22 vs. 60.09; p=0.0093) and from 0 to 12 weeks (61.31 vs. 58.75; p=0.0163). Egg yolk color in LEX-fed hens increased compared to that of the LECI hens, from 4 to 8 weeks (2.72 vs. 2.28; p=0.0326) and from 0 to 12 weeks (2.44 vs. 2.21; p=0.0360). Dietary supplementation of LECI did not influence (p>0.05) any of the evaluated parameters compared to control. In conclusion, the study shows that adding a combination of lysolecithin, monoglycerides and synthetic emulsifier to a control diet improved FCR and daily egg mass and tended to improve laying rate compared to lysolecithin alone.

PS4 - Solution to improve the nutritional value of feed**PS4-011 Dietary α -galactosidase and xylanase preparation to improve the nutritional value of corn-soybean meal diets of broiler chickens**A. Viñado¹, J. Mascarell², R. Morales¹, J. Estévez¹, S. Carné¹¹Industrial Técnica Pecuaria S.A. (ITPSA S.A.), Barcelona, Spain, ²Experimental Nutrition Center of Analytical Profile Co. LTD (ENCAP), Khlong Nueng, Thailand

Two experiments were performed to assess the effects of an enzyme preparation (CAPSOZYME SB PLUS; α -galactosidase activity: 40 GALU /g; xylanase activity: 50 AXC /g) on broiler chicken's performance, carcass traits, footpad dermatitis score and nutrients digestibility. In the first experiment, a total of 320 1-day old male Ross 308 chickens were fed 4 experimental treatments: 1) control diet (PC), corn and soybean meal ; 2) PC diet supplemented "on top" with 350 ppm of the enzyme preparation (PC+Enzyme 350 ppm); 3) Negative control diet (NC), PC diet with a 4% reduction of apparent metabolizable content (AME) and crude protein (CP); 4) NC diet supplemented with 500 ppm of the enzyme preparation (NC+Enzyme 500 ppm). In the second experiment, a total of 96 1-day old male Ross 308 chickens were fed either PC or PC+Enzyme 350 ppm and chromic oxide was added (0.3%) to perform a digestibility balance between the day (d) 24-28 of life. Energy utilization (AME and AMEn) was determined by excreta collection, whereas apparent ileal digestibility (AID) of CP and amino acids (AA) was performed by distal ileal digesta collection. The enzyme preparation supplementation at 350 and 500 ppm significantly improved the overall (0 to 35 d) feed conversion ratio in PC and NC diet, respectively (P<0.01); however, no effects were associated to the enzyme supplementation on overall feed intake (P>0.05). Regarding carcass yields evaluation, the enzyme addition in PC and NC diet tended to reduce the relative weight of the abdominal fat pad in relation to the carcass weight (P<0.1), but no other effects were described. In relation to footpad dermatitis score, animals fed NC+Enzyme 500 ppm tended to present a lower value than animals fed NC (P<0.1). Concerning the digestibility balance, PC+Enzyme 350 ppm diet presented a higher feed AME and AMEn value than PC diet (P<0.05). The enzyme supplementation also improved AID of proline (P<0.05) and tended to increase AID of cysteine (P<0.1). In addition, numerical improvements (P>0.05) on AID values of CP (+1.75 percentual points) and all the AA assessed (from +2.03 up to +4.28 percentual points) were observed on the animals fed PC+Enzyme 350 ppm. In conclusion, these data demonstrate that the enzyme preparation combining an α -galactosidase and a xylanase improves birds feed efficiency by increasing energy and nutrients digestibility.

PS4 - Solution to improve the nutritional value of feed**PS4-012 Double Lactobacilli strain-based pro- and post-biotic improved broiler performance and affected minerals metabolism diet-dependently**

S. Jansseune^{3,1,2}, F. Blanc², F. Calenge², J. van Baal³, A. Lammers³, A. Mahieu¹, M. Aoun¹, M. Pinard van der Laan², W. Hendriks³

¹Idea, Sautron, France, ²INRAE, Jouy en Josas, France, ³Wageningen University, Wageningen, Netherlands

Lower quality ingredient use in broiler diets and maintenance of performance is a challenge. Under more challenging conditions, dietary supplementation with pro- (Pro) and post-biotics (Post) can elevate potential negative effects. The study aimed to assess the effects of a co-culture of *Lactobacillus rhamnosus* and *L. formosensis*-based Pro as well as the derived Post under two dietary conditions (standard [SD] and challenge [CD]), and determine their biological effects. Following a 2x3 randomised block design, day-old Ross male broilers (n=1368) were fed 1 of 2 diets (SD and CD) and as well as additives (Pro and Post) next to control diets from d1 to 42 with 6 pen replicates per treatment. Control SD and CD were formulated to meet broiler nutritional requirements and were iso-metabolizable energy, protein, digestible essential amino acids, calcium (Ca) and phosphorus (P), and fed from d1 onwards. The CD was formulated to be greater in non-starch polysaccharide content. Readout parameters included growth performance and tibia health, strength and composition at d35 as well as blood minerals at d21 and 35. Results were analysed by ANOVA and PERMANOVA, with body weight (BW) correction. Compared to SD, CD decreased BW at d42, while increasing 1-42d feed conversion ratio (FCR). CD also impaired bone health parameters (higher tibial dyschondroplasia (TD) and tibia head mineralization zone, lower tibia stiffness, dry matter (DM) and ash), thereby confirming the challenging effect of CD. Pro increased BW in CD but not in SD at d42, through increased feed intake, without affecting FCR. Post significantly increased BW in CD at d35 and numerically at d42. Pro increased plasma total Ca at d21 and 35 and P at d35, without affecting Ca/P and magnesium (Mg) at both ages. Post only increased plasma Mg at d21. Post but not Pro increased tibia stiffness and reduced TD score. Tibia DM and ash were not affected by Pro and Post. Tibia Ca and P content was only affected for Pro in SD with a reduction compared to the control SD. Tibia Mg was not affected by Pro and Post. Diet composition modulated the Pro and Post effects, with both improving broiler performance under “challenging” dietary conditions. Additionally, Pro and Post affected mineral metabolism, with potential beneficial effects of Post on TD and tibia strength.

PS4 - Solution to improve the nutritional value of feed**PS4-013 Effect of 1-monoglycerides on performance, ileal mucosa morphometry and footpad dermatitis in broilers**

Y. Shastak¹, M. Kalyoncu², P. Sacakli³, Ö. Sizmaz³, M. Pirpanahi³, A.G. Bayraktaroglu⁴

¹BASF SE, Ludwigshafen am Rhein, Germany, ²Kartal Kimya A.S., Gebze/Kocaeli, Turkey, ³Department of Animal Nutrition & Nutritional Diseases, Ankara, Turkey, ⁴Department of Histology and Embryology, Faculty of Veterinary Medicine, Ankara University, Ankara, Turkey

The objective of this study was to evaluate the effect of a 1-monoglycerides mixture on performance, ileal mucosa morphometry and footpad dermatitis in broilers. For the control, a maize-soybean meal-based diet was formulated in accordance with dietary recommendations of Aviagen (2019). This control diet was fed as is or supplemented with four levels of a 1-monoglycerides mixture (BalanGut LS P, BASF SE, Germany) at 300, 500, 1500 or 3000 g/mt of feed. BalanGut LS P (a powder form) is a mixture of 1-monoglycerides of butyric, caprylic and capric acid. A total of 350 one-day-old Ross 308 male broiler chicks were given mesh experimental diets for 42 days. Live vaccines for the control of coccidiosis have been employed by the hatchery. The animals were raised in floor pens (110 × 80 cm) with wood shavings and no additional filling or cleaning of the floor was executed during the trial. Each of the five diets was fed to seven replicate pens of 10 birds. Body weight for each pen was recorded on days 1 and 42 post hatch. Feed intake was measured on a pen basis. Tissue samples were obtained from the ileum for histomorphological analysis at d 21 post hatch (2 birds per pen). Footpad lesion score as well as litter quality (feather dirtiness, caking and scoring of the litter) were determined at d 42. Data were analyzed using the ANOVA procedure of SPSS version 14.01 (SPSS Inc., Chicago, IL, USA). Inclusion of 1-monoglycerides in the maize-soybean meal-based diet numerically improved (P > 0.05) BWG, FCR as well as uniformity of broilers at d 42 for all four supplementation levels compared with the control. Treatment effects were not significant (P > 0.05) for mortality. Inclusion of 1-monoglycerides in the maize-soybean meal-based control diet significantly decreased (P < 0.001) crypt depth and significantly increased (P < 0.001) villus height: crypt depth ratio compared with the control. The supplementation of 1-monoglycerides to the control diet significantly improved (P < 0.05) footpad dermatitis score compared with the control. Litter quality was also improved by supplementation of 1-monoglycerides to the control diets. In conclusion, supplementation of 1-monoglycerides can improve ileal mucosa morphometry and footpad dermatitis scores in broiler chickens. Further studies are required to evaluate 1-monoglycerides under more challenging conditions in broilers.

*PS4 - Solution to improve the nutritional value of feed***PS4-014** Effect of a “structured” micro pellet feed during the first five weeks of live of laying hensC. Alfonso-Carrillo¹, R. Akbari Moghaddam Kakhki¹, R. Franco-Rosselló¹, A.I. García-Ruiz¹¹Poultry Research Center, Trouw Nutrition, El Viso de San Juan, Toledo, 45950, Spain

The first weeks of age of laying pullets are critical to allow the animal to express its maximum genetic potential in the productive phase. Body weight (BW) at five weeks is a standard indicator to predict a future flock's success. Feed form (pellet or crumbles) influences feed intake (FI) and nutrient digestibility, increasing BW. However, the small particle size decreases gizzard function and peristaltic movements of the intestinal tract. This study aimed to evaluate the effect of different feeding strategies during the first five weeks using several feed forms: mash (M), crumble (C), micro-pellet (P) and a “structured” micro-pellet (SP) with an increased internal particle size of the pellet by including 3% oats hulls without grounding. In total, 520 day-old commercial brown pullets were distributed to four dietary treatments with 13 cages each. All diets were iso-nitrogenous and isocaloric. From arrival to five weeks of age, individual BW was recorded weekly. At two and five weeks, FI, gizzard development and bone quality were assessed. In general, birds fed M diet had significantly lowest BW and FI, and the highest feed conversion (FCR) throughout the experimental period. During the first week, no differences in BW were observed between C, P and SP diets. However, at 2-week age, the use of SP diet improved BW by 14.3 % ($p<0.001$) relative C diet, whereas P diet was intermediate. At 5-week age, similar results compared to week 2 were observed, although the relative magnitude of the differences decreased (by 3%). No differences in FI and FCR between C, P and SP feeds were found. At 2-week age, SP diet increased the BW uniformity by 10 points compared to M diet ($p<0.05$), while no differences were observed in other comparisons. None of the tibia quality traits studied were significantly affected by feed forms. Relative empty gizzard and proventriculus weight (%BW) was lower in C and P diets than M and SP diets at two (3.9% vs. 3.1%; $p<0.001$) and at five weeks (2.4% vs. 3.1%; $p<0.001$); whereas SP values did not differ to M diet. In conclusion the use of SP during the first weeks of life decreased the detrimental effect on gut development, usually observed using standard pellet or crumble feeds. In addition, it improved the growth of pullets at five weeks, increasing the probability of success of a future flock.

*PS4 - Solution to improve the nutritional value of feed***PS4-015** Effect of a dietary NSPase and grinding method at two nutrient densities on nutrient digestibility & growth performance of Ross 308 broilersC. Raybaud¹, M. Bournazel¹, T. Condry¹, C. Le Dain¹, A. Smith², J. Thoby³¹MIXSCIENCE, BRUZ, France, ²DSM, HEANOR, DERBYSHIRE, United Kingdom, ³DSM, LA GARENNE-COLOMBES, France

Grinding method impacts raw material particle size, which may affect non-starch polysaccharides (NSP) availability and, therefore, nutrient release by NSPase enzymes. The aim of this trial was to study the effect of grinding method on NSPase efficacy at two nutrient densities. A total of 512 male Ross 308 were randomly allocated to a 2 x 2 x 2 factorial design with 2 nutrient densities (ND : standard levels of ME, d.Lys and CP ; ND- : -100 kcal/kg, -0.04 point of d.Lys and -0.6 point of CP), 2 grinding methods (H : hammer mill; D : disc mill) with or without NSPase (MG : incorporated at 60g/t of feed). Each treatment was replicated 16 times with 4 birds per cage for 35 days. Growth performance was measured at 10, 21, 28 and 35 d. At 36 d, apparent total tract nitrogen (N) and fat (F) digestibility was measured. A three-way ANOVA was used to compare groups and P-values <0.05 were deemed significant. The ND diet had superior performance at each age. At 35d, FCR was significantly lower compared to the ND- diet (1.41 vs 1.47, $p<0.05$) irrespective of the grinding method and presence of MG. These results were consistent with N digestibility: without NSPase, ND diet tended to have a higher N digestibility (ND vs ND-: +0.8%, $p<0.1$). Birds fed with MG had lower 0-35d corrected FCR (-1pt, all treatments). This effect was better seen on ND diets: with H grinding, addition of MG decreased FCR by -3.5pts vs -1pt for D grinding ($p<0.1$). MG also improved F digestibility by 4.2% and 4% for ND- and ND levels, respectively, with D grinding. The type of grinding had no significant impact on growth performance of broilers, even if N utilization seemed to be higher with use of D grinding (D : 63.5% ; H: 59.8%). This trial indicates that MG effects on growth performance can be observed across the range of grinding methods & nutrient densities tested, but also that the effects are stronger on high density/H ground diets. Such trial may help the commercial poultry nutritionist to assess the economical relevance of NSPase in different formulations & industrial contexts.

PS4 - Solution to improve the nutritional value of feed**PS4-016 Effect of a dietary supply of double-buffered sodium butyrate on performance of layers in a context of reduction of energy and protein in the diet**C. Marecaille¹, A. Ablanedo², X. Roulleau¹¹DIETAXION SAS, Le Loroux Bottereau, France, ²Facultad de Ciencias Veterinarias, Universidad de Buenos Aires, Argentina

In the context of rising prices of feed ingredients, the objective of the poultry sector is to increase feed efficiency. Previous studies have shown the benefit of a double-buffered sodium butyrate (DBSB) on the performance and intestinal health of broilers fed low energy and protein diets. The aim of this new study was to evaluate the effect of this uncoated form of sodium butyrate on the performance of layers. A total of 576 Hy-line W-80 layers were divided into 3 groups from week 71 to 77 of age: a control group (CTRL) fed a basal diet (requirement Hy-line, 2019), a group LEP fed with a diet low in energy and protein (-3% in energy, protein and lysine, methionine, threonine), and a LEP-B54 group fed a diet LEP supplemented with 600ppm of DBSB. The birds were randomly allocated in 8 lines (replicates) of 24 individual cages for each treatment. The layers were weighted at the beginning of the trial. The parameters studied were feed intake, number of collected eggs and their weight, enabling to calculate the mass of eggs produced and the feed conversion ratio (FCR). Mortality was used to correct the feed intake and FCR. Data were statistically analysed using ANOVA with initial layer weight as covariable, followed by a Duncan test for comparisons of means. No difference in feed intake and egg weight was observed between treatments ($P>0.05$). However, hens in LEP group laid significantly less eggs (-4%) in comparison with the other groups ($P<0.05$). The number of collected eggs in CTRL and LEP-B54 did not differ from each other ($P>0.05$). Mass of eggs produced during the trial was significantly lower in LEP group compared with the CTRL group by -8% ($P<0.05$), while layers in LEP-B54 partly compensate the reduction in nutrients thanks to the supplementation of DBSB, leading to intermediary results between LEP and CTRL group. Regarding the FCR for kg or dozens of eggs, significant differences were obtained between the groups ($P<0.05$), with the LEP diet presenting the worst performance in all cases. There was no significant difference in FCR for layers in LEP-B54 group in comparison with CTRL group fed a diet containing more nutrients ($P>0.05$). In a context of layers' diets containing a lower nutritional level than the genetic guideline recommendation (-3% of energy and protein), the addition of 600ppm of double-buffered sodium butyrate enables a better egg production and feed conversion ratio.

PS4 - Solution to improve the nutritional value of feed**PS4-017 Effect of chestnut tannins and vitamin E supplementation to linseed oil-enriched diets on performance and meat quality of broiler chickens**L. Perić¹, D. Žikić¹, M. Đukić Stojčić¹, V. Tomović², J. Leskovec³, J. Salobir³, V. Rezar³¹University of Novi Sad, Faculty of Agriculture, Department of Animal Science, Novi Sad, Yugoslavia - Serbia,²University of Novi Sad, Faculty of Technology, Novi Sad, Yugoslavia - Serbia, ³University of Ljubljana, Biotechnical Faculty, Department of Animal Science, Ljubljana, Slovenia

The aim of the experiment was to determine the effect of supplementation of linseed oil-enriched diets with vitamin E or chestnut tannins on growth performance, dressing percentage and meat quality of broiler chickens. A total of 240-day-old male chickens (Ross 308) were allocated to 3 treatments with 4 replicates of 20 male birds. From the day 21 to day 40 the 5 % of cold-pressed linseed oil was added to the experimental basal diet and three treatments were formed: finisher without additives; finisher + 200 IU vitamin E/kg; finisher + 500 mg/kg of chestnut wood tannin extract. At 40 days of age 12 animals per group were killed by cervical dislocation to determine the dressing percentage (ready-to-cook), and yield of primal cuts (breast, legs, wings, and back). The analysis of pH was carried out on the breast muscle 24 h and 48 h post-mortem. Water holding capacity was determined 24 h post-mortem. Obtained data were analyzed by one-way ANOVA. Fisher LSD post hoc test was used to separate LS means. No significant influence of treatments was established on body weight or feed conversion ratio. Negative effect on feed intake ($P<0.05$) was found in vitamin E group compared to the control group, but without negative consequences on body weight gain or feed conversion ratio. The addition of vitamin E increased dressing percentage ($P<0.05$) compared to the other two groups and increased the breast meat yield (%) ($P<0.01$) compared to control group. The legs yield (%) was lowered in vitamin E group compared to control and tannin group ($P<0.01$). No significant effects of both vitamin E and chestnut tannins were found on the water holding capacity or pH of breast meat. It can be concluded that vitamin E supplementation in oil enriched-diets improved carcass percentage and breast meat yield, while the addition of chestnut tannins had no effect on broiler performance or carcass quality. Research supported by the Slovenian Research Agency (grant No. P4-0097) and Ministry of Education, Science and Technological Development of Republic of Serbia (No. 451-03-68/2020-14/ 200117).

PS4 - Solution to improve the nutritional value of feed**PS4-018 Effect of coated calcium butyrate, monobutylin, and a combination thereof on growth performance and mRNA abundance of genes related to tight junction proteins in broilers**

K. Schuh-von Graevenitz¹, E. von Heimendahl², L. Barnard³, K. Seibt⁴, H. Sadri⁴, H. Sauerwein⁴, G. Dusel⁵

¹Institut Feed Research GmbH, Bingen, Germany, ²Eastman Chemical Company, Langenfeld, Germany, ³Eastman Chemical Company, Newport, United Kingdom, ⁴University of Bonn, Bonn, Germany, ⁵University of Applied Science Bingen, Bingen, Germany

Butyric acid is widely used in broiler diets since it improves gut development, balances the microflora, and reduces cellular oxidative stress and inflammation. Various butyric acid products are available but might have different physiological effects based on their chemical properties. This study aimed to compare the effects of coated Ca-Butyrate, monobutylin, and a combination thereof on growth performance and parameters related to barrier function. A total of 120 one-day-old broiler chicks (Ross 308, sexed males) were randomly allocated to 4 dietary treatments. Birds received a wheat-soybean meal-based pelleted diet in 3 phases (starter d1-7; grower d7-21, finisher d21-35). Broilers were housed in 15 cages, with 30 broilers per treatment. Treatments were (T1) Negative control, (T2) Ca-Butyrate (CaBu), (T3) Monobutylin (MB), and (T4) a combination of CaBu and MB. Supplemented diets were calculated to be isobutyric and delivered 240/170/170 butyric acid mg/kg in starter, grower, and finisher diets, respectively. Body weight (BW) and feed intake (FI) were recorded weekly. Average daily gain (ADG) and feed conversion ratio (FCR) were calculated for the starter/grower (d1-21), finisher (d21-35), and total period (d1-35). Six birds per treatment were slaughtered on d21, and intestinal tissue samples were collected for assessing the mRNA abundance of 18 genes related to intestinal barrier function (MUC1, 2, 13, CLDN1, 2, 4, 5, OCLN, JAM2, 3, TJP1, 2, VCAM1, PECAM1, MADCAM1, SELL, ICAM2). Birds fed T4 had higher BW at d28 (1.94 vs 1.84 kg) and d35 (2.74 vs 2.62 kg), resulting in higher ADG in the finisher (112 vs. 105 g/d) and the overall period (77 vs. 74 g/d) compared to T1 ($P < 0.05$). FI of birds in T4 compared to T1 was higher in the finisher period (176 vs 167 g/d; $P < 0.05$). FCR was 1.41 for T3 and 1.45 for T1 ($P = 0.118$). 3 genes out of 18 were significantly influenced by treatment: MUC2, CLDN1, CLDN2. However, the effect differed between the ileum and jejunum, e.g., CLDN1 and CLDN2 mRNA abundance was increased more than 2- and 3-fold in the jejunum of T3 and T4 compared with T1 ($P < 0.01$ and $P < 0.05$), respectively, whereas the ileal expression was not affected. Conversely, MUC2 was increased by about 60% in the ileum but not in the jejunum of birds in T2 compared with T1 ($P < 0.05$). In conclusion, MB and the combination of CaBu and MB positively affected growth performance and the jejunal mRNA abundance of the tight junction proteins CLDN1 and 2 in broilers.

PS4 - Solution to improve the nutritional value of feed**PS4-019 Effect of encapsulated lysine on growth performance and carcass quality in broilers**

E. Gonzalo¹, R. Bouvet², W. Lambert¹, T. Chalvon-Demersay¹

¹METEX Animal Nutrition, Paris, France, ²Zootests SAS, Ploufragan, France

The supplementation of free amino acids (AA) can be used to improve gut health in chickens. Encapsulating these AA could help them to reach the lower part of the intestine and to modulate microbiota activity. Precedent internal trials have shown that encapsulated Lysine (enc-L-Lys) reduced mortality in broilers, tended to increase dry matter content in mid-jejunum, and increased butyrate in mid jejunum and cecum, a product of the catabolism of Lys. The aim of this trial was to study the effect of enc-L-Lys on growth performance, feed efficiency and carcass quality of broilers. For this purpose, 9 batches of 200 Ross 308 male broilers were randomly fed during 3 growth phases (0-12, 12-21 and 21-35 days of age) with 3 different treatments: T1: standard diet (std), T2: std + 0.6 kg/T I-Lys; T3: std + 2kg/T enc-L-Lys. Enc-L-Lys contained 30% of I-Lys embedded in a 70% vegetable fat matrix. Diets were based on corn, wheat, soybean meal and soya and palm oils and contained adequate levels of indispensable amino acids (TD basis). Diets were isonitrogenous and isoenergetic. Measurements of body weight (BW), daily gain (ADG), feed intake (FI), feed conversion ratio (FCR) and carcass quality (carcass yields, wooden breast and white striping), European Production Index (EPI), litter scoring, pododermatitis (FPD) and mortality were carried out. Digesta samples (ileum and cecum) were also collected (results not shown). Regarding the global period (d0-35), results showed that 2kg/T of enc-L-Lys had a numerical effect on broilers' BW and ADG (+2% and +2%, respectively; $P = \text{NS}$) comparing to control birds (T1). For the FCR, the enc-L-Lys presented a significant lower FCR ($P < 0.01$) compared to T1 and T2 (-1.4% and -1%, respectively). No statistical differences between treatments were found for mortality, litter scoring, FPD and EPI, however this last parameter was numerically increased (+2%; $P = \text{NS}$) with enc-L-Lys at 2kg/T. In terms of carcass quality, enc-L-Lys at 2 kg/T presented a numerical slightly higher carcass proportion (+0.5%; $P = \text{NS}$) compared to T1. For the abdominal fat proportion, the enc-L-Lys presented a lower value than T2 (-18%; $P = 0.05$) and T1 (-16%; $P = \text{NS}$). In conclusion, this trial showed that a diet supplemented with encapsulated lysine at 2kg/T presented a beneficial effect on feed efficiency and carcass quality of broilers from 0-35 days old compared to a control diet with or without a supplementation of an equivalent level of free lysine.

PS4 - Solution to improve the nutritional value of feed**PS4-020 Effect of low-level calcium and phosphorus diets supplemented with calcium pidolate on broiler body weight and rate of culled birds**B. Iglesias¹, M.V. Charriere¹, V. Fain Binda¹, J. Melo²¹Sección Avicultura, EEA Pergamino, Instituto Nacional de Tecnología Agropecuaria (INTA), Pergamino, Argentina, ²Departamento de Tecnología, Universidad Nacional de Luján (UNLu), Luján, Argentina

Decreasing dietary Ca may improve phosphorous (P) utilization, while an excess of Ca may aggravate a P deficiency. Therefore, different researchers have shown that a moderate reduction in dietary Ca had no deleterious effects on broiler performance. Besides, calcium pidolate (PCa) is known as an ingredient directly promoting the absorption of calcium and indirectly phosphorus. The aim of this study was to evaluate the effect of low-level Ca-P diets with PCa supplementation on broiler body weight and rate of culled birds. A total of 342-day-old male broilers chicks (Cobb-500) were allocated in floor pens in a completely randomized block design (9 replicates/treatment). Pre-starter (1-7 d), starter (8-21 d), grower (22-35 d) and finisher (36-42 d) diets were used for dietary treatments. Control diets (CTRL) were formulated according to requirements used by the industry in South America (0,94-0,63 and 0,49-0,32, for CaT and Pav, respectively). Low Ca and P diets (LCP) were formulated to obtain a 20-36% reduction in total Ca and available P, and no differences in metabolizable energy and four digestible amino acids (Lys, Met+Cys, Thr). PCa (PIDOLin PCa, Dietaxion) was included on-top between 0-21 d at 300 ppm in the LCP diets. Birds were weighed weekly, and the mortality recorded daily. Parametric data were analyzed using ANOVA and non-parametric data through the Chi-square Test. The pen was considered the experimental unit. There were not significant differences ($P>0.05$) in body weight at 21 d and at the end of the experiment. Mortality and culled birds were not statistically significant at the end of the experiment ($P>0.05$), but there was a significant difference between treatments in the rate of culled birds due to leg problems ($P<0.1$), with a lower rate for LCP broilers supplemented with PCa (1.2 vs 2.3%). It can be concluded that total Ca and available P concentrations can be reduced by 20-36% in broiler diets supplemented with PCa to obtain similar body weight and livability results. The use of PCa during 0-21 d could explain the tendency to improve the rate of culled birds due to leg problems.

PS4 - Solution to improve the nutritional value of feed**PS4-021 Effect of lysophospholipids and xylanase supplementation on growth performance in turkeys**I. Somers¹, A. Wealleans¹, D. Scholey², A. Debruslais¹, D. Gonzalez Sanchez¹, E. Burton²¹Kemin Europa N.V., Herentals, Belgium, ²Nottingham Trent University, Brackenhurst Campus, Southwell, United Kingdom

Providing livestock with the best nutrition, whilst maintaining profitability, is still the major challenge facing the feed industry. Xylanase is routinely added to monogastric feed to degrade non-starch polysaccharides. Likewise, lysophospholipid (LPL)-based additives have been found to support the digestion and absorption of various nutrients, however, there is a scarcity of data on the effect of combining xylanase and LPL-based additives on growth performance. The present study was conducted, using a 2 x 2 factorial arrangement, to compare the effects of a LPL-based additive containing LPL, monoglycerides and a synthetic emulsifier (LEX) and xylanase supplementation on growth performance in turkeys. BUT 6 mixed-sex turkeys (4 per pen and 12 replicates per treatment) were obtained from a commercial hatchery and were assigned to four treatments: (1) negative control diet (NC), (2) NC diet with LEX (500 g/T), (3) NC diet with xylanase at a concentration of 45,000 U/kg (15 g/t XygestTM HT) and (4) NC diet supplemented with LEX (500 g/T) and xylanase (45,000 U/kg). Water and diets based on wheat, soybean meal, full-fat soybeans and corn were available ad libitum. Body weight and feed intake were measured weekly from 0 to 35 days, and body weight gain and feed conversion ratio (FCR) were calculated. No interactions were observed for any of the performance parameters. LEX improved ($p<0.05$) the final average body weight of turkeys by almost 100 g compared to the control (1629g vs 1530g). Feed intake was not significantly affected by any of the treatments. During the total trial period, a trend ($p=0.09$) was observed for the effect of xylanase on FCR. Xylanase reduced the FCR ($p=0.26$) compared to the control (1.50 and 1.57, respectively). Additionally, the FCR was further improved in the treatment receiving the combination of xylanase and LEX, 10 points less than the control ($p=0.09$). The results of this study indicate that supplementation of LEX and xylanase, alone or in combination, induced positive performance effects compared to the control; however, the response of the combination of LEX and xylanase did not show an additive effect. Further studies on the mode of action of LEX and xylanase are needed to expand the knowledge on the combined use of these additives in turkeys.

*PS4 - Solution to improve the nutritional value of feed***PS4-022** Effect of oil quality and supplemental vitamin E source on the performance and vitamin E retention in the liver and breast meat of 21-day-old broiler chickensS. Adedokun¹, R. Adefioye¹, M. Lindemann¹, M. Ford¹, A. Pescatore¹, M. Azain²¹Department of Animal and Food Sciences, University of Kentucky, Lexington, KY, United States, ²Department of Animal Sciences, University of Georgia, Athens, GA, United States

The objective of this study was to evaluate the effect of oil quality and supplemental vitamin E (VE, α -tocopheryl acetate or mixed-tocopherol at 150 ppm) on birds' performance, liver and breast meat VE content in 21-day-old broiler chickens fed corn-soybean meal-based diets. The experiment used 252-day-old male by-product Cobb chicks in a randomized complete block design consisting of 6 treatments with 7 replicate cages of 6 birds per cage. Fresh soy oil (peroxidized value [PV] = 9 meqO₂/kg) was oxidized by continuous heating at 95 degrees Celsius for 84 hours resulting in PV of 148 meqO₂/kg. Liver and breast meat samples from 3 birds/pen were freeze-dried and ground prior to VE analysis. Data were analyzed as a randomized complete block design using the GLM procedure of SAS. In addition to the determination of the treatment effect, specific orthogonal contrasts were used to compare predetermined contrasts. The effect of oil quality and VE supplementation on performance was not significant across the 6 treatments. However, within the first 7 days, supplemental VE (α -tocopheryl acetate) resulted in higher ($P < 0.05$) feed intake compared to birds on diet with fresh soy oil but without supplemental VE. Diet containing fresh oil and mixed-tocopherol resulted in a decrease ($P < 0.05$) in feed intake compared to birds on diet containing fresh oil with supplemental α -tocopheryl acetate during the same period. Liver and breast meat VE retention was influenced by oil quality and VE source. Oxidation of soy oil resulted in a decrease ($P < 0.05$) in the liver (56%) and breast meat (36%) VE levels. Supplementation of VE to the basal diet containing fresh oil with α -tocopheryl acetate resulted in 254% (liver) and 215% (breast meat) increase in VE. These increases were 101% (liver) and 91% (breast meat) for the diets containing oxidized oil without and with mixed tocopherol supplementation. Results from this study showed that both sources of VE, irrespective of oil quality, increased VE deposition in both the liver and the breast meat but α -tocopheryl acetate resulted in higher VE deposition in both tissues.

*PS4 - Solution to improve the nutritional value of feed***PS4-023** Effect of phytase and limestone particle size on performance, eggshell quality, bone mineralization and mineral digestibility in laying hensF. Hervo^{1,2}, M. Létourneau-Montminy¹, B. Méda², M. Duclos², A. Narcy²¹Département des Sciences Animales, Université Laval, Québec city, G1V 0A6, Canada, ²INRAE, Université de Tours, BOA, 37380, Nouzilly, France

The objective of this trial was to investigate the interaction between microbial phytase and limestone particle size (LmPS) in Lohmann Tradition laying hens. Seventy-two hens were used in a randomized complete block design according to a 2 × 2 factorial arrangement to evaluate the effect of two coarse limestone (CL) inclusion, i.e. a mix (MIX) of 75% CL (2-4 mm) and 25% fine particles (FL, <0.5 mm) or 100% FL, in two different basal diets formulated without (MIX0 and FLO) or with 300 FTU of phytase/kg diet (MIX300 and FL300). Diets contained equivalent levels of Ca (3.5%) and aP (0.30%) considering the P equivalency of phytase in MIX300 and FL300 diets. Performance and eggshell quality (eggshell proportion, weight, thickness and breaking strength) were measured from 31 to 35 week of age. At the end of the trial, bone parameters (tibia breaking strength, elasticity and ash), the apparent pre-caecal digestibility (APCD) of P and Ca and the phytic P (PP) disappearance at the ileal level were determined. No differences were observed between treatments on feed intake, feed conversion ratio and bone parameters, confirming the phytase equivalency. Feeding MIX diet increased the eggshell proportion, weight and thickness in the group receiving the diet without phytase (+6.5%, +6.9%, and +4.5%, respectively; Phytase × LmPS, $P < 0.05$) in comparison to group fed FLO diet. Phytic P disappearance at the ileal level was increased with phytase in hens receiving the MIX diet (+30 percentage points; Phytase × LmPS, $P = 0.005$). The APCD of P was reduced in diets with phytase and FL (Phytase × LmPS, $P < 0.001$). The lower availability of P observed when using exclusively FL can be explained by the formation of complexes between Ca and phytic acid within the gastrointestinal tract. Phytase and MIX together increased the APCD of Ca by 7.3 percentage points (Phytase × LmPS, $P < 0.001$) in comparison to FL diet. In conclusion, addition of CL heightens the effect of microbial phytase on P and Ca digestibility, partly by reducing the formation of phytate-Ca complexation.

PS4 - Solution to improve the nutritional value of feed**PS4-024 Effect of wheat, maize, rice or pea in combination with rapeseed meal or soybean concentrate and sunflower meal on broiler chickens' growth**M. Mireaux¹, A. Bertin², C. Regnier², K. Bebin²¹Deltavit, Janzé, France, ²CCPA, Janzé, France

Energy, mainly brought by starch, and crude protein (CP) are the two main nutrients determining broiler performance. Beyond energy and protein levels, their sources can affect their digestibility and metabolic fate in the animal and therefore animal performance. The objective of this study was to evaluate the impact of 4 sources of starch (wheat, corn, rice and pea) and two sources of CP: rapeseed meal (RM) or a combination of soybean protein concentrate and sunflower meal (SPC-SFM) on broiler performance. Ross 308 male broilers (4 per cage, 12 replicates per treatment) were randomly assigned to 8 groups in a four-by-two factorial design with 4 sources of starch and 2 sources of CP. Starter (day 1 to 10), grower (10 to 21) and finisher (21 to 35) diets had similar metabolizable energy, starch, CP (with similar inclusion levels of RM in groups 1 to 4 and of SPC-SFM in groups 5 to 8, adjusted on soybean meal) and digestible essential AA levels. After similar performance in the starter phase, groups receiving SPC-SFM had higher body weight (BW, $P=0.005$) and average daily gain (ADG, $P=0.001$) and lower feed conversion ratio (FCR, $P<0.001$) than groups receiving RM in the grower period. Within CP source, performance was lower with wheat and higher with pea. This was confirmed in finisher and global periods with a positive effect of SPC-SFM over RM on BW (2816 ± 120 vs. 2676 ± 123 respectively), ADG and FCR (1.46 ± 0.03 vs. 1.50 ± 0.04 ; $P<0.001$ for all parameters). Feed consumption was lower with RM than with SPC-SFM. Starch sources also impacted performance with, in the global period, a higher BW and ADG with pea (2786 ± 123 and 78.3 ± 3.5 respectively) than with wheat (2705 ± 106 and 76.0 ± 3.0) or rice (2724 ± 177 and 76.5 ± 5.1 ; $P=0.023$). FCR was optimal with pea (1.46 ± 0.02), intermediate with maize and rice and degraded with wheat (1.51 ± 0.05 ; $P<0.001$). The source of protein had the strongest impact on performance with a positive effect of rapidly degraded CP (in-vitro analysis) from SPC-SFM. To a lesser extent, performance was influenced by starch source, with a strong positive effect of pea. Pea starch is hydrolyzed more slowly than other sources, and also has a high CP content. Wheat leads to degraded performance, possibly due to its fiber content (it had similar starch hydrolysis kinetics to maize). Rapidly digested CP had a positive impact on broiler performance and a slowly hydrolyzed starch source can also improve performance.

PS4 - Solution to improve the nutritional value of feed**PS4-025 Effects of 2 limestone solubilities and 3 calcium levels in diets with a phytase on performance, mineral digestibility, and tibia ash of broilers**C. Kwakernaak¹, Y. Dersjant-Li², V. Lagos¹, L. Marchal², A. bello²¹Schothorst Feed Research, Lelystad, Netherlands, ²Danisco Animal Nutrition & Health, Oegstgeest, Netherlands

Effects of limestone solubility, dietary Ca level and a novel consensus bacterial 6-phytase variant (PhyG) on broiler growth performance, bone ash, and Ca and P digestibility were investigated. Five diets were formulated with 2 limestone sources (high solubility [HSL], 94% or low solubility [LSL], 58% after 5 min at pH3), for a total of 10 experimental treatments. With each limestone, a positive control (PC) starter, grower and finisher diet based on wheat/corn/soybean meal was formulated to meet requirement of retainable P (3.8, 3.5 and 3.1 g/kg, respectively) and total Ca (9.5, 8.5 and 7.5 g/kg, resp.). A negative control (NC) diet was formulated with reduction of retainable P by 1.7 g/kg and total Ca by 3 g/kg vs PC. Three test diets were formulated as the NC with 0 (low), 1.5 g/kg (medium) and 3.0 g/kg (high) added Ca via limestone, and 1500 FTU/kg of PhyG. Per feeding phase diets only differed in limestone, MCP, phytase, and diamol inclusion and were fed as pellets to Ross 308 males from 0-10-20-35 days of age (6 pens/treatment and 30 birds/pen). Ileal digesta was collected at d20 to determine apparent ileal digestibility (AID) of Ca and P, and tibia ash was measured at d10, 20 and 35. Data were analyzed by 2-way ANOVA using limestone source x diet type as treatment model. Overall mortality was low (3.8%). BWG, FI and FCR 0-35d did not differ among PC and phytase diets but were worse in NC ($P<0.05$). Compared to HSL, the use of LSL ($P<0.05$) resulted in higher AID P (+2.4%) and lower AID Ca (-4.4%). This had no effect on tibia ash at any phase but it increased ($P<0.05$) BWG by 3% (d0-20) and 2% (d0-35). NC had lower ($P<0.05$) tibia ash and AID P than PC and the 3 phytase diets. Among phytase diets, AID P decreased ($P<0.05$; 82, 77, and 71%, for low, medium, and high Ca) and AID Ca also decreased (from 66% to 54%) as dietary Ca level increased. Tibia ash at d20 and 35 was lower ($P<0.05$) at low Ca level compared to medium or high, while BWG 0-20d was higher in low than in high Ca ($P<0.05$ +3%). Compared to PC, total AID P was higher ($P<0.05$) with phytase and low Ca level ($P<0.05$; 3.58 vs. 3.23 g/kg). In conclusion, low Ca content in the phytase diets resulted in best AID P and Ca. However, to maximize tibia ash content, a higher Ca level was needed than to maximize BWG. It is suggested that optimal dietary Ca levels has to be fine-tuned to the conditions in practice which may depend on limestone solubility and likely also on phytase source and dose levels.

PS4 - Solution to improve the nutritional value of feed**PS4-026 Effects of a synergistic blend of trace minerals on the performance and economics of broilers**S. Chee¹, A. Legawa¹, A. Rahajeng¹, V. Maria¹, L. Pineda², K. Sekarlangit², I. Yu², S. van Kuijk²¹PT Malindo Feedmill, Tbk, Jakarta, Indonesia, ²Trouw Nutrition, Amersfoort, Netherlands

Growing environmental concerns about trace mineral (TM) excretion have led to increasing interest in effective alternatives to inorganic TM (ITM) sources. Organic TM (OTM) are effective replacements but are expensive. Recently, an innovative mineral solution (Selko IntelliOpt, IBOP) comprising a synergistic blend of Hydroxychloride (Selko IntelliBond) and OTM (Selko Optimin) was developed. This product consistently delivers highly bioavailable minerals for absorption for optimal animal performance at a reasonable price. This study aims to evaluate the effect of replacing ITM with IBOP on performance, footpad, and the economics of broilers. Male broiler chicks (n=2800) were allocated into 5 treatments with 20 replicates of 28 birds/pen: ITM with 100ppm Zn, 120ppm Mn and 15ppm Cu in the form of sulphates; IBOP-P with 80ppm Zn, 80ppm Mn and 12ppm Cu; IBOP-SD as IBOP-P given during the pre-starter phase, then with 40ppm Zn, 40ppm Mn and 5ppm Cu during the starter-finisher phases; IBOP-F with 40ppm Zn, 40ppm Mn and 6ppm Cu; and IBOP-FH with 20ppm Zn, 20ppm Mn and 3ppm Cu. The experiment was conducted under commercial conditions with high stocking density in a closed housing system. Birds were fed with a pre-starter crumble from d0-10, starter crumbles from d11-21, and finisher pellet from d22-33. The feed consumption, ADG and FCR were measured at the end of each feeding phase. On d33, footpad was assessed and the cost to produce a kilogram liveweight (FC/LW) was calculated. IBOP, irrespective of the inclusion rates, significantly improved broilers' ADG, feed intake, and FCR during the starter phase. Overall, broilers fed with IBOP-F had numerically higher ADG (1.1%, P>0.05), whereas broilers given IBOP-P (1.7 points) and IBOP-SD (3.7 points) had a lower FCR compared with ITM. The mortality rate tended to be lower (1.99%, P=0.08) in broilers fed with IBOP-P and IBOP-SD. Feeding diets with IBOP-P (\$0.710) and IBOP-SD (\$0.699) reduced FC/LW in comparison with ITM (\$0.714). On all parameters measured, the effects of IBOP-F and IBOP-FH were similar to those of ITM. The footpad integrity was not affected by the treatments. In conclusion, the reduced TM usage in the form IBOP can completely replace ITM in broiler diets and can be a strategy to promote sustainable poultry production. IBOP-P and IBOP-SD are cost-effective replacements that can enhance broilers' survival rate and FCR.

PS4 - Solution to improve the nutritional value of feed**PS4-027 Effects of an encapsulated phytogenic and phycogenic solution when used in a diet formulated with or without matrix value on growth performance, intestinal functions, and plasma biomarkers of broiler chickens**S. Ladirat¹, A. Elolimy², M. Shourrap³, M. Madkour²¹NUQO S.A.S, Annecy, France, ²Animal Production Department, National Research Centre, Giza, Egypt, ³Poultry Production Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt

Natural health-promoting solutions are widely used to improve gut health and broiler performance, and occasionally for their nutrient-sparing characteristics that may aid in alleviating high diet costs. The goal of this trial was to study the effects of an encapsulated solution containing a blend of phytogenics (thymol, cinnamaldehyde, eugenol) and phycogenics (*Ascophyllum nodosum*) (NUQO® NEX, NUQO, France) when used in a diet formulated with or without a matrix value on growth performance, intestinal functions, and plasma biomarkers in broiler chickens. Day-old Arbor Acres broilers were randomly allocated to four dietary treatments: 1. Control diet (CO), 2. Energy and protein reduced diet (NC) formulated with the feed additive matrix value: 30 kcal and 0.3% crude protein, 3. CO supplemented with the encapsulated solution (CO-NUQO), and 4. NC supplemented with the encapsulated solution (NC-NUQO). Each group had 10 replicates of 25 birds each. The encapsulated solution was added at 100 g/ton feed during the whole trial period (35 days). Zootechnical parameters were recorded weekly at the pen level, while jejunum tissue samples and blood samples were collected on one bird per pen to assess histology and plasma biomarkers. Data were analysed with SAS software using a one-way ANOVA followed by a Tukey's test. At day 35, NC reduced growth performance compared with CO, although the differences were not significant. NC-NUQO improved FCR compared with NC (P<0.05), and restored growth performance compared with CO. CO-NUQO improved FCR compared with CO (P<0.05). Both NUQO treatments improved jejunum morphology compared with CO and NC, respectively (P<0.05), including muscle layer thickness, villus height and crypt depth. Plasma biomarkers showed a reduction in alanine transaminase, total cholesterol, and low-density lipoprotein cholesterol in both NUQO treatments compared with CO (P<0.05), indicating hepatoprotective effect. Together, the results showed that the supplementation of the encapsulated solution improved intestinal and liver functions that would attribute to better feed efficiency in the diets formulated with or without matrix value. Observed effects may be due to the anti-inflammatory and anti-oxidant properties of the active components and their modulating effects of transient receptor potential vanilloid type 1. Overall, the solution is a promising tool to help poultry operations to either produce more with less or to reduce feed costs.

PS4 - Solution to improve the nutritional value of feed**PS4-028 Effects of dietary microalgae (*Chlorella vulgaris* and *Spirulina platensis*) on eggs' carotenoid content and yolk color intensity**T.D. Panaite¹, M.G. Cornescu¹, N.C. Predescu², M. Sărcilă¹, A.E. Untea¹, I. Vărzaru¹

¹Laboratory of Nutrition and Physiology, National Research-Development Institute for Animal Biology and Nutrition (IBNA), 1 Calea București, Balotesti, 077015, Ilfov, Romania, ²Faculty of Veterinary Medicine, University of Agronomic Sciences and Veterinary Medicine, 105 Splaiul Independentei, 050097 Bucharest, Romania

Yolk colour ranks third amongst egg quality parameters, after freshness and eggshell quality. Therefore, becomes an important task to look for alternatives to improve the nutritional eggs' quality taking into consideration consumers' requirements and purchase preferences. A 8-week feeding trial was conducted on 120 Lohmann Brown layers (38 weeks) assigned randomly to 3 groups (C, E1 and E2) housed in cages (20 replicates x 2 birds/cage) under computer controlled microclimate (16h light/24h; T=23.08±0.98°C; H=66.35±5.68%). All groups were fed corn-soybean meal basal diet (2750 kcal/kg ME; 17.8% CP). Unlike conventional diet (C), the experimental groups were supplemented with 2.0% *Chlorella vulgaris* (E1) and 2.0% *Spirulina platensis* (E2). *Chlorella vulgaris* has a concentration of 5.56 mg/g chlorophyll a; 0.88 mg/g chlorophyll b; 975.21 ppm of lutein+zeaxanthin and 73.29 DPPH% inhibition antioxidant activity, whereas *Spirulina platensis* has a higher content of chlorophyll a (9.06 mg/g), chlorophyll b (1.34 mg/g); a lower content of lutein+zeaxanthin (494.98 ppm) and a higher antioxidant activity (81.27 DPPH% inhibition). These values significantly increased dietary carotenoids concentration of egg yolk. At the end of the experimental period 18 eggs/group (6 yolk samples/group, 3 eggs/sample) were collected for β-carotene, lutein+zeaxanthin, yolk colour (Roche colour fan) and antioxidant capacity assessment. The lutein+zeaxanthin concentration of E1 (11.60 ppm) and E2 (6.84 ppm) groups were highly significant ($p < 0.0001$) compared to C group (3.45 ppm). Beta-carotene concentration of E1 and E2 groups (36.82; 38.26 μg/g) increased significantly ($p < 0.001$) compared to C group (30.77 μg/g). The antioxidant capacity increased highly significant ($p < 0.0001$) of E1 and E2 groups (25.14; 28.16 DPPH% inhibition) compared to C group (16.84). The yolk colour intensity of E1 and E2 groups was significantly higher ($p < 0.05$) compared to C group. The microalgae (*Chlorella* and *Spirulina*) significantly ($p < 0.001$) increased yolk colour (8.11; 11.06 vs. 4.06 value), and the yolk redness a* color parameter (3.14; 4.94 vs. 1.25 value). Boiling the eggs for 10 minutes, significantly ($p < 0.001$) increased the yellowness b* color parameter of E1 and E2 groups (33.14; 32.16 value) compared to C group (17.39 value). The results of the study showed that laying hens' dietary supplementation with *Chlorella* and *Spirulina* enriched significantly the carotenoids content and the yolk color of the egg.

PS4 - Solution to improve the nutritional value of feed**PS4-029 Effects of dietary sugar beet pulp incorporation along with AMEn reduction in broilers at two levels of crude protein content**P. Sakkas¹, K. Bebin², F. Richard²

¹DELTA VIT, CCPA Group, Janzé, France, ²CCPA Group, Janzé, France

Dietary inclusion of low levels of fibre rich ingredients such as sugar beet pulp (SBP) at specific stages of growth, promote intestinal function and may improve protein and energy digestibility and performance. Herein, we investigated whether low levels of SBP inclusion (2.5%) at intermediate stages of growth (d10-30) would improve performance in broilers offered high or low levels of CP (d0-42). 840 Ross 308-day-old male chicks were allocated to 36 pens and were offered starter (d0-10), grower1 (d10-21), grower2 (d21-d30) and finisher diets (d30-42) containing either high or low levels of CP (HP vs LP; 1 % dif.) with the same limiting digestible EAA content (lys, TSAA, Thr, Trp, Val). During the grower1 and 2 periods birds were offered diets containing SBP or not (control). SBP diets had less AMEn (-80kcal) according to previously reported improvements in energy digestibility at the same level of dietary incorporation. Performance was measured at the end of each production stage. The incidence and severity of footpad dermatitis (FPD) was assessed at d21 and d35 in 90 birds/treatment and carcass yield (%) at d42 in 48 birds/treatment. Offering HP in comparison to LP diets consistently improved ($P < 0.05$) ADG and FCR across all periods (121 vs 117 g/day and 1.74 vs 1.78 for d0-42, respectively), increased carcass and breast yield and decreased abdominal fat content, but deteriorated FPD ($P < 0.05$). Offering SBP diets decreased ADFI ($P < 0.05$) and penalised FCR and ADG ($P < 0.01$) during the grower1 period. During the grower2 period SBP birds had increased ADFI and ADG ($P < 0.001$), but higher FCR ($P < 0.05$). Effects of SBP diets were not present following feed ingredient removal and restoration of AMEn levels during the finisher period. During the overall production period SBP diets increased FCR (1.54 vs 1.56, $P < 0.05$), without affecting ADG and ADFI and increased carcass and breast yield ($P < 0.05$). In conclusion, addition of SBP with a parallel reduction of AMEn initially penalised performance (d10-21) and although compensatory growth was observed at later stages growth (d21-30), overall feed efficiency was reduced, independently of CP level. Effects did not persist after re-alimentation of SBP fed birds to control diets. The positive effects on carcass parameters present an economic interest and future trials should further investigate the timing and duration of SBP incorporation and the extent of AMEn reduction.

PS4 - Solution to improve the nutritional value of feed**PS4-030 Effects of limestone origin and a new phytase on performance, nutrient digestibility and tibia ash of conventional and slow growing broiler breeds**C. Kwakernaak¹, C. Walk², V. Lagos¹, L. Levrouw³, A. Smith²¹Schothorst Feed Research, Lelystad, Netherlands, ²DSM Nutritional Products Ltd, Heanor, United Kingdom, ³DSM Nutritional Products N.V., Deinze, Belgium

A 5-20d study was performed to evaluate interactions among 2 limestone (LS) origins (UK or France), 4 increasing levels of a novel 6-phytase, and 2 broiler breeds, conventional (Ross 308; RB) or slow growing (Hubbard JA757; HB) on growth performance, nutrient digestibility, and tibia ash of male broilers. For each breed and LS source, a starter (5-14d) and grower (14-20d) negative control (NC) diet based on wheat/corn/soybean meal and including an NSP enzyme was formulated. The starter HB diet contained 20 kcal/kg AME, 0.4 g/kg dLys, and 0.1 g/kg P less than the RB diet (AME = 2900 kcal/kg, dLys = 11.5 g/kg, total Ca = 6.8 g/kg, retainable P (rP) = 1.9 g/kg). The grower HB diet contained 25 kcal/kg AME, 0.6 g/kg dLys, and 0.1 g/kg P less than the RB diet (AME = 2975 kcal/kg, dLys = 10.9 g/kg, total Ca = 6.3 g/kg, rP = 1.8 g/kg). Phytase was added at 0, 300, 900 and 2700 FYT/kg to the NC diets, for a total of 16 experimental treatments. For each breed and phase, diets only differed in LS, phytase, and diamol inclusion and were fed as pellets to 6 pens/treatment (34 RB or 36 HB birds/pen). A commercial diet was fed from 0-5d and performance was evaluated from 5-20d. Tibia ash content was measured at d14 (4 birds/pen) and the apparent ileal digestibility (AID) of CP, Ca, and P was determined at d20 (10 RB or 12 HB birds/pen). Data were analyzed by ANOVA with breed × LS × phytase level in the model. No 3- or 2-way interactions were observed and there was no effect of LS origin on broiler performance, tibia ash, or AID of nutrients. Tibia ash was not influenced by breed, but body weight gain (BWG) was higher (P<0.05) and feed conversion ratio (FCR) lower (P<0.05) in RB compared to HB. The AID of nutrients was higher (P<0.05) in RB than in HB (+2.4% Ca, +2.5% P, +1.8% CP). Overall, phytase inclusion increased (P<0.05) tibia ash and improved (P<0.05) broiler performance. Phytase addition from 300 to 2700 FYT improved (P<0.05) BWG by 7% and FCR by 2%. The AID of P increased (P<0.05) with each phytase dose from 48 to 80%. The AID of Ca increased (P<0.05) from 48 to 55% and the AID of CP increased (P<0.05) from 76 to 79% with increasing doses of phytase. In conclusion, positive effects of phytase on performance, tibia ash, and nutrient digestibility are independent of breed and LS origin. Further research is needed to evaluate the effect of broiler breed on nutrient digestibility.

PS4 - Solution to improve the nutritional value of feed**PS4-031 Effects of replacing inorganic trace minerals with glycines on production parameters of older broiler breeder hens during a heat stress period**S. Rothstein¹, S. Mashahiri², M.A.K. Torshizi², F. Shariatmadari², R.V. Torshizi², H. Ahmadi²¹Biochem Zusatzstoffe Handels- und Produktionsgesellschaft mbH, Lohne i. Old., Germany, ²Tarbiat Modares University, Department of Animal and Poultry Science, Tehran, Iran (Islamic Republic of)

1. Aim: This study evaluated the effects of a 50 % replacement of inorganic trace minerals (ITMs) by glycines (GLYs) on production parameters and eggshell quality in 50-65-week-old broiler breeder hens during a 6-week heat stress period. 2. Methods: In total, 240 Arbor Acres broiler breeder hens (initial BW: 4.01±0.15 kg) aged 50 weeks were divided into 2 treatments, with 12 replicates of 10 hens each, housed in cages. Experimental treatments were as follows: 1. ITM (premix with 80 ppm Zn, 10 ppm Cu, 80 ppm Mn and 50 ppm Fe-Sulfates), and 2. GLY (50 % of ITM replaced with Zn, Cu, Mn and Fe-Glycines as organically bound trace minerals (E.C.O.Trace®, Biochem)). The duration of the study was 15 weeks, with a six-week heat stress period (Ø 31±0.53°C and 35 % humidity) from week 60-65. Birds consumed all daily feed (160g/cage/day from 50-60 wks and 155g/cage/day until the end) and did not differ between treatments. Egg production, hatchability, embryonic mortality, and measures of eggshell quality (eggshell strength and thickness) were measured during the heat stress period. Statistical analysis was performed by one-way ANOVA and Tukey Test (post hoc) by using Minitab software ver. 18.0, differences were considered significant if p<0.05. 3. Results: Throughout the heat stress period, egg production was higher for group GLY, with greater differences during week 65 (Hen week egg production: ITM 46.99 % and GLY 52.38 %). The GLY group realized significantly higher hatchability (% of fertile eggs) in week 65 compared to the ITM group. Moreover, those birds on ITM had higher embryonic mortality throughout the entire heat stress period compared to the GLY group. A significant improvement in eggshell quality in week 65 was noted in the GLY group for both eggshell thickness (ITM: 0.25 mm, GLY: 0.32 mm) and eggshell breaking strength (ITM: 2.33 kg, GLY: 3.01 kg) compared to the ITM group (p<0.05). 4. Conclusion: The results of this study indicate that 50 % replacement of ITMs by Glycines in feed can efficiently support older broiler breeder hens during periods of heat stress as evidenced by improvements in production parameters, significant improvements in average shell thickness and egg strength, and decreased embryo mortality compared to diets consisting of ITM only.

*PS4 - Solution to improve the nutritional value of feed***PS4-032** Efficacy of a biosynthetic bacterial 6-phytase on performance, bone mineralization and precaecal digestibility of phosphorus in broilers fed normal- or high-phytate dietsM. Jlali¹, M. Ceccantini², B. Yavuz², S. Ozbek¹, E. Devillard¹¹Adisseo France SAS, Commentry, France, ²Adisseo France SAS, Antony, France

The aim of this study was to investigate the effects of a new bacterial 6-phytase on growth performance, bone mineralization and precaecal digestibility (pcd) of P in broilers fed corn-soybean meal-based diets (ME = 3000 kcal/kg; CP = 20.85%, Ca = 0.70%, avP = 0.25%) with varying levels of phytate-phosphorus (PP) during the first 21 days of age. A total of 1,600 one-day-old male Ross 308 chicks were allocated into 8 treatments in a randomized complete block design with a 2 x 4 factorial arrangement of increasing levels of dietary PP (0.25% or 0.43%) by increasing the incorporation of rice bran and doses of phytase (0, 500, 1,000 or 2,000 FTU/kg diet). All treatments had 8 replicate pens with 25 birds per pen each. Experimental diets (as pellets) and water were offered ad libitum throughout the experimental period. Body weight (BW), BW gain, feed intake (FI), and feed conversion ratio (FCR) were measured. On day 22, tibia samples were collected for tibia ash content determination. In addition, precaecal ileal digesta samples were collected for the determination of pcd of P. Increasing dietary PP level decreased ($P < 0.0001$) final BW, BW gain, FI, tibia ash content and pcd of P and increased FCR. Regardless of dietary PP level, increasing phytase dose from 0 to 2,000 FTU/kg linearly ($P < 0.0001$) increased the final BW (1,191 g vs 1,120 g), BW gain (1,146 g vs 1,075 g) and FI (1,340 g vs 1,296 g). Phytase dose quadratically decreased ($P = 0.04$) the FCR from 1.21 to 1.17 and increased ($P = 0.02$) tibia ash content from 1.168 g to 1.391 g and pcd of P from 47.6% to 77.2%. A significant interaction ($P = 0.01$) was observed between phytate level and phytase dose on precaecal digestible P content. Depending on its dose and dietary PP level, the addition of this new bacterial 6-phytase in broilers diets can release up to 0.247% points of digestible P. In conclusion, dietary PP impaired growth performance, bone mineralization and digestibility of P while phytase supplementation counteracted these negative responses.

*PS4 - Solution to improve the nutritional value of feed***PS4-033** Efficacy of a new biosynthetic 6-phytase added at 500 FTU/kg diet in broilers from 1 to 35 days of age: data from four independent performance trialsM. Jlali¹, C. Hincelin², B. Yavuz², S. Ozbek¹, M. Ceccantini², A. Preynat², E. Devillard¹¹Adisseo France SAS, Commentry, France, ²Adisseo France SAS, Antony, France

Four broiler performance studies were carried out in four different facilities to evaluate the efficacy of a novel bacterial 6-phytase added at 500 FTU/kg diet on growth performance of broilers fed diets reduced in available phosphorus (avP) and total calcium (Ca). Design was the same for all studies, with three treatments: positive control (PC) diet formulated to meet or exceed the requirements of birds, negative control (NC) diet reduced similarly by 0.15% units in avP and Ca, and the NC diet supplemented with phytase (NC + Phytase) at 500 FTU/kg diet from one to 35 days of age. Body weight (BW) and feed intake were measured at 21 and 35 days of age, and average daily gain (ADG), average daily feed intake (ADFI), feed conversion ratio (FCR), body weight gain-corrected FCR (FCRc) and mortality were calculated for the global experimental period. In addition, tibia ash content and precaecal digestibility of P (pcdP) were measured at 21 days of age. The P and Ca deficiency in the NC diet resulted in a lower ($P < 0.001$) final BW (-6.3%), ADFI (-5.8%) and ADG (-6.2%) leading to a higher FCRc (+2.0%, $P < 0.001$) compared with the PC diet. Compared to birds fed PC diet, tibia ash content was reduced ($P < 0.01$) by 4.0% unit in broilers fed NC diet. The supplementation of NC diet with phytase improved ($P < 0.001$) the final BW (+7.9%), ADFI (+7.3%), ADG (+8.1%), and FCRc (-2.8%). Phytase addition also increased ($P < 0.001$) the tibia ash and pcdP by 4.4 and 11.1% unit, respectively, in comparison to NC diet. These performance parameters as well as tibia ash and P content were comparable to or better than the positive control diet. The results indicate that broiler diets could be lowered similarly by 0.15% units in avP and Ca by using the new bacterial 6-phytase at 500 FTU/kg diet.

*PS4 - Solution to improve the nutritional value of feed***PS4-034** Efficacy of a total substitution of synthetic choline chloride by a natural polyherbal-based product in broilers feedsC. Sol¹, M. Dewez¹, J. González¹¹Nuprox, Etoy, Switzerland

The aim of this trial was to validate the efficacy of a natural polyherbal-based product (PH), rich in phosphatidylcholine and other phospholipids, to totally replace choline chloride 50% (CC) in broiler feeds at a ratio of 1:5.7 (PH:CC 50% w/w) inclusion rate. The study was conducted at Zootests' research facility, Ploufragan (France). One-day-old male broiler chicks (1170, Ross 308) were allocated to 3 treatments with 13 replicates each, with a density at set of 22 chicks/m², ground floor with wood shavings, with feed and water ad libitum. Feeding program was: starter 2844 kcal/kg and 217 g/kg crude protein (CP), grower 2928 kcal/kg and 200.2 g/kg CP, finisher 2999 kcal/kg and 186.1 g/kg CP. The treatments consisted of a control group (CON, with no supplementation of either PH or CC), a group supplemented with CC (CC50%, at 720g/tn in starter feed, 600g/tn in grower feed and 480g/tn in finisher feed) and a group supplemented with PH (PH, at 125g/tn in starter feed, 105g/tn in grower feed and 85g/tn in finisher feed). The trial duration was 42 days. Fixed effects were tested by ANOVA using SAS. There were no statistical differences among treatments in final body weight (BW, 3172g, 3186g and 3188g for CON, CC50% and PH, respectively) and cumulative feed intake (FI, 115.2 g/b/d, 114.3 g/b/d and 114 g/b/d, for CON, CC50% and PH, respectively) at 42 d of age. Although FI did not differ ($p < 0.05$), broilers fed the control feed, not supplemented with any source of choline, required to consume more feed to reach a similar BW than the supplemented groups. Consequently, the feed conversion ratio (FCR) was higher for the control group than the other treatments (1.550a, 1.528b and 1.528b, for CON, CC and PH, respectively; $p < 0.05$). The FCR of broilers fed either PH or CC was not different ($p > 0.05$). This study demonstrates that a natural polyherbal-based product can fully replace choline chloride 50% in broilers diets without any significant impact on zootechnical performance.

*PS4 - Solution to improve the nutritional value of feed***PS4-035** Efficacy of some herbal methionine formulations on nutrient metabolizability and gut health status of broilersS. Bypanahalli¹, S. Mysore², G. Bekkere², H. Gangavadi², B. Ganguly³¹Veterinary College, Karnataka Veterinary Animal and Fisheries Sciences University, Bengaluru, India, ²Veterinary College, Karnataka Veterinary Animal and Fisheries Sciences University, Hassan, Karnataka State, India, ³Ayurvet Pvt Ltd., Baddi, Solan, Himachal Pradesh, India

Methionine is the first limiting amino acid in practical type corn-soybean meal-based broiler diets and its supplementation has become mandatory. The polyherbal formulations (Methiorep, AV/BMP/65, AV/BMP/37B, AV/BMP/37W) were assessed as a partial replacer for synthetic methionine (DL-Met) on metabolizability of various nutrients and gut health status of broiler birds. A basal diet without supplemental methionine served as control (T0) and test diets were prepared supplementing basal diet with DL-Met @ 0.2% (T1), DL-Met + Methiorep (T2), DL-Met + AV/BMP/65 (T3, administered through water), DL-Met + AV/BMP/37B (T4) and DL-Met + AV/BMP/37W (T5) in 60:40 ratio and included @ 0.2%. Each diet prepared for starter (1-14 days), grower (15-28 days) and finisher phases (29-42 days) was assigned six replicates of 8 chicks each (day-old, straight run, Cobb). A metabolism trial conducted during last three days of the experiment indicated that the metabolizability of crude protein in diets with DL-Met + AV/BMP/37B (T4) and DL-Met + AV/BMP/37W (T5) was higher ($P < 0.001$) than the control (T0) and DL-Met group (T1). However, metabolizability of dry matter and organic matter remained similar among all the groups. The morphometry of intestinal segments collected on 42nd day of experiment indicated that the duodenal villi length ($P = 0.051$) was higher in birds fed diets supplemented with DL-Met (T2) and DL-Met+Methiorep (T3) compared to control (T0) while villi length of jejunum and ileum, crypt depth of duodenum, jejunum and ileum were comparable to each other groups. It was concluded that the polyherbal preparations can replace 40% of the synthetic methionine (DL-Met) in the broiler diets with better crude protein metabolizability and duodenal villi length of broilers.

*PS4 - Solution to improve the nutritional value of feed***PS4-036** Emulsifier effect on performance of broilers fed diets with different metabolizable energy levelsC. de Wildt¹, O. Lemâle¹¹Adisseo NL B.V., Raamsdonksveer, Netherlands

Energy is the most expensive nutritional parameter of feed. Fat is an important source of energy for animals, generally being highly digestible and well absorbed. However, fat digestibility can still be improved by using certain feed additives like emulsifiers. Consequently, fat levels and feed costs can be reduced while increasing the sustainability of meat production. This study proposes to demonstrate the effect of a specific and efficient emulsifier, based on hydrolysed lecithin with a high lysophospholipids (LPL) content (FRA® LeciMax Dry, containing 6% of LPL), applied in a broiler diet. For this objective, eight hundred and sixty-four (864), male day-old chicks (Cobb 500) were randomly allocated to 6 treatments with 9 replications in a randomized complete block design experiment using 16 chicks per pen as an experimental unit. A practical corn-soybean meal-based diet was formulated and used as the positive control diet (PC), presenting 3008, 3086 and 3167 kcal/kg and 6.38, 7.61 and 9.10% crude fat for the starter, grower and finisher phase, respectively. Two negative control diets were formulated (NC1, NC2) with reduced dietary ME by 75 and 100 kcal/kg, respectively. Three additional treatment groups received one of three control diets with the emulsifier at 500 g/Mt on top. Feed and water were provided ad libitum. Pen weight and feed intake were measured at 0, 10, 28, 35 and 42 days of age. Body weight gain, feed intake, feed conversion ratio (FCR) and liveability were calculated. Dead and culled birds were monitored and recorded daily. All data were subjected to an ANOVA analysis (SAS software version 9.4, 2015). Significance was considered at P<0.05 levels. No significant differences were found at intermediate ages. At 42 days of age, diets supplemented with the emulsifier when compared to diets not supplemented presented a significant better body weight gain for PC (3442g to 3529g) and for NC2 (3420g to 3482g). For NC1, the emulsifier did not improve weight gain, but did show a significant improvement in FCR (1.576 to 1.558), and partially recovered the FCR compared to PC (1.536). In conclusion, using this emulsifier based on hydrolysed lecithin improves weight gain on top of diets higher than 5% in fat content, or in diets reduced in ME by 100 kcal, while improving the FCR when ME is decreased by 75 Kcal/kg. Additionally, total feed cost per kg gain was significantly (p<0.0035) reduced with the emulsifier from THB\$ 28.66 to THB\$ 27.96 (-2.50%).

*PS4 - Solution to improve the nutritional value of feed***PS4-037** Evaluation of pellet microstructure particle size as consequence of secondary grinding on pellet quality and gizzard development in broilersM.A. Ebbing¹, N. Yacoubi², M. Gierus¹¹Institute of Animal Nutrition, Livestock Products, and Nutrition Physiology, Vienna, Austria, ²Evonik Operations GmbH, Hanau- Wolfgang, Germany

Corn is used in broiler diets worldwide. To shape its particle size (PS) for pelleting and subsequent broiler needs, it must be ground, as is for soybean meal (SBM). Hammer or roller mills are normally used in commercial feed mills for grinding; however, the grinding continues during the entire process, known as secondary grinding. Thus, the objective of this study was to evaluate the intensity of secondary grinding, pellet durability index (PDI) and gizzard weight of broilers (total 864 with 24 birds/pen, 6 pens/treatment) fed standard corn-soybean diets with the major ingredients (corn and SBM) ground together in 3 average PS: 0.8, 1.2, and 1.6 mm using a hammer mill or a roller mill. Grower and finisher diet, mills and conditioning were used as replications, n=6 (2 diets, 2 mill types and 2 conditionings). These items were not considered as experimental factors. The ground ingredients were mixed to the other ingredients, conditioned and then pelleted using or not an expander prior to pelleting. Samples were taken immediately after mixing and finished pellets immediately after cooling. Mash diets were sieved using the dry method and the pellets by wet sieving and results shown as Q3 values, exposing the size that 90, 50 and 10% of particles pass through the different sieves tower. The PS for treatment 0.8, 1.2, and 1.6 were for 10, 50 and 90%, respectively: 0.313, 0.820, and 1.742 mm; 0.366, 1.081, and 2.270 mm; 0.395, 1.241, and 2.829 mm, being the average (50%) significantly different between themselves (P < 0.001). PS after pelleting was significantly reduced (P < 0.001), being 0.053, 0.408, and 1.512 for the 0.8 treatment, 0.050, 0.413, and 1.641 for treatment 1.2, and 0.050, 0.531, and 2.226 for treatment 1.6, representing a reduction of 49.7, 38.2 and 42.8% respectively. After mixing the average particles were different between the treatments, however, after pelleting the difference was just between the 0.8 and 1.6 groups. However, the pellet PDI was not affected by PS (P = 0.055), being in average 83.6%. The gizzard weight follows the results obtained in the pellet PS, being 1.02, 1.06, and 1.10% relative to live body weight, respectively for treatments 0.8, 1.2, and 1.6, being the treatments 0.8 and 1.6 significantly different (P = 0.02). The results showed that the secondary grinding happened, and the resulted pellet microstructure still have a positive impact in gizzard development, being important the adopting of coarse grinding at the mill step in the feed processing line.

*PS4 - Solution to improve the nutritional value of feed***PS4-038** Evaluation the nutrient composition and protein quality of different soybean varieties

N. Such¹, L. Pál¹, Á. Bartos¹, L. Wágner¹, M.A. Rawash^{1,2}, Á. Mazólaki³, P. Strifler¹, K.G. Tewelde¹, K. Dublec¹

¹Hungarian University of Agriculture and Life Sciences, Keszthely, Hungary, ²Regional Center for Feed and Food, Agricultural Research Center, Giza, Egypt, ³Agrofeed Ltd., Győr, Hungary

The main goal of this research was to determine the variance of the chemical composition of non-GMO soybean seed samples, selected in the Agricultural Research Centre, in Martonvásár, Hungary. Sixty-eight soybean samples of different varieties were used and their crude protein, crude fat, crude fibre, NDF, ADF, crude ash, starch, amino acid and trypsin inhibitor activity (TIA) were analysed with the official methods. The variance of the nutrients was evaluated with the coefficient of variation (CV). Pearson's correlation was used to find interactions between the different nutrients. The protein quality of the seeds was also determined. In this case the question was, how constant is the essential amino acid composition of soybean protein, depending on the change of the protein content of the seed. The calculation was carried out in this case with linear regression between the essential amino acid content of protein (g/100g protein) and the crude protein content of the seed. The averages of the measured parameters were: c. protein: 38.01%, C. fat: 18.35%, c. fibre: 5.21%, NDF: 11.72%, ADF: 6.19%, c. ash: 5.40%, starch: 4.88%. Among the nutrients the fibre fractions (CV%: 9.22-15.6), methionine (CV%: 8.63), phenylalanine (CV%: 8.36), histidine (CV%: 8.08) and TIA (CV%: 48.56) showed the highest variance. Significant positive correlation was found between fat and TIA content, while negative correlation existed between crude fat and crude fibre, crude protein and crude fat, crude protein and TIA. The essential amino acid contents of the seed increase parallel with the crude protein content. However, the relative ratio of amino acids in the protein is not constant. We found that the lysine and threonine content of the soybean protein is not affected by the change in the c. protein. However, the ratio of methionine and valine in the protein decrease significantly with increasing crude protein content of the seed. It could result inaccuracy if the amino acid composition of soybean is predicted from the crude protein content, using constant amino acid ratios. This work was supported by the Hungarian Government and the European Union, with the co-funding of the European Regional Development Fund in the frame of Széchenyi 2020 Programme GINOP-2.3.2.-15-2016-00029 project.

*PS4 - Solution to improve the nutritional value of feed***PS4-039** Feed cost optimization and gut health improvement by dietary incorporation of multi-enzyme product in commercial broilers

P. Das¹, Y. Bashir¹, V. Shelke¹, C. Raju¹, T. K^{1,1}

¹Kemin Industries South Asia Pvt Ltd, Chennai- 600058, India

An increase in the cost of conventional energy and protein sources, i.e., maize and soya led to profitability reduction for broiler producers across South Asia. It led broiler producers to search for alternatives to maize and soya. However, the inclusion of alternate protein and energy sources may lead to performance reduction possibly because of higher presence of certain anti-nutritional factors like non-starch polysaccharides (NSPs), phytate, protease inhibitors, tannins, etc. Exogenous enzymes like Multi-NSPases and Multiproteases help take care of various negative aspects of lower digestibility and increase nutrient utilization. A study was conducted to assess the productive performance and gut health (studies of lesion scoring for dysbacteriosis & coccidiosis as per standard guidelines) of broilers by dietary incorporation of a multi-enzyme product (MEP). MEP is a unique combination of multi-NSPase and Multiprotease enzymes embedded in a matrix of lysophospholipids. The diet contained standard conventional and alternate energy (Bajra and Deoiled Rice Bran) and protein sources (Meat and Bone Meal & Mustard Deoiled cake), maintaining nutrient specifications as per Vencobb-430 standards. A total of 600-day-old commercial broilers were divided into three groups, a positive control (PC), a negative control (NC- containing conventional & alternate ingredients) with a reduction of pre-determined digestible amino acids (7.5%) and metabolizable energy (150 kcal/kg), and a treatment group with the addition of MEP at 500g to the NC. Each dietary group had 10 replicates with 20 birds per replicate. MEP treated group had shown a statistically significant ($P \leq 0.05$) improvement in body weight at 90 g with an improved feed conversion ratio (FCR) of 8 points over NC and comparable to PC diet. Gut health improvement was noticed in MEP treated group as assessed by intestinal lesion scoring conducted on 3 birds from each group for dysbacteriosis and coccidiosis. Mortality was lowest in the MEP-treated group with a higher European efficiency factor (EEF) and lowest broiler production cost generating a better return on investment. This study revealed that the MEP helped maintain the productive performance over the positive control with better economic returns and improved gut health. The better performance of the MEP may be attributed to better digestion and absorption of nutrients with reduced microbial fermentation in the lower gut

*PS4 - Solution to improve the nutritional value of feed***PS4-040** Grain moisture at harvest and drying temperature impact the non-starch polysaccharides content of four corn varieties

J. Cabanas-Ojeda¹, N. Mejia-Abaunza¹, P.A. Lozano-Cruz¹, M. Ali¹, G.A. Gomes², E.O. Oviedo-Rondón¹

¹Prestage Department of Poultry Science, North Carolina State University, Raleigh, NC, United States, ²AB Vista, Plantation, FL, United States

Non-starch polysaccharide (NSP) content varies with corn genetics, agronomic conditions, and post-harvest practices. These variations represent a risk of increased viscosity in the digesta of broilers and consequently impair nutrient utilization. This effect could combine chemical changes due to plant maturity and moisture content at harvest (MH). The effects of MH and drying temperatures (DT) on the NSP profile have not been evaluated. Therefore, this study aimed to evaluate the effects of MH on the NSP composition of four corn varieties (CV) dried at two temperatures. Seeds from four commercial yellow dent CVs were obtained and planted in four plot fields within one mile under similar soil types. Hybrids used were DEKALB® 6205, 6208, 6869, and 6357. Standard agronomic practices were used to minimize variability in results due to crop management. Kernel moisture was evaluated twice weekly in the final stage of plant maturation. Samples from each CV were obtained with 34, 28, 22, and 16% grain MH. Shelled kernel samples were dried in an air-forced oven at 35 or 120°C to obtain corn grains with moisture near 13% for storage. Kernel moisture was measured before and after drying using a portable moisture tester. Post-drying kernels were evaluated for protein solubility index (PSI), vitreousness, and NSP. Data were analyzed in a 4x2x4 factorial arrangement of treatments in a randomized design using a three-way ANOVA, and the means were separated by Tukey's HSD test. No three-way interaction effects were detected for NSP content ($P>0.05$). However, interaction effects ($P<0.001$) between MH and CV were observed for insoluble arabinose, xylose, and total NSP. Corn with 22% MH presented the lowest arabinose, xylose, and total NSP content, while there was a higher total NSP content at 28% MH. An interaction between MH and DT was also detected ($P<0.05$) for insoluble arabinose, xylose, and PSI. 120°C decreased PSI by 33.9, 29.3, 27.2, and 20.7% compared to 35°C at 34, 28, 22, and 16% MH, respectively. Corn with 16% MH presented the highest vitreousness ($P<0.05$). In conclusion, MH and DT affected the NSP content. Total NSP increased more than 20% points in higher MH corn (28 and 34%) compared to 22% MH, which presented the lowest total NSP content. Drying at 35°C had higher total NSP content when MH was lower (16 and 22%). However, when MH was higher (28 and 34%), total NSP was higher in 120°C DT. Lower DT had higher PSI and 16% MH had the highest vitreousness values.

*PS4 - Solution to improve the nutritional value of feed***PS4-041** Grape polyphenols can replace synthetic vitamin E under standard and challenging formulations

C. Sol¹, F. Horta¹, M. Dewez¹, J. González¹

¹Nuproxa, Etoy, Switzerland

Polyphenols work as antioxidants by quenching free radicals, chelating metal ions that induce the production of free radicals and by increasing the activity of antioxidant enzymes like SOD, CAT and GPx. The aim of this study was to evaluate the capacity of a natural product based on dry grape extracts (*Vitis Vinifera* spp. *Vinifera*) which contain high levels of polyphenols and proanthocyanidins with high antioxidant capacity, to partially or totally replace synthetic vitamin E (VE) in broilers fed with a diet with high levels of polyunsaturated fatty acids, Fe and metabolizable energy (ME). The study was conducted with the research service of ZOOTEEST, Ploufragan, and within a commercial barn (GAEC de La Ville Geste, Geste 22640). One thousand- and twenty-day-old ROSS-308 chicks (100% males) were weighed and randomly distributed among 60 pens (17 chicks/pen) and 6 treatments (T). Treatments T1 and T4 were control diets supplemented with 50 mg/kg of VE. In T2 and T5, 50% of the VE was replaced with 2.3 mg/kg of grape polyphenols (GP) and in T3 and T6, 100% of the VE was replaced with 4.6 mg/kg of GP. The replacement ratio was 1:11 (GP:VE) on a weight basis, based on results from previous studies (Dewez et al., 2022). T4 to T6 were higher in ME and contained 5% of linseed oil and 0.2% of FeSO₄ to increase the oxidative stress in the birds (challenged feeds). The trial lasted 42 days. Broilers fed the challenged feeds (T4 to T6) achieved a lower body weight (BW) at 42 days, nevertheless, the only significant difference ($P<0.05$) was observed between T1 and T3 compared to T6 (2.72a, 2.71ab, 2.74a, 2.62ab, 2.62ab and 2.57b in kg, for T1, T2, T3, T4, T5, and T6, respectively). Within the type of feed, no differences were observed among treatments. The lower BW observed in birds fed the challenged feed was a consequence of a reduction in feed intake. The feed conversion ratio (FCR) was improved ($P<0.05$) in the birds fed the challenged diet, likely due to the higher ME in these feeds (1.67a, 1.66a, 1.66a, 1.63b, 1.63b, 1.64b, for T1, T2, T3, T4, T5, and T6, respectively). Among the type of diets, no differences were observed between the different treatments. Overall, results show no differences in performance of broilers supplemented with synthetic vitamin E or grape extract, either with partial or full replacement. The grape extract can partially or totally replace synthetic vitamin E with a 1:11 ratio, without compromising zootechnical performance.

PS4 - Solution to improve the nutritional value of feed**PS4-042 Growth performance and gut response of broiler chickens fed diets supplemented with a grape pomace extract**

A. Trocino¹, M. Boskovic Cabrol¹, F. Bordignon¹, M. Birolo¹, A. Pascual Guzmán¹, G. Radaelli², C. Ballarin², G. Xiccato¹

¹Department of Agronomy, Food, Natural Resources, Animal and Environment (DAFNAE), University of Padova, Padova, Italy, ²Department of Comparative Biomedicine and Nutrition, University of Padova, Padova, Italy

During the last decade, interest in dietary supplementation in animal feeding with extracts originating from wine by-products has grown, mainly due to the antioxidant properties and the potential immune response stimulation in animals of the polyphenolic compounds they contain. Therefore, this study aimed to evaluate how the dietary supplementation with polyphenols from grape pomace (0 mg/kg, 250 mg/kg, 500 mg/kg, and 1000 mg/kg) affected growth performance of 560 female Ross broiler chickens from hatching to 41 d of age, and jejunum gut morphology at different ages (12, 23, and 34 d). The dietary supplementation with 1000 mg/kg grape pomace polyphenols resulted in significantly lower body weight ($P < 0.01$) and daily weight gain ($P < 0.01$) compared to the control diet and the diets with 250 and 500 mg/kg polyphenols. The addition of grape pomace extract did not affect feed intake at a significant level ($P > 0.05$), even though it was numerically the lowest in chickens fed the highest supplementation level (86.8 g/d, 87.1 g/d, 88.5 g/d and 85.1 g/d in pens fed diets at 0 mg/kg, 250 mg/kg, 500 mg/kg, and 1000 mg/kg). On the other hand, the supplementation with 500 mg/kg and 1000 mg/kg polyphenols significantly increased feed conversion ratio ($P < 0.01$) compared to the control diet or the diet with 250 mg/kg. Regarding gut morphological analysis, jejunum villi height was higher ($P < 0.01$) in chickens fed the diet containing 500 mg/kg polyphenols compared to the ones fed the other diets. Additionally, villi height significantly increased over time ($P < 0.01$), and significant interactions between age and diet were recorded showing that differences among dietary treatments increased over time ($P < 0.01$). In conclusion, a different response was observed depending on the dietary supplementation level of polyphenols which has been associated by other authors to the effects on feed intake level and the immune response (stimulating or suppressive effects). In detail, in the present study, no effect of the lowest dose was recorded; villi height increased when chickens were fed the intermediate dose (500 mg/kg) while growth performance was depressed with the highest inclusion level (1000 mg/kg). Funding: The research grant of M. Boskovic Cabrol is supported by the DEMyo project (No 101063055) funded by the European Commission under the HORIZON-MSCA-2021-PF-01 call.

PS4 - Solution to improve the nutritional value of feed**PS4-043 Gut health improvements with dietary β -mannanase in meat producing broiler chickens**

H. Corentin¹

¹Elanco, Sèvres, France

β -Mannans are antinutritional factors found in most feed ingredients. β -Mannans induce wasteful innate response leading to gut inflammation which in turn reduce poultry productivity. The study objective was to evaluate, in field conditions, the effect of 1,4- β -mannanase (Hemicell™ HT Dry, Elanco Animal Health) addition on digestive parameters and zootechnical parameters in poultry. Fifty-one lots of broilers, raised in field conditions (1,143,545 animals), were allocated to 2 treatments groups. The animals were fed wheat, maize and soybean-based diets. Xylanase and phytase were used in the diet. T1: Control receiving a standard diet (n=27), T2: as T1 less 60 kcal ME/kg + 330 g enzyme / ton of feed ie 52800 IU / ton of feed (n=24). Zootechnical performances (ADG, Body weight and FCR) were recorded. For each lot, autopsies of 5 chickens were performed by veterinarian between 23 and 25 days of age. Gizzard erosion, intestinal tone, water content, mucus, cellular sloughing were evaluated. No significance difference between T1 and T2 was observed for zootechnical parameters. No significant difference was reported for intestinal tone and mucus between T1 and T2. Gizzard erosion, water content, cellular sloughing were lower for T2 in comparison to T1. In this study, the use of a β -Mannanase in field conditions allowed to maintain zootechnical performance while decreasing the energy expenses in feed. Improvement of digestive tract health indicators demonstrate improvement of intestinal health of poultry with addition of dietary β -Mannanase.

*PS4 - Solution to improve the nutritional value of feed***PS4-044** Impact of lowering the levels of Ca and P in feed on broiler performance, Ca and P digestibility, bone strength and bone ashL. Nollet¹, J. Michiels²¹Huvepharma NV, Antwerp, Belgium, ²Ghent University, Ghent, Belgium

The aim of this study was to evaluate the impact of lowering levels of Ca and P on broiler performance and bone formation. Three times 6 pens with 24 male Ross 308 male per pen were fed a feed containing a phytase (OptiPhos® Plus) at 1000 FTU/kg (1.76 g/kg available P (aP) matrix value) and an endo-1,4- beta-xylanase (Hostazym® X) was added on top (1500 EPU/kg). Starter feed (day 1-10) contained 22.0 % crude protein (CP), 1.23 % dig Lys, 2925 kcal/kg ME broiler, 0.85 % Ca and 0.45 % available P (aP). Grower feed (day 10-21) contained 20.3 % CP, 1.11 % dig Lys, 3000 kcal/kg ME broiler, 0.70 % Ca and 0.36 % aP. The finisher feed (day 21-35) contained 18.7 % CP, 0.98 % dig Lys, 3050 kcal/kg ME broiler, 0.60 % Ca and 0.30 % aP. In addition, a second feeding strategy was initiated by reducing the Ca and aP level in all feeds with 2.0 g and 1.5 g, respectively so that the grower and finisher feed did not contain any added inorganic P. Technical performance was measured for every feeding phase. At day 21, the tibiae from 3 birds per pen were removed and analysed for bone strength. Afterwards, the 3 tibiae were pooled into 1 sample for the determination of ash after fat extraction and drying (a total of 9 samples per treatment). At day 35, a mixed faecal sample was taken from 5 birds per pen for the determination of Ca and P digestibility. The technical performance was high (close to 2.7 kg bird weight at 35 days with an FCR of 1.4). Lowering the Ca and P level in the feed did not have a negative effect on performance. On the contrary, it increased end weight by 22 g (from 2675 to 2697 g). However, the bone ash lowered slightly from 47.5 to 46.8 %, although not significantly. Similarly, bone strength decreased from 548 to 532 N but also not significantly. On the contrary, lowering the Ca and aP levels in the feed significantly increased the Ca digestibility (51.7 to 66.4 %) and P digestibility (77.3 to 83.2 %). Based on feed intake and analysed Ca and P levels in the feed, this yielded a significantly lower dig. Ca uptake (0.49 vs 0.62 g per bird per day) but increased the dig. P intake significantly from 0.53 to 0.57 g per bird per day. The date of this trial demonstrated that lowering the Ca and P levels in a diet that contains a phytase and and NSPase enzyme, does not have a negative impact on performance, increases Ca and P digestibility, and has a limited impact on bone ash and bone strength.

*PS4 - Solution to improve the nutritional value of feed***PS4-045** Impact of lysolecithin, monoglyceride and emulsifier combinations on emulsion stability and rate of lipid hydrolysisR. Spaepen¹, S. Ravichandran¹, K. Bierinckx¹, A.L. Wealleans¹¹Kemin Europa NV, Herentals, Belgium

Use of lysolecithin has been shown to improve the ability of birds to absorb lipids; this can be further enhanced by combination with synthetic emulsifiers and monoglycerides (ME), but little research is available on the effect of lysolecithin dose. Therefore, in vitro experiments were conducted to assess the impact of increasing lysolecithin concentration and synthetic emulsifier and monoglyceride inclusion on emulsion stability and lipid hydrolysis. Products used: a dose series of soybean lysolecithin/rapeseed oil mixes was created (0, 25, 35, 45, 55, and 65% lysolecithin). Lysolecithin dilutions were then either tested alone (LPL-) or with the inclusion of ME at 8.85% (LPL+). Emulsion stability: 1g LPL was added to 49g rapeseed oil and 50mL brine solution (15% NaCl and blue colorant) and mixed for 30s at 25,000 RPM. The homogenous mixture was transferred to a measuring cylinder and stability was followed for 120 min. Hydrolysis: 1g LPL, 49g rapeseed oil and 150g simulated intestinal fluid were mixed for 30s at 25,000 RPM, then placed in a 40°C water bath and stirred at 700 RPM. Next 4g of porcine pancreatin was added to start hydrolysis. At each timepoint, a 2mL sample was pipetted into 40mL 80°C neutralized ethanol solution and titrated with 0.1M KOH solution till equivalence point was reached. The level of formed free fatty acid (FFA, expressed in % oleic acid) was calculated. Emulsion stability declined over time, though there were significant interactions with lysolecithin dose and ME addition (P<0.01). Repeated measures analysis revealed a significant, positive non-linear relationship between lysolecithin concentration and emulsion stability in both LPL- and LPL+. However, there was a significant interaction between lysolecithin dose and LPL+/-, with the strength of the response to increasing lysolecithin dose reduced in LPL+ treatments (P<0.0001). LPL+ treatments created significantly more stable emulsions than LPL- at the same lysolecithin concentrations (P<0.05). LPL level also significantly increased release of FFA (P<0.0001), with the difference in release between LPL concentrations increasing with time (P=0.0009). The results showed that addition of supplemental ME was effective at increasing emulsion stability. Further research is required to elucidate the effect ME on rates of hydrolysis. Further work should investigate the applicability of these findings to the absorption of a range of dietary lipids, both in vitro and in vivo.

PS4 - Solution to improve the nutritional value of feed**PS4-046 Improvement of intestinal health in broiler chickens fed diets supplemented with β -mannanase: updated meta-analysis study**K. Poulsen¹, N. Mathlouthi², J. Borgen³¹Elanco Animal Health, 2018 Antwerp, Belgium, ²Elanco Animal Health, 1073 Montplaisir, Tunisia, ³Elanco Animal Health, Greenfield, IN 46140, United States

The β -mannans are an intensely antinutritive fiber found in common broiler feed and they are degraded by β -mannanase. The effect on intestinal health of using β -mannanase was evaluated in a meta-analysis of lesion scoring data from 28 field trials completed in 13 countries from Europe and the Middle East. The primary endpoint of interest was the Intestinal Integrity Index, and secondary endpoints of interest were the incidence of the lesions from conditions closely associated with intestinal health. The data available for all endpoints included the mean treatment difference from each trial when comparing broilers not supplemented with β -mannanase to the broilers supplemented with β -mannanase. The meta-analysis demonstrated that the addition of β -mannanase to commercial broiler diets improved several conditions related to intestinal health and bird welfare. Notably, β -mannanase significantly reduced ($P < 0.05$) the prevalence of excessive cellular sloughing by 7.49 %-points, poor intestinal tone by 6.68 %-points, excessive feed passage by 3.20 %-points, abnormally thin intestines by 4.03 %-points, litter eater or abnormal presence of litter in the gizzard by 1.99 % and gizzard erosion by 8.45 %-points. β -Mannanase also reduced ($P < 0.05$) the average lesion score for pododermatitis. The general improvement of intestinal health was also evident in the intestinal integrity index, which increased by 1.04 units in flocks fed diets with β -mannanase ($P < 0.001$). The analysis therefore suggests that β -mannan fibers from feed adversely affect a broad range of intestinal conditions, and consequently that the use of β -mannanase may improve intestinal health and welfare of commercial broiler flocks.

PS4 - Solution to improve the nutritional value of feed**PS4-047 Inclusion of a Bacillus-based probiotic in the diets of nutritionally challenged broilers**F. Goodarzi Boroojeni¹, Y. Duangnumsaewang¹, D. Jozefiak², D. Sandvang³, J. Zentek¹¹Institute of Animal Nutrition, Freie Universität Berlin, Berlin, Germany, ²Department of Animal Nutrition, Poznań University of Life Sciences, Wołyńska 33, 60-637, Poznań, Poland, ³Chr. Hansen A/S, Hoersholm, Denmark

This study evaluated the effects of different inclusion levels of a 3-strain Bacillus-based probiotic (BP, a B. amyloliquefaciens and two B. subtilis strains) in diets with different concentration of rye (RY) on growth and nutrient digestibility of broilers. Using a 3 × 3 factorial arrangement, 9 isocaloric and isonitrogenous diets were produced by adding 0, 1.2 × 10⁶ and 1.2 × 10⁷ CFU/g of BP to broiler diets (wheat-rye-soybean) containing 0, 20% and 40% of RY. In total, 2,160 one-day-old broilers were randomly allocated to 216 pens. Performance variables were recorded weekly and the apparent ileal digestibility (AID) of nutrients was measured at d 35. Data were subjected to ANOVA using the GLM procedure. Inclusion of BP in diets increased body weight gain (BWG) during the grower period (d 7-21) but had no impact on the rest of performance variables, ileal (IV) and fecal viscosity (FV) as well as ileal flow of galactosamine (as a marker for mucin) and footpad dermatitis score (FPD). Adding RY to diets impaired BWG during the finisher (d 22-35) and entire experimental period, while birds feeding 40% RY diets showed lowest BWG during the starter (d 1-7) and grower period ($P \leq 0.05$). Feed conversion ratio (FCR) of birds feeding 40% RY diet was higher than those feeding 0 and 20% RY diets during the starter and finisher period ($P \leq 0.05$) however, birds receiving diets with RY showed higher FCR than those feeding diets with no RY during the grower period ($P \leq 0.05$). At d 35, broilers in 0 and 40% RY groups showed the lowest and highest FCR, respectively ($P \leq 0.05$). Increasing RY level in diets, increased IV (0% < 20% < 40%) and decreased (0% > 20% > 40%) AID of crude protein, P and all the amino acids. Broilers receiving 40% RY diets showed higher FV and lower AID of fat and Ca than other two groups ($P \leq 0.05$). However, adding RY to the diets led to higher FPD and higher ileal flow of mucin (mucus loss) compared with broilers feeding diets with no RY ($P \leq 0.05$). Adding BP to diets impaired AID of P, while birds receiving diets with highest BP content showed highest AID of Met and Cys ($P \leq 0.05$). There was no interaction between BP and RY for all the variables measured. In conclusion, adding rye to broilers diets increased digesta viscosity which led to higher rate of mucus loss, higher FPD, lower nutrients digestibility and finally worse growth performance. However, adding high level of BP to broilers diets could improve AID of Met and Cys.

*PS4 - Solution to improve the nutritional value of feed***PS4-048** Influence of feeding whole wheat on gut development, energy digestion and hygienic aspects in growing broiler chickenK. Schuh-von-Graevenitz¹, J. Trautwein², D. Feuerstein², G. Dusel¹¹University of Applied Sciences Bingen / Institut Feed Research Bingen, Bingen, Germany, ²BASF SE, Ludwigshafen, Germany

The addition of whole wheat to industrial broiler feed can provide an economic benefit to farms by reducing feed costs. Moreover, both feed and drinking water are potential entry pathways for undesirable microorganisms, especially under unfavorable hygienic conditions. To evaluate the effects on nutrient digestibility, gut characteristics, hygiene parameters and broiler performance, a digestibility trial was conducted in a 2-factorial design: pH of drinking water (pH 7 without additive, pH 4.0 or 4.5 achieved with a buffered mixture of formic and propionic acid) and gradual addition of whole wheat (pure pelleted broiler diet (C), C combined with a gradual addition from 0% in week 1 to 20% in week 5 of untreated whole wheat (WW) or WW treated with 0.5% sodium formate (WWT)). The design resulted in 9 treatments, and the trial was conducted with 216 male one-day-old Ross 308 broiler housed in 12 cages per treatment for 35 days. The apparent total tract digestibility (n=6 cages per treatment) of gross energy was increased for WWT (78.2%) compared to C (76.5%) at week 3 (+10% whole wheat; $P < 0.05$) and for WWT (77.7%) compared to C (75.3%) at week 5 (+20% whole wheat; $P < 0.05$). Organ evaluation at day 35 (n=6 birds per treatment) showed that the addition of whole wheat (WW and WWT) was reflected in a higher empty gizzard weight and higher gizzard to body weight ratio compared with C ($P < 0.001$). Further, a 3-point scoring system was used to evaluate the effects of treatment on proventriculus morphology on day 35. Treatments WW and WWT were reflected by a stronger wall thickness of the proventriculus and more visible glands. At the highest level (20%), the addition of whole wheat to the diets reduced both gross energy and crude protein per kg of feed by up to 0.2 MJ and 19 g, respectively. Performance data collected during the digestibility study showed an increased ($P < 0.001$) daily weight gain during the whole trial period in C (85 g) compared to the treatment groups WW (81 g) and WWT (81 g), reflecting the energy and protein dilution by the wheat addition. The addition of organic acids to both drinking water and whole wheat resulted in a reduction of the microbial load in the respective medium. Feeding whole wheat had a positive effect on morphology of the avian stomach. The addition of sodium formate to whole wheat improved not only the hygiene condition but also increased energy digestibility of the feed.

*PS4 - Solution to improve the nutritional value of feed***PS4-049** Interaction between feeding regimen, NSPase enzyme and particle size of barley in pelleted diets on the performance of broiler chickensK. Itani¹, M. Ahmad¹, A. Smith², B. Svihus¹¹Faculty of Biosciences, Department of Animal and Aquacultural Sciences, Norwegian University of Life Sciences, Ås, Norway, ²DSM Nutritional Products Ltd, Heanor Gate Industrial Estate, Heanor, Derbyshire, United Kingdom

The effect of feeding regimen, NSPase addition, diet structure, and their interaction on the performance, ileal digestibility and digestive organ characteristics of broilers were studied in this experiment. A total of 1408 one-day-old Ross 308 male broilers had either ad libitum (ADL) or intermittent (INT) access to barley-based pelleted diets, with or without NSPase, and with main ingredients either finely (2mm) or coarsely (6mm) ground, thus constituting a 2x2x2 factorial arrangement with eight replications of 22 birds per treatment. Formic acid (85%) was sprayed on the pellets at 0.7% to reduce diet pH to around 4.7 which is optimal for the exogenous NSPase and TiO₂ was used as an indigestible marker. The birds were allocated to 64 floor pens bedded with wood shavings and kept on a starter diet until d10 and were exposed to 18h of light with a darkness period from 10pm to 4am. From d11, half of the birds had ADL with 8h darkness and 16h access to feed from 2am to 3am and 7am to 10pm. The remaining INT fed birds had access to feed also from 2am to 3am and with 1h of feeding followed by 3h of no feed (by lifting the feeders) between 7am to 10pm, so in total, 6h of feeding. Birds and feed were weighed on d11 and 32. Coarse grinding reduced ($p=0.04$) the pH of gizzard contents, increased gizzard relative weight (RW) and contents weight ($p<0.05$). INT feeding increased gizzard RW compared to ADL feeding. Under ADL feeding, NSPase improved starch digestibility in the coarsely ground diet only, resulting in an interaction ($p=0.049$) between grinding and enzyme. NSPase improved protein digestibility with fine grinding under INT feeding only, causing a 3-way interaction between feeding regimen, structure and NSPase addition. Although ADL group gained more weight, they still had a similar FCR compared to the INT group. NSPase increased ($p=0.02$) weight gain and tended to improve it ($p=0.06$) in INT fed birds only. Fine grinding with NSPase improved FCR only with INT feeding ($p=0.03$) resulting in an interaction between feeding regimen and enzyme addition. Under INT feeding, NSPase improved ($p=0.04$) FCR in fine ground diets only. In conclusion, finely ground barley in pelleted diets responded better to an NSPase enzyme than coarse ground, particularly under INT feeding which is known to increase feed retention in the crop and is hypothesised to improve the catalytic activity of exogenous enzymes.

PS4 - Solution to improve the nutritional value of feed**PS4-050 Interactive effect of xylanase or stimbiotic with dietary grain source on growth performance and digesta viscosity of broiler chicks**M. Toghyani^{2,1}, S. MacElline^{2,1}, G. González-Ortiz³, M. Bedford³, S. Liu^{2,1}*¹Poultry Research Foundation, The University of Sydney, Sydney, NSW 2570, Australia, ²School of Life and Environmental Sciences, Faculty of Science, The University of Sydney, Sydney, NSW 2006, Australia, ³AB Vista, Marlborough, Wiltshire SN8 4AN, United Kingdom*

This study was performed to determine the interactive effect of an exogenous xylanase or a stimbiotic (xylanase + functional fibre) combined with different dietary grain sources on performance and small intestine viscosity in broiler chicks. Based on a completely randomized design, 48 floor pens were allocated to 6 dietary treatments with 8 replicate pens of 27 birds (off-sex male Ross 308) per treatment, employing a 2 x 3 factorial arrangement. The experimental factors included two sources of cereal grains (corn or wheat-barley) with three additives as non, 100 g/t of xylanase or stimbiotic. Birds were offered starter (1-13 d), grower (13-28 d), and finisher (28-42 d) diets. On day 27, 3 birds per replicate were euthanised and the content of duodenum, jejunum and ileum were gently squeezed out and pooled per replicate pen for viscosity analyses. Final bodyweight (42 d) was not affected by the experimental factors or their interactions ($P > 0.05$). There was an interactive effect of grain and additive on feed intake (FI; 1-42 d), where the stimbiotic decreased FI in birds fed wheat-barley-based diets but had no effect on FI in birds fed corn-based diets ($P < 0.05$). The extent of improvement in feed conversion ratio (FCR) in response to stimbiotic and xylanase was greater for the birds fed the wheat-barley-based diets than the birds fed corn-based diets, resulting in an interaction between grain and additive ($P < 0.05$). However, correcting FCR values to the bodyweight of the control birds with no xylanase, this interaction disappeared, and birds fed the diets supplemented with stimbiotic or xylanase, irrespective of grain source, exhibited lower FCR than the control birds ($P < 0.05$). Birds fed the wheat-barley-based diets obtained higher digesta viscosity across all the small intestine segments than the birds fed corn-based diets ($P < 0.05$). There was no significant effect of additives on duodenal or jejunal digesta viscosity. An interaction between grain and additives resulted in reduced ileal digesta viscosity with stimbiotic and xylanase in birds fed wheat-barley-based diets but not the corn-based diets ($P < 0.05$). In conclusion, reduced ileal digesta viscosity in birds fed wheat-barley-based diets to some extent could account for improved FCR in response to xylanase and stimbiotic. The FCR improvement in birds fed corn-based diets in response to the additives might be due to hydrolyzation of arabinoxylans and improved diet's energy digestibility.

PS4 - Solution to improve the nutritional value of feed**PS4-051 Modelling tool to fine-tune the nutrients requirements for laying hens in cage and cage-free**N. T. Ferreira¹*¹TN Innovation, Trouw Nutrition, Puslinch, Canada*

The demand for mathematical tools to help decision-making about nutritional requirements more accurately has been discussed for a long time. Thinking of a decision-making tool that improves the static nutritional recommendation tables, a mechanistic model was developed to calculate these requirements using target performance. A model was developed based on the one proposed by Emmans and Fisher (1986) to calculate the energy and amino acid requirements through factorial equations. The model's inputs are body weight (BW), egg weight (EW), egg production (EP), and feed intake (FI) to adjust the concentration of nutrient recommendations. Two different scenarios (High - HEM and Low - LEM Egg Mass) were simulated, changing EP and EW from recommended performances by the genetic guideline (Hy-Line Brown) for 30-week birds in cage and cage-free. The predicted nutritional levels and those recommended by the guideline were based on 1.9 kg BW and 98 g of FI. The inputted data for HEM were 98% EP and 61g of EW, and for LEM, 96% EP and 59g EW, for cage and cage-free. The recommendation of energy (ME - (kcal/b/d) and lysine (SID Lys - %) by the Hy-Line Brown guideline are 315-330 kcal/bird/d and 0.84%, respectively. The recommendations for birds in cage simulations were 317 kcal/b/d and 0.833% Lys for HEM and 310 kcal/b/d and 0.802% Lys for LEM. In the cage-free simulations, the simulated requirements were 334kcal/b/d and 0.833% Lys for HEM and 326kcal/b/d and 0.802% Lys for LEM. The amino acid requirement is mainly determined by daily egg mass production, and daily feed intake, so different requirements were observed among different performances but not among types of systems. However, the variation in energy requirement is observed in all simulations. Comparing the same performances and different systems was observed higher energy requirement to the cage-free due to energy requirements for activity. This modelling tool allows nutritionists to design flexible and dynamic feeding programs, making better decisions to adapt to the specific need of each scenario, improving performance, increasing profitability, and reducing the environmental impact of animal production. Consequently, this model can take precision animal nutrition further by using a wide range of real-time information.

PS4 - Solution to improve the nutritional value of feed**PS4-052 Multi-component protease modulates the gut microbiome and enhances performance in broiler birds partially fed with an unconventional protein source**K. Venkatasubramanian¹, K. Manohar¹, R. Mani¹, T. Kaliaperumal¹¹Kemin Industries South Asia Pvt. Ltd. , Chennai , India

Soybean meal is increasingly being replaced with cheaper proteinaceous ingredients because of its cost fluctuations. Most of the alternate protein sources such as meat and bone meal (MBM), mustard de-oiled cake (MDOC), de-oiled rice bran (DORB), etc. are poorly digestible and create a conducive environment for pathogenic microbes in the gut which in turn affects the poultry performance. In vitro studies on the combination of coated tri proteases (Acid, neutral and alkaline proteases) with intrinsically heat-stable papain (from Papaya) showed improvement in protein digestibility for unconventional protein substrates. The current study focused on understanding the modulation of the gut microbiome of broiler birds supplemented with a combination of proteases. A 42-day trial was conducted in the Cobb 430 breed with 360 one-day-old chicks divided into 5 groups, 6 replicates with 12 birds per replicate. A corn-soya diet was partially replaced with unconventional raw materials such as MBM, MDOC, and DORB. The test groups include positive control with a normal diet, a negative control diet reformulated with 8% amino acid replacement, and 3 treatment groups with papain, coated tri proteases, and a tetra proteases combination (coated tri protease + Papain). Ileal digesta samples were collected on day 42 for apparent ileal digestibility and metagenomic analysis. The tetra protease combination showed significant improvement in body weight gain 85g ($P < 0.05$), and feed conversion ratio (FCR, 6 points difference, $P < 0.05$) in comparison to the negative control group. Apparent ileal digestibility of amino acids was also observed to be improved in the tetra protease combination group with the average digestibility of essential amino acids observed to be higher by 52.7% than the negative control. In the metagenomic analysis, all the protease-supplemented groups showed an improved abundance of firmicutes while the negative control group had nearly 10% of harmful proteobacteria. At the genus level, *Lactobacillus salivarius* was observed in a higher proportion (>20%) in the tetra protease combination group which is known to improve performance and gut health. In summary, improved protein digestibility by tetra protease combination has potentiated the beneficial modification in the intestinal microbiota in broiler birds fed with non-conventional protein sources which resulted in better performance.

PS4 - Solution to improve the nutritional value of feed**PS4-053 Novel β -mannanase improves dietary nutrient digestibility in fattening poultry**A. Fickler¹, M. Francesch², G. Pasquali¹, P. Ader¹¹BASF SE, Ludwigshafen, Germany, ²IRTA-Animal Nutrition, E-43120 Constantí, Spain

Production costs of fattening poultry have increased significantly due to the increase of feed ingredient prices. Plant-derived feed ingredients contain non-starch polysaccharides (NSPs), which are known to be antinutritive factors that can decrease nutrient utilization and impair animal performance. In soybean meal, one of the main NSPs is β -mannan. For that, we evaluated in two studies if a novel β -mannanase can increase the dietary nutrient digestibility in turkeys and broilers and thereby help to improve the profitability of animal protein production. In the first study, female turkeys (Aviagen B.U.T. Premium) were allocated to 3 treatments with 12 replicates of 4 poult per treatment. From day 1-14, poults received a commercial diet and from day 14 poults received the experimental corn-soy diets. Dietary treatments were Control (C), C + mannanase 800 TMU/kg and C + mannanase 1200 TMU/kg. The apparent total tract digestibility (ATTD) of dry matter (DM) and the apparent metabolizable energy (AME) of the diets were measured from 21-24 d, using titanium dioxide as a marker. Ileal digesta were collected and pooled per cage on day 25 to measure the apparent ileal digestibility (AID) of nitrogen and amino acids. In the second study, male broilers (Ross 308) were allocated to 2 treatments with 9 replicates of 2 broilers per treatment. From day 1-7, broiler received a commercial diet. From day 7 on, broilers received the experimental corn-wheat-soy diets Control (C) and C + mannanase 800 TMU/kg. On days 18-20, excreta samples were collected for the ATTD of nitrogen and the AMEn measurement. Moreover, ileal digesta viscosity was measured on day 20. In turkeys, mannanase supplementation at both dosages (800 and 1200 TMU/kg) increased ($p < 0.001$) the ATTD of DM and the AME relative to C diet (DM: over +5.4%, AME: over +122 kcal/kg). Mannanase also increased the AID of nitrogen by over +2% ($p < 0.05$) and 10/17 of the analyzed amino acids ($P < 0.05$). In broilers, mannanase supplementation increased the AMEn (+98 kcal/kg) ($p < 0.01$) and tended to increase the ATTD of nitrogen (+2.4 percent points) ($p = 0.122$). The ileal digesta viscosity was decreased from 4.77 to 3.61 mPa.s by the addition of the mannanase to the diet ($p = 0.051$). Dietary β -mannanase can improve the digestibility of the diet in both turkeys and broilers fed different types of diets. Thus, β -mannanase can help to improve animal protein production's profitability.

PS4 - Solution to improve the nutritional value of feed**PS4-054 Reduction of anti-nutritional effects of β -mannan and energy sparing with addition of dietary β -mannanase in meat turkeys**C. Herisson¹¹Elanco, Sèvres, France

β -Mannans induce wasteful innate response that reduce poultry productivity. The objective of this study was to evaluate the zootechnical interest of dietary β -mannanase in meat turkeys under controlled farming conditions. A total of 256 males BUT Premium Aviagen turkey were allotted to one of three treatments with eight replicates in a completely randomized design at 1 day of age. Three dietary treatments with different metabolizable energy levels were applied. The energy level of the control diet (T1) was formulated according to Aviagen® recommendations with five phases feeding program with wheat-corn-soya based diets (T1: 2780-3120 kcal/kg). The treatments 2 (T2) and 3 (T3) were formulated at 120kcal/kg under Aviagen recommendations for energy. T3 received dietary β -mannanase supplementation at the level of 52,800 UI/kg. A Xylanase was used on all diets, valued at 105 kcal ME/kg. All dietary treatment were iso-nitrogenous. The feeding trial was conducted for 126 days, covering a period from November to February. Feed intake, body weight and conversion ratio were recorded at 126 days of age. Feed consumptions were higher for T2 and T3 (low energy density treatments) than T1 ($p < 0.05$). Body weights were not significantly different between T1 and T3. However, body weight was significantly improved for T3 in comparison to T2 ($p < 0.05$). Dietary treatments significantly influenced feed conversion ratio; T1 (2.29) < T3 (2.36) < T2 (2.42) ($p < 0.001$). The difference resulting from a drop in energy of 120 kcal/kg leads to a difference of 13 points in feed conversion ratio (T2-T1). The gain allowed by Hemicell™ HT by degrading β -mannans is 6 points in feed conversion ratio (difference between T2-T3). These 6 points are worth: $(6 \times 120) / 13 = 55.4$ kcal. Thus, β -mannanase addition permit a minimal energy uplift estimated at 55.4 kcal/kg in a highly challenged context. These results enhance anti-nutritional effect of β -mannan on turkey and benefice of β -mannanase addition for energy sparing and relocation to animal growth.

PS4 - Solution to improve the nutritional value of feed**PS4-055 Revealing the physical restrictions of caecal influx to improve caecal fibre fermentation in broilers: effect of insoluble fibre particle size and age**P. Vanderghinste¹, A. Bautil¹, M. Bedford², G. Gonzalez Ortiz², C. Courtin¹¹KU Leuven, Leuven, Belgium, ²AB Vista, Marlborough, United Kingdom

The microbial fermentation of dietary fibre in the caeca of broilers has been shown to improve broiler health and performance. The enhancement of this fermentation seems an important step towards antibiotic-free broiler production. However, most of this fibre fraction may be too large to enter the caeca. The conditions for caecal influx have yet to be completely understood. Hence, the caecal influx mechanisms of digesta need further investigation to improve our understanding of fibre fermentation. This study aimed to determine the physical limitations of caecal digesta influx with broiler age. To this end, a broiler trial using 210 male 1-d-old chicks (Ross 308) with four dietary treatments, including 1% of different sizes of cellulose beads (Cellets® of 100, 200, 300, 700 μ m), was set up. Caecal development (anatomy & microscopy), caecal digesta particle size distribution (laser diffraction) and the caecal influx of beads were evaluated after euthanasia of 18, 12, 6 and 6 chicks per treatment on respectively d 8, 15, 25 and 36. Caecal lobe weight, length and the diameter of the caecal entrance strongly increased with age ($P < 0.05$). The D50 (median particle size) of the caecal digesta also increased with age from 5 μ m (d 8) to 20 μ m (d 36) ($P < 0.05$). These digesta particle sizes were much smaller in the caeca than in the ileum (400 μ m) at all ages, illustrating the strong impact of the caecal filtering mechanism. Sections of the caecal entrance showed that the actual caecal opening was decreased compared to the measured outer diameter due to the presence of villous structures. This may explain the difference between the caecal digesta D50 (5 - 20 μ m) and the larger caecal opening (500 - 1,000 μ m) that was measured. Remarkably, cellulose beads of all sizes (100 - 700 μ m) were found in the caeca at every broiler age, which seems to contradict the caecal digesta D50 values. However, microscopic quantification estimates showed that only a low fraction (2-10%) of beads present in the ileum also entered the caeca. These results show that caecal influx is strongly age-dependent and that the particle size that can enter may increase with age. To increase the influx of insoluble fibre particles into the caeca, extensive particle size reduction ($< 20 \mu$ m) may be required. An improved understanding in this research area can provide new guidelines for feed and fibre modification to enhance caecal fibre fermentation and consequently improve broiler health and performance.

PS4 - Solution to improve the nutritional value of feed**PS4-056 Serum biochemical profile of laying hens fed diets with functional fibers and xylanase**

D.A. Cordeiro¹, N.F. de Oliveira¹, I.C. Fernandes Filho^{1,2}, L.A. Duarte^{1,2}, T.L. Amaral^{1,2}, A.B. de Brito³, J.H. Stringhini^{1,2}

¹Universidade Federal de Goiás, Goiania, Brazil, ²CNPq Agency, Brasilia, Brazil, ³ABVista LATAM, Sao Paulo, Brazil

This study aimed to evaluate the effect of supplementation of a xylanase associated with fermentable oligosaccharides (FO - XOS) in commercial laying hens diets fed from the 33rd to the 48th week of age on serum biochemical profile. 320 Hy-Line W-80 laying hens were allocated in four treatments, arranged in 10 replicates of 80 birds each, in a completely randomized design. The experimental diets were: Positive control; Negative control (reduction in nutritional density of xylanase); Negative control + xylanase; Negative control + xylanase and FO - XOS. Blood (5.0 mL) were collected from the wings' brachial vein of 24 birds at the 48th week of age, one per replicate. The variables obtained were uric acid (mg/dL), albumin (g/dL), total protein (g/dL), total calcium (mg/dL), total phosphorus (mg/dL), total cholesterol (g/dL), glycose (mg/dL), total triglycerides (mg/dL), aspartate amino transferase (IU/L) and alkaline phosphatase (IU/dL). For data evaluation, F and Scott-Knott tests ($p < 0.05$) were analyzed by the free software R-Project. Total protein (g/dL), total phosphorus (mg/dL), total cholesterol (g/dL), glycose (mg/dL), total triglycerides (mg/dL), aspartate amino transferase (IU/L) and alkaline phosphatase (IU/dL) were not affected by the nutritional treatments. The uric acid content for birds fed the diet with xylanase + FO - XOS was higher (1.87 mg/dL; $P < 0.01$) compared to the positive (0.56 mg/dL) and negative control (0.75 mg/dL) and xylanase inclusion (0.64 mg/dL), even so, not a potential risk to bird health (> 15 mg/dL). Positive and higher results were also found for albumin for birds that consumed xylanase (1.32 g/dL; $P = 0.04$) compared to the positive (1.08 g/dL) and negative control (1.15 g/dL) and xylanase + FO - XOS inclusion (1.18 g/dL). The same occurred for total calcium contents for xylanase treatment (10.17 mg/dL; $P = 0.04$) compared to the positive (8.65 mg/dL) and negative control (9.25 mg/dL) and xylanase + FO - XOS supplementation (9.55 mg/dL). The increase in the degradation and availability of nutrients can cause an increase in the uric acid content when the power of the enzyme is potentiated with the association with the oligosaccharides, and when there is no association between the compounds, the bird maintains the level of uric acid low and increases the albumin and calcium levels. Xylanase inclusion brings more benefits to the bird's biochemical serum content, which reflects in the avian nutritional metabolism and health.

PS4 - Solution to improve the nutritional value of feed**PS4-057 Soybean meal nutrient composition, amino acid digestibility, and energy content according to the origin and year of harvest: The value of Near-Infrared Reflectance Spectroscopy**

E.O. Oviedo-Rondón¹, A. Toscan², N.S. Fagundes², J.K. Vidal², J. Barbi², P. Thiery³

¹Prestage Department of Poultry Science, North Carolina State University, Raleigh, NC, United States, ²Adisseo Latin America, São Paulo, SP, Brazil, ³Adisseo France, Antony, France

Soybean meal (SBM) is a frequent source of protein for poultry, and SBMs from diverse origins are used. There is significant variability in SBM nutrient, energy value, and amino acid (AA) digestibility due to origin, harvest, and processing. Besides, analytical variability among labs can create bias in comparisons. Near-infrared reflectance spectroscopy (NIRS) can reduce these analytical inconsistencies. This study evaluated the effects of origin and year of harvest and processing on SBM nutrient, AME, AMEn, and AA contents, and AA digestibility coefficients (dig) estimated with NIRS. The database contained 77,621 SBM samples scanned from Argentina (ARG), Brazil (BR), and the United States (USA) between 2018 and 2021, collected using the PNE system (Adisseo®). PNE has a unique NIRS curve generated with in vivo data of standard poultry metabolizable energy and AA digestibility methods. A two-way analysis of variance was conducted to evaluate the effects of SBM country of origin and year of harvest in a 3 x 4 factorial design on nutrient composition, energy value, and AA dig. Significant interaction effects ($P < 0.001$) were observed for all parameters evaluated. SBM varied by country of origin, but there is variability due to harvest year. In general, and across years, BR SBM had the highest CP, fat, and CF values but the lowest AME and AMEn. USA SBM had the highest AME and AMEn and had intermediate values on CP, fat, ash, and CF. BR SBM had the highest Lys, Val, Ile, Leu, Phe, and His values. ARG had the highest sulfur AA, Thr, and Trp contents but the lowest Lys, Val, Ile, Leu, Phe, His, and Arg values. USA SBM had the highest dig of all AAs except for Lys, Leu, His, and Arg. BR SBM had the highest Lys and Ile dig, intermediate dig for sulfur AA, Trp, Val, and Phe, and the lowest dig for Thr, Leu, His, and Arg. ARG SBM had the lowest dig of Lys. The distribution of samples per cluster indicated the most expected quality of SBM from each country. The BR SBM with the highest CP, Lys, Val, and Leu values corresponds to 19.50% of the samples; in contrast, 80.50% of BR SBM samples had 75 to 152 kcal less AMEn than other SBM, with higher fat and CF. All clusters of ARG SBM had higher Cys content consistently. Most USA samples (87.78%) had the highest AA dig, except for Lys. In conclusion, the NIRS PNE system was able to detect the variability caused by the interaction of country of origin and year of harvest in SBM nutrient and energy content and AA digestibility.

PS4 - Solution to improve the nutritional value of feed**PS4-058** Supplementation of a combination of lysophospholipids, a synthetic emulsifier and monoglycerides improves the performance and welfare of broilersA. Desbruslais¹, D. Gonzalex-Sanchez¹, A. Wealleans¹¹Kemin Europa, Herentals, Belgium

With high production costs and growing concerns on animal welfare, the poultry industry is in need for solutions that reduce feed costs without impairing performance, while keeping welfare to the highest standards. Supplementation of a combination of lysophospholipids, a synthetic emulsifier and monoglycerides (LEX) in liquid and dry form to broiler diets with different energy levels was investigated to determine their effect on performance, litter quality and subsequent occurrence of footpad lesions. 1248, day-old Ross 308 broilers were assigned to one of six treatments for a 42-day study: a control basal diet with a normal energy content (NE); NE + 300g/t LEX in liquid form; NE + 500g/t LEX in dry form; a control basal diet with a low energy content (LE, -90 kcal/kg respect to NE), LE + 300g/t liquid LEX and a LE + 500g/t dry LEX. Each treatment consisted of 13 pens (replicates) of 16 birds each. Feed intake and weight were measured on days 0, 10, 21 and 42. On day 42 a litter sample was collected from each pen (5 sites within the pen) and two birds per pen were assessed for footpad lesions. Data was analyzed in the Fit Model platform of JMP 16, with means separation achieved using Tukey's HSD. Statistical significance was declared at $p < 0.05$. Results showed a higher ($p < 0.05$) cumulative bodyweight gain (BWG) with LEX supplementation. However, there was no effect ($p < 0.05$) of energy level or interaction between energy and supplementation. Increased ($p < 0.05$) feed intake was observed for the LE diets, however there was no significant difference in cumulative feed efficiency (FCR) between the LE + LEX treatments ($p > 0.05$) compared to the NE control, which suggests LEX application allowed the birds to cover the energy gap. The cumulative FCR of the LE diets were significantly increased ($p < 0.05$) compared to the NE, however there was a tendency ($0.05 < p < 0.1$) towards improved FCR when LEX was used. A significantly improved dry matter percentage was found in the litter of birds fed LEX, compared to the control NE and LE groups. This resulted in lower ($p < 0.05$) occurrence and severity of footpad lesions in birds supplemented with LEX compared to the two control treatments. In conclusion, feeding broilers a combination of lysophospholipids, a synthetic emulsifier and monoglycerides resulted in improved bird performance. Adding LEX to LE diets resulted in same BWG as the NE control. The use of the LEX also improved litter quality and footpad health therefore improving animal welfare.

PS4 - Solution to improve the nutritional value of feed**PS4-059** Supplementation of hydroxy trace minerals improves growth performance, health and oxidative status in broilersA. De Grande¹, S. Leleu¹, E. Delezie¹, A. Van der Aa², M. Brink², L. Vande Maele²¹Institute for Agricultural, Fisheries and Food Research, 9090 Melle, Belgium, ²Orffa Additives BV, Minervum 7032, 4817 ZL Breda, Netherlands

In order to support normal growth and broiler health, it is important to meet the nutritional requirements of trace elements (TE). The nutritional value of TE can differ between sources. TE from inorganic sources, such as sulphates, can form complexes with other dietary constituents, resulting in a lower availability and a large proportion of the minerals excreted to the environment. Therefore, a broiler trial was conducted at ILVO to compare the nutritional value of hydroxy trace minerals (Excential Smart, Orffa) with that of sulphates. A three-phase feeding scheme was applied (starter d0-14, grower d14-28, finisher d28-39). The trial consisted of 8 dietary treatments (10 replicates of 34 birds), all dietary treatments were supplemented with all three types of TE Cu (7.5 mg/kg), Zn (45 mg/kg) and Mn (45 mg/kg), and were combined either as a sulphate or hydroxy form (source), resulting in 8 different treatments, of which T1 contained all TE as sulphate and T8 contained all TE as hydroxy TE. In order to create a nutritional challenge for the birds, a wheat-rye based diet with a high level of non-starch polysaccharides (NSP), without the addition of NSP enzyme and lowered phytase level was fed. Performance and oxidative stress parameters (malondialdehyde (MDA) and Mn superoxide dismutase (MnSOD) were determined. Additionally, litter quality and footpad dermatitis (FPD) was scored (Welfare quality[®] assessment protocol). All zootechnical parameters and analysis results were analyzed by a General Linear Model (GLM) with treatment as a fixed factor and block as a random factor. A Tukey HSD test was used to compare the treatments if the GLM determined a significant ($P < 0.05$) treatment effect. A significant interaction (source*type) effect was observed for the starter period (d0-14) and overall period (d0-39) for Cu*Zn and Zn*Mn, with the treatment containing Cu, Zn and Mn as hydroxy TE showing the highest body weight and weight gain numerically. At slaughter age, FPD scores were significantly impacted by TE source ($P < 0.001$), which was not related to litter quality ($P = 0.340$). MDA levels were lower when hydroxy Cu was supplied compared to Cu sulphate ($P = 0.032$), and MnSOD was increased with hydroxy Cu ($P = 0.049$). This trial shows that the supplementation of hydroxy TE, affects growth performance of broilers, health and oxidative status. Especially the supplementation of Cu as a hydroxy TE, has the largest positive effect on oxidative stress parameters.

PS4 - Solution to improve the nutritional value of feed**PS4-060 Synergistic effect of a novel bacterial phytase and endogenous phosphatases for myo-inositol release evaluated in-vitro**D. Rosso¹, J. Jensen², M. Tovborg²¹Novozymes Latin America, Araucaria, Brazil, ²Novozymes A/S, Kgs. Lyngby, Denmark

Myo-inositol hexakisphosphate (InsP6) and its salt (phytate) are natural sources of phosphorous in plant seeds. Phytate, however, is considered an anti-nutritional factor (ANF) due to the limited availability for monogastric animals. Substantial degradation of phytate during gastric conditions is therefore required to reduce anti-nutritional effects of the intact molecule. Phytases cleave the phytate molecule into phosphate and inositol phosphate with different phosphorylated states (InsP1-5). Inositol phosphate with few phosphates is substrate for intestinal phosphatases where the final reaction products are myo-inositol and phosphate. The main objective of this work was to demonstrate the synergistic effect of a bacterial phytase (HiPhorius™, DSM Nutritional Products) and endogenous phosphatases for myo-inositol release in an in-vitro set-up. The experiment simulated conditions from broiler gastro-intestinal tract, including gizzard (pH 3, 30 minutes) and intestines (pH 6, 240 min). Endogenous protease pepsin (3000 U/g diet) and bacterial phytase (2000 FYT/kg diet) were added in gizzard phase, while alkaline phosphatase (10 U/ml) was added in intestinal phase. Control treatment without phytase or phosphatases was included. Aliquots were collected every 15 minutes and myo-inositol quantified using a spectrophotometric assay (Myo-Inositol Assay Kit, Megazyme). Percentage of myo-inositol release was calculated based on initial phytate concentration and results analyzed using Tukey-Kramer HSD. The alkaline phosphatase did not result in a statistically significant ($p < 0.05$) increase in myo-inositol release compared to control treatment. The inclusion of bacterial phytase, contrary, led to a significant increase in myo-inositol (13.1%) after 150 min compared to the control (3.65%) and alkaline phosphatase (5.33%) treatments, an increase also observed throughout the remainder of the hydrolysis reaction. The combination of phytase and alkaline phosphatase, moreover, resulted in a larger phytate degradation with consequent higher myo-inositol release. The synergistic effect was noted at 60 min reaction, with a myo-inositol release of 27.3%. After completion of the enzymatic reaction, 79.2% of myo-inositol was released, evidencing the synergistic effect between treatments. The results demonstrate that the novel bacterial phytase degrades phytate while acting in synergy with endogenous phosphatases during the digestion, thus maximizing the release of myo-inositol.

PS4 - Solution to improve the nutritional value of feed**PS4-061 Synergy between dietary xylooligosaccharides (XOS) and xylanase supplementation in broiler chickens**S. Niknafs¹, G. Gonzalez Ortiz², M. R Bedford², A. Kumar¹, C. Castro¹, E. Roura¹¹The University of Queensland, Brisbane, Australia, ²AB Vista, Marlborough, United Kingdom

Xylooligosaccharides (XOS) are dietary ingredients with functional properties including the modulation of the microbiota through fermentation (prebiotic). In addition, at low levels of dietary inclusion, XOS have been found to improve gut function and performance in chickens. However, since the amount of substrate reaching the hindgut is negligible, it has been speculated that the beneficial impacts of XOS relate to being an initial stimulator of fibrolytic bacteria in the gut. Thus, it is possible that XOS exert their impacts by the initial activation of microbiota while xylanase provides larger quantity of XOS, by breaking down dietary arabinoxylans (AX), to be fermented by the microbiota. Such complementary roles set the objective for this study to identify potential synergic effects between supplementation of XOS at different levels and xylanase in wheat-based diets (rich in AX) in broiler chickens through the stimbiotic mechanism of action. Two levels of xylanase (0 and 100 g/t) and three levels of XOS (0, 50, and 500 g/t) were tested in a 2x3 factorial design. Each treatment had 16 replicates (floor pens) of 8 chicken/pen (total of 768 Ross 308 male broilers). Wheat-soybean based mash diet was provided ad libitum in three phases of two weeks each including starter (CP: 23.2%, AME: 12.5MJ/kg), grower (CP: 21.3%, AME: 12.9MJ/kg), and finisher (CP: 19.4%, AME: 13.3MJ/kg). Chickens were kept for six weeks, and performance parameters were measured weekly. Data were analysed using SAS 9.2 in PROC GLM. Results showed that xylanase supplementation over 42 days period increased weight gain (2942g to 3003g; $P = 0.028$) improved FCR (1.600 to 1.571; $P = 0.088$) and increased the European Broiler Index-EBI (421 to 446; $P = 0.012$). XOS supplementation of 50g/t significantly improved FCR (1.612 to 1.559; $P = 0.045$), but the reduction of FCR was not significant for 500g/t (1.586; $P > 0.05$) compared to the control. There was a significant interaction between XOS and xylanase supplementation for EBI ($P = 0.014$). Combining XOS at 50g/t and 500g/t with xylanase compared to the control group increased EBI from 434 to 456 and 463, respectively ($P < 0.05$). In conclusion, dietary supplementation of xylanase and XOS improves performance parameters in broiler chickens. In addition, combined supplementation of XOS at 50g/t and xylanase 100g/t showed synergistic effects through the stimbiotic mode of action on the EBI indicating improved welfare, growth, and efficiency. Acknowledgements: This work was supported by ABVista Pty Ltd.

PS4 - Solution to improve the nutritional value of feed**PS4-062 The benefits of a higher dose of phytase in the pre-starter phase in broilers up to day 42 of age**Q. Zhang¹, C. Walk², R. Aureli³, J. Sorbara², K. Stamatopoulos²¹DSM Nutritional Products, Bazhou, China, ²DSM Nutritional Products, Kaiseraugst, Switzerland, ³DSM Nutritional Products, Village-Neuf, France

A high dose of phytase supply is assumed to be especially important to young birds where the P requirement is high, skeletal development is critical and the intestinal phosphatases are not developed yet. Therefore, a floor pen study was conducted to explore the benefits of a higher dose of phytase in the pre-starter phase in broilers up to day 42 of age. Three treatment diets (with 8 replicate pens of 19 birds per pen) were fed to Ross 308 male broilers in three phases. The positive control (PC) feed was formulated to be nutritionally adequate and contained: pre-starter (PS, 10 d), 0.49% nPP and 0.90% Ca; starter (S, 13 d), 0.41% nPP and 0.80% Ca; grower and finisher (GF, 19 d), 0.33% nPP and 0.70% Ca. The negative control (NC) in all phases was formulated to contain 0.17% less nPP and 0.10% less Ca. The NC was supplemented with phytase (HiPhoriusTM, DSM Nutritional Products Inc.) at 2,000 FYT/kg at PS, and 1,000 FYT/kg at S and GF. The right tibia from 4 birds/pen and ileal digesta from 7 birds/pen were collected at day 23. The plasma samples from 2 birds/pen were collected at day 22 and 42. Data were analyzed with a one-way ANOVA followed by Tukey's multiple comparison test. The contrast analysis was further applied for PC vs phytase. The results showed NC had significantly lower ($P < 0.05$) body weight (BW) gain and feed intake, higher ($P < 0.05$) BW corrected feed conversion ratio (BWcFCR) over the 42-d period, and lower ($P < 0.05$) tibia ash, Ca and P in comparison with PC. Phytase significantly reversed ($P < 0.05$) all the negative effects in growth performance and tibia mineralization observed in NC. The contrast analysis showed phytase had a tendency to increase 0-42 d BW gain by 4.2% ($P=0.08$) and tibia P by 2.0% ($P=0.07$), and numerically improved 0-42 d BWcFCR by 3.8 point compared to PC. Additionally, NC showed no difference from PC regarding ileal P digestibility, but a higher ($P < 0.05$) ileal phytate P degradation. Compared to NC and PC, phytase significantly increased ($P < 0.05$) ileal P digestibility and phytate-P degradation and increased ($P < 0.05$) plasma myo-inositol at day 22 and 42. In summary, a higher dosing of HiPhoriusTM phytase at 2,000 FYT/kg for the first 10 days and standard dosing thereafter demonstrated additional benefits beyond PC in terms of BW gain, tibia P and ileal P digestibility, which was supported by the effective removal of anti-nutritional phytate esters in ileum and the increase of myo-inositol availability in plasma.

PS4 - Solution to improve the nutritional value of feed**PS4-063 The changing role of endoxylanases in wheat-based broiler diets: from mitigating the anti-nutritive effect towards feeding the microbiome**A. Bautil¹, M. Bedford², C. Courtin¹¹KU Leuven, Leuven, Belgium, ²AB Vista, Marlborough, United Kingdom

The use of endoxylanases in wheat-based broiler feeds is widely accepted. We postulate, however, that the relative importance of the 3 most cited mechanisms for endoxylanase functionality in the GIT of broilers, i.e. the viscosity reduction, uncaging and prebiotic production mechanisms, has shifted over time. Here, we discuss the intrinsic changes in broiler genetics and feed formulations, such as the ban on in-feed antibiotics, that possibly induce this change in the role of endoxylanases in broiler feeds. To this end, data from the literature from 1990 to 2015 and 3 broiler trials performed in our research group from 2015 to 2022 are compared and critically analysed to advance our understanding of the mode of action of these enzymes in current wheat-based diets. We observed that the range of intestinal viscosity values decreased 4 to 10-fold over the past 3 decades, indicating that the viscosity-inducing effect of wheat has lessened and might be less of a concern nowadays, especially in older broilers. Our data suggest that the enzymatic release of viscous polysaccharides, leading to a marginal increase in viscosity (1 cP) along the GIT, will not per se be detrimental to broiler performance. Endoxylanase action, in this case, will not primarily result in diet-related viscosity reduction (as seen in the past) but can also result in increased fibre fermentation by intestinal microbiota. Indeed, depending on broiler age and fibre type in the diet, this small increase in viscosity can be attributed to a more arabinoxylan (AX) solubilising and fermenting microbiome. Uncaging of the nutrients trapped in the endosperm cell walls to enable a better attack of protease and amylase to wheat starch and proteins has for many years been proposed as an important mode of action, supported by microscopic evidence of in vitro work and in vivo digestibility values. This hypothesis can, however, be questioned based on recent digestibility data, showing that control birds from 3 wks onwards were already able to hydrolyse all endosperm cell wall AX. Hence, our recent data seems to support the idea that endoxylanase functionality nowadays results from the interplay of the microbiome with AX that were made more readily available for fermentation. This paper illustrates that long-lived knowledge in the field should be reevaluated regularly rather than be defended as established and unchangeable dogma due to the rapid and global changes in feed formulation and broiler genetics.

PS4 - Solution to improve the nutritional value of feed**PS4-064** The effect of amylase in the diet with pea and faba bean on growth performance, nutrient utilization, and sialic acid excretion in broiler chickenK. Perz¹, M. Hejdysz¹, S. Nowaczewski¹, S. Kaczmarek²¹Department of Animal Breeding and Product Quality Assessment, Poznan, Poland, ²Department of Animal Nutrition, Poznan, Poland

The present study aimed to determine the effect of protein source, addition of exogenous amylase, and their interaction on growth performance, nutrient digestibility, and excretion of sialic acid in broiler chickens. A total of 960 one-day-old male Ross 308 broiler chickens were randomly divided into 4 experimental groups (30 replications/8 chickens each). Diets for the first and the second group were prepared using pea seeds, whereas the third and fourth group were fed diets with faba bean seeds. Additionally, the second and fourth group were supplemented with amylase (0.14 g/kg as feed). Feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR) were measured on the 1st, 14th and 35th days of age. Excreta were collected from the 32nd to the 35th, thrice a day. Chickens were sacrificed on the 35th day to collect ileal digesta samples. No interaction between protein source and amylase was found for growth performance. Feeding faba bean diets from 0 to 35 days, resulted in higher BWG, lower FI, and lower FCR. Groups fed enzyme supplemented diets had a higher BWG and FCR from 0 to 35 days, with a tendency for higher FI from 15 to 35 days. No interaction between protein source and enzyme was found for AMEN, sialic acid excretion, and apparent ileal digestibility (AID) of nutrients. The AMEN value was higher in faba bean diets but was unaffected by amylase addition. Amylase decreased the total sialic acid content in excreta. A higher AID of starch and crude protein was seen in birds fed faba bean seeds, and enzyme supplementation led to higher AID of dry matter and starch and tended to increase AID of crude protein. The AID of both essential amino acids such as Lys, Met, Val, Leu, Phe, His, Arg, and non-essential amino acids was higher in faba bean diets. Amylase supplementation increased the AID of nearly all essential amino acids (except for Cys, Met, and Tre) and non-essential amino acids (except Pro). The present study indicates that faba bean can be a more valuable protein source in broiler chicken nutrition compared to pea seeds, due to improvements on growth performance and higher nutritional value. The inclusion of an exogenous amylase was effective in improving growth performance and dietary nutritional value regardless of the protein source.

PS4 - Solution to improve the nutritional value of feed**PS4-065** The use of phytogenic feed additives with nutritional matrix values can decrease feed costs and maintain the production performance of laying hensM. De Laet¹, C. Donaldson¹, R. Montanhini Neto¹¹Delacon Biotechnik GmbH, Engerwizdorf, Austria

For laying hens, feed costs are crucial and account for 60-70% of the total costs. Raw material prices have increased dramatically versus historical norms. Thus, it is necessary to optimize layer diet formulations. Phytogenic feed additives (PFA) can improve nutrient digestion and utilization. Based on several digestibility studies managed by Delacon, nutritional matrix values were developed for PFA. In this trial, the effect of a PFA based on a combination of spices, bitter substances, essential oils, and saponins (Biostrong® 510), used with nutritional matrix values, was evaluated by measuring the production performance of 200 ISA Brown laying hens, 20 replicates with 5 birds/replicate for each treatment from 19 to 34 wks of age. The objective was to achieve the same production parameters with a lower feed cost per kg output. Two dietary treatments were tested: 1) control feed and 2) control + 150 g/MT PFA from 19 to 34 wks of age (nutritional matrix values are used from 25 until 34 wks). At the onset of lay, a rapid increase in nutrients is necessary as the birds must still cover nutrient requirements to reach adult body weight but also to achieve a rapid increase in egg weight and reach peak production of close to 1 egg per day. As birds can use all possible nutrients at the start of lay, PFA were added on top of the feed from 19 to 25 wks and the nutritional matrix values were used from 25 wks onwards. Only data of minimum 70% laying rate are considered (from 21 wks onwards). From 21 to 25 wks of age, the laying rate (+3.03%) increased and FCR (-5.3 point) decreased significantly ($P < 0.05$) when PFA were added on top of the diet. Previous research from Delacon proved that this effect is due to an improved nutrient utilization. From 26 to 34 wks of age, when the matrix values were used, the laying rate (+0.64%) and FCR (+0.2 pt) did not change significantly ($P < 0.05$). As a conclusion, in this experiment, the use of nutritional matrix values from 25 wks onwards allowed a reduction in feed cost per kg product output by 2-3%. The ROI (current value of investment/cost of investment) of using PFA with nutritional matrix values in this trial was 3.3.

*PS4 - Solution to improve the nutritional value of feed***PS4-066** Verification of the claimed P and Ca matrix values of an intrinsic heat stable granular phytase dosed at 500 FTU/kgC. Picart¹, L. Nollet², P. Quero¹¹ADM Animal Nutrition, Saint Nolff, France, ²Huvepharma NV, Antwerp, Belgium

The aim of this study was to evaluate the impact of applying an intrinsic heat stable phytase dosed at 500 FTU/kg on animal performance, bone ash and P and Ca in bone ash, to verify its claimed matrix values. The trial was set up at CRZA, Montfaucon (France) using 560 Ross 308 birds (as hatched) distributed over 56 pens of 10 birds each at a density of 11.5 broilers per m². Broiler were fed a starter feed (2.5 mm pellets from day 1 to 21; crumbled) followed by a grower feed (3.5 mm pellet) from day 22 till day 33. Four treatments were imposed: (1) feed deficient in P and Ca (0.15 % available P (aP) in starter and grower, and 0.59 and 0.57 % Ca in starter and grower respectively, (2) a positive control 1 (PC1) by adding 0.1 % aP and 0.13 % Ca to the negative control, (3) a positive control 2 (PC2) by adding 0.2 % aP and 0.26 % Ca to the negative control and (4) the negative control to which granular phytase, OptiPhos® Plus, was added at 500 FTU/kg (OPP). Technical performance was measured at day 9, 21 and 33 (after fasting for 4 h). At day 21, 14 animals per treatment were selected (one of each pen, weight as close as possible to the average weight of the pen) and euthanised humanely. The tibia was removed, weighed, and analysed for dry matter, ash, P and Ca. On the basis of the live weight (day 21), the tibia ash and P content recorded at day 21, the P and Ca released by phytases was calculated by linear regression equations. Due to welfare reason, the broilers of the negative control group were all euthanised at day 21 after collection of the tibia. The addition of the phytase brought the growth performance back to PC 2 (2335 g vs 2327 g final body weight respectively), different significantly from PC1 (2216 g, p<0.001), without significant difference on feed conversion: 1.38, 1.39 and 1.38 for PC1, PC2 and OPP. There were no significant differences in bone ash, Ca, and P percentage in bone dry matter between the phytase treatments and the positive controls, all being significantly different from the negative control except for the PC1 for P contents in bone ash. Based on body weight at day 21, an aP equivalency could be calculated for OptiPhos® Plus of 0.178 % and 0.212 % for Ca. Based on day 21 tibia ash, the equivalency was 0.145 % aP and 0.172 % Ca, while based on tibia P the equivalency was 0.178 % aP. It was concluded from this research that it supports the claimed matrix values for P and Ca for this phytase at this inclusion level (0.155 %).

*PS4 - Solution to improve the nutritional value of feed***PS4-067** Xylanase can release energy of broiler diets with different wheat cultivars before and after post-harvest storage of wheatG. Pasquali¹, M. Francesch², D. Feuerstein¹, A. Fickler¹¹BASF SE, Ludwigshafen, Germany, ²IRTA, Animal Nutrition, Tarragona, Spain

Two studies were conducted to evaluate the effects of a xylanase on the AMEn of broiler diets with six wheat cultivars, collected from different regions of Germany and without/with storage. In the first assay, wheat cultivars were added to the diets right after harvest (<1 month). A second trial was conducted with the same cultivars after 8 months of post-harvest storage. In each assay, a total of 192 d-old male Ross 308 chicks were fed a wheat-soybean based diet from hatch until the start of the experimental period at d 7. Then birds were allotted to 96 cages in a 6 × 2 factorial arrangement with six wheat cultivars × without/with 100 ppm of xylanase (endo-1,4-β-xylanase, 5600 TXU/g) on top. The diets were based on wheat (63.5%) and soybean meal and identical in composition across all dietary treatments. Excreta samples from each cage were collected from d 21-23 and TiO₂ was used as a tracer. Data of each study were subjected to 2-way ANOVA. Data of both trials were combined to elucidate the enzyme effect on different cultivars when added before or after storage using a 2-way ANOVA (before and after storage × 6 wheat cultivars), considering the difference between xylanase-supplemented and the average of the non-supplemented group for each cage. Statistical differences were considered significant at P<0.05 and means separated by LSD's test. No correlation between AMEn and fiber characteristics of wheat was observed. After harvest, a trend for interaction between cultivar and xylanase on AMEn (p=0.067) was observed; AMEn was increased by xylanase in diets with cultivars 2, 4, 5 and 6. Without xylanase, cultivars 1, 3 and 4 resulted in higher AMEn than cultivar 2 (p<0.05), whereas with xylanase no differences between cultivars were observed. After storage, xylanase increased the AMEn (p<0.01) of the diet by 56 kcal/kg on average. Use of cultivar 4 resulted in higher AMEn than all other cultivars (p<0.01). There was a trend for interaction between storage and cultivar for the xylanase effect (p=0.065). Wheat storage did not affect the xylanase effect on AMEn (p>0.05), but it was numerically higher before storage for cultivars 2, 5 and 6 and after storage for cultivars 3 and 4. The xylanase effect on AMEn was lower in cultivar 1 than in all other cultivars. In conclusion, xylanase was efficacious in releasing energy of diets with different wheat cultivars after harvest or after storage for 8 months, but the magnitude of the effect was cultivar dependent.

PS4 - Solution to improve the nutritional value of feed**PS4-068 β -mannanase as an effective tool to increase intestinal health and uniformity of broilers**A. Gouveia¹, L.M. de Paulo¹, A.G.F. Dias¹, J.M.M. Batista¹, M. Kipper², J.H. Stringhini^{1,3}¹Universidade Federal de Goiás, Goiania, Brazil, ²Elanco Animal Health, Sao Paulo, Brazil, ³CNPq Agency, Brasilia, Brazil

This study was run to evaluate how reducing dietary ME affects performance and intestinal health and how the β -mannanase may compensate it. 1680 Cobb 500-day-old chicks were set up according to a completely randomized factorial 3x2 design, with a combination of 3 ME reduction levels (control, -45 and -90 kcal/kg) and diets with or without β -mannanase (Hemicell™ HT, Elanco Animal Health) with 8 replicates of 35 birds. Basal energy levels used were: 3000, 3100, 3200 and 3250 kcal ME/kg, in pre-starter, starter, grower and final phases, respectively. Performance and 10% uniformity were measured at 21 and 42 days of age and one bird per replicate was selected for intestinal integrity assessment. Birds were euthanized and necropsied to observe macroscopic lesions, including intestinal tonus, thin intestine, excessive intestinal fluid and mucus, cellular sloughing, coccidiosis lesions, intestinal hyperemia and hemorrhage, necrotic enteritis and cecal gas. In addition, one bird per replicate was selected and fasted for 2 hours and 0.2 mL of FITC-dextran were administered by gavage. After 2.5 hours, the blood was collected, and the marker was determined, and data was analyzed by Tukey test ($P>0.05$). No effect ($P>0.10$) was obtained for ME levels and interaction among effects, therefore, only the means with and without the β -mannanase are presented. At 21 days, feed intake (1.38 vs 1.39 kg), and FCR (1.19 vs 1.18) did not differ ($P>0.25$) among groups, but body weight (1.16 vs 1.18 kg; $P=0.04$) was higher in the β -mannanase group. At 42 days, feed intake (5.50 vs 5.55 kg), body weight (3.67 vs 3.68 kg) and FCR (1.50 vs 1.50) did not differ ($P>0.30$) among groups. uniformity was superior for the β -mannanase group at 21 (67.3 vs 71.7%; $P=0.03$) and 42 days (82.0 vs 86.6%; $P<0.01$). Intestinal integrity was superior for the β -mannanase group at 21 (93.7 vs 95.5%; $P=0.06$) and 42 days (89.7 vs 92.4%; $P=0.11$). Permeability was reduced for the β -mannanase group at 21 (0.150 vs 0.138 $\mu\text{g/mL}$; $P=0.11$) and 42 days (0.223 vs 0.159 $\mu\text{g/mL}$; $P<0.01$). The ME levels did not influence the performance, suggesting that the lowest level already supplied enough ME required for the birds. Even in this condition, the β -mannanase was useful to improve the uniformity, probably due to higher intestinal health observed by the increase in intestinal integrity. Thus, we conclude that the β -mannanase is an important tool to improve birds' health leading to a better flocks' uniformity.

PS5 - Non-soy protein sources**PS5-001 Apparent ileal protein digestibility in broilers of Black Soldier Fly Larvae (*Hermetia illucens*) raised on differing substrates**N. Abdelaal¹, E. Burton¹, D. Scholey¹, A. Hirst¹, A. Alkhtib¹¹Nottingham Trent University, Nottingham, United Kingdom

Soya bean meal has been the main protein source in poultry diet for many years. However, there is now concern over the environmental impacts of excessive soyabean production and global transportation. The investigation of insects as alternative protein source has become of recent interest globally as a means to lower environmental impact of poultry production. Aim The aim of the current study was to determine the proportion of digestible protein available for broiler chickens from Black Soldier Fly Larvae (BSFL) reared on differing substrates in comparison to soya bean meal (SBM). Methods The trial was conducted in the UK after a favourable opinion from the University's ethical review group. Black Soldier Fly Larvae (BSFL) commercially reared on Brewer's Waste (BW) or experimentally reared on either fruit waste (FW) or bran (BR) substrate in comparison to soya bean meal (SBM). BSFL reared experimentally were euthanised by freezing and separated from frass before freeze drying and grinding. One day old, male Ross 308 broiler chicks were fed standard diet to day 18 and then the experimental diets to day 21. Six replicate pens each containing 6 chicks were allocated to one of four protein sources. Each protein source (SBM, BSFL BR, BSFL BW or BSFL FW) was included as 60% of an otherwise nitrogen-free diet containing a vitamin mineral premix, oil, dextrose, corn-starch and titanium dioxide (TiO₂) digestibility marker. Nitrogen and TiO₂ were determined in digesta and feed and used to calculate nitrogen digestibility coefficient. Results Total protein contents (DM basis) were 48.84%, 48.52%, 39.94%, and 31.34%, respectively for SBM, BSFL BW, BSFL BR or BSFL FW respectively. BSFL FW and BSFL BR significantly increased ($P<0.05$) nitrogen digestibility coefficient (0.814^a and 0.806^a respectively) compared to control (0.738^b) however, there was no significant difference in the nitrogen digestibility coefficient of any of the diets compared to BSFL BW (0.752^{ab}). Conclusion Protein content of BSFL BR and BSFL FW were lower than expected; suggesting contamination with frass. All the BSFL meals showed nitrogen digestibility coefficients as good or better than soya suggesting they are an attractive candidate protein source for poultry diets. Acknowledgments We thank Richard Small and Inspro for providing BSFL for the study and the support of the Egyptian Ministry of Higher Education for this PhD project is gratefully acknowledged and also advice from Mohammed Naeem.

PS5 - Non-soy protein sources**PS5-002 Black soldier fly larvae meal as an alternative protein source in broiler chicken's diet**N. Stöhr¹, P. Harig¹, R. Ibrahim¹, K. Schuh -von Graevenitz², R. Jha³, G. Dusel¹¹University - Animal Nutrition, Bingen, Germany, ²Institute Feed Research, Bingen, Germany, ³University of Hawaii at Manoa, Honolulu, United States

The demand for poultry meat is increasing due to its popularity and desirable nutritional value. To meet the high demand for protein-rich feeds for poultry production, the use of black soldier fly larvae meal (BSFL) as an alternative protein source to soybean meal (SBM) is becoming increasingly important. This study evaluated the effect of partially replacing SBM with defatted-BSFL in the broiler's diets. A total of 90 one-d-old male chicks (Ross 308) were equally allocated (6 pens/treatment, 5 birds/pen) to one of three treatments: 0, 7.5, and 15 % SMB replaced by BSFL diets (BSFL0, BSFL7.5, BSFL15). The trial diets were isonitrogenous and as far as possible isocaloric, when replaced with defatted-BSFL compared to the equivalent SBM diet. Birds were fed diets in two phases (starter d1-21; finisher d21-35; ad libitum) and raised in a standard commercial management system. Body weight (BW) and feed intake (FI) were recorded weekly to calculate average daily feed intake (ADFI), average daily gain (ADG), and feed conversion ratio (FCR). There was no difference ($P>0.05$) in BW and ADG of birds among treatments BSFL 0 and BSFL7.5 over the whole trial period (e.g., BW35: 2.80 kg and 2.81 kg, respectively; $P=0.97$), whereas BSFL15 had lower BW (e.g., BW35: 2.03 kg; -28 %; $P<0.05$) and ADG total (-28 %; $P<0.05$) than control. Also, ADFI was not different between BSFL0 and BSFL7.5 (108 g/d/broiler and 112 g/d/broiler, respectively; $P=0.37$). The decrease in BW of birds in BSFL15 was due to significantly lower FI (-19 % DFI; $P<0.05$) compared to BSFL0. The lowest FCR was observed for BSFL0 during the grower and total trial period (BSFL0 < BSFL7.5 < BSFL15; $P<0.05$). In conclusion, SBM can be replaced by 7.5 % BSFL, without significant reductions in performance in the diets of broiler chickens. However, a replacement of SBM with 15 % of BSFL in the diet negatively affected growth performance compared to the control diet.

PS5 - Non-soy protein sources**PS5-003 Comparative use of several microalgae in broiler feeds**B. VILA ¹, B. Villca¹, A. Perez-Vendrell¹¹IRTA - Institute of Agrifood Research and Technology. Animal Nutrition Program, Mas Bové. 43210, Constantí, Spain

The aim of this study was the evaluation of four microalgae: *Chlorella vulgaris* (Chv), *Nannochloropsis oceanica* (No), *Spirulina platensis* (Sp) and *Tetraselmis chuii* (Tc) as ingredients for broiler feeds. These microalgae were characterized for hygroscopicity, flowability and in vitro digestibility. Mash and pelleted wheat-based feeds were prepared by replacing half of soybean crude protein by each of the microalgae and characterized for flowability, in vitro 2-phase digestibility, homogeneity of mixing and stability, pellet durability. The moisture of microalgae increased by ~5 points over a week at ambient conditions oscillating according to relative humidity. The flowability of microalgae ranged from 43 (No) to 56 degrees (Chv), while when included in feeds it ranged from 36 (Tc) to 52 degrees (Chv) versus 35 degrees for soybean control feed. The in vitro digestibility of crude protein ranged from 36% (No) to 69% (Tc) for microalgae vs 77% determined on soybean meal; from 61% (No) to 78% (Sp) for mash feeds vs 80% for soybean control and increased from 69% (Tc) to 87% (Sp) for pelleted feeds vs 90% for soybean control. The homogeneity of mixing determined by crude protein content had a CV<1% for all mash feeds. No clear differences were detected over three months on stability of mash or pelleted feeds measured by analyzing the contents of vitamin E, vitamin B6 and FRAP antioxidant capacity. All microalgae increased the feed pellet durability from 1 to 2 points compared to soybean feed (95.1%). Although some feed parameters did not reach the values obtained for the soybean control, it is considered that these microalgae could partially replace soybean meal in broiler feeds. This work is part of the WP5 of the European project Profuture (Grant Agreement: 862980; LC-SFS-17-2019 Alternative proteins for food and feed).

PS5 - Non-soy protein sources**PS5-004 Effect of cereal and protein sources on broilers performance and feed digestibility**C. Margetyal¹, N. Saliez², M. Traineau³, M. Vilariño³, C. Launay¹, J. Danel⁴¹ADM Animal Nutrition, Château-Thierry, France, ²ADM Animal Nutrition, Saint-Nolff, France, ³ARVALIS - Institut du végétal, Poultry and swine nutrition research unit, Villerable, France, ⁴ARVALIS - Institut du végétal, Poultry and swine nutrition research unit, Ploërmel, France

Increasing demand and competition for stable protein sources has shaped the market looking for local sources. Rapeseed meal (RSM) has been identified as a promising one for European market. However, previous research showed a loss of energy value presumably attributed to the wheat content of the feed. Two trials were conducted to check the effect of RSM incorporation on broilers performance (Trial1), and to evaluate the digestibility of diets (Trial2). The experimental design of both trials consisted of 4 treatments with equivalent nutritional values (energy, protein, and main digestible amino acids): wheat/Soybean meal (SBM), wheat/RSM, corn/SBM and corn/RSM. There were 14 pens of 20 birds each per diet in Trial1 and 12 broilers in individual cages per diet in Trial2. After a common starter period (0-9 days), birds received the four profiles' experimental diets during the grower (9-21 days) and the finisher (21-33 days) phases. In both trials, birds were weighed at their arrival, at 9, 21 and 33 days of age. Feed intakes (FI), average daily gain (ADG) and feed conversion ratio (FCR) were calculated. In Trial2, apparent total tract digestibility (ATTD) of starch, nitrogen and nitrogen-corrected apparent metabolizable energy (AMEn) values were evaluated on the four finisher diets with an indigestible marker, on 28 days old chickens. Excreta were individually collected for 3 days. In Trial1, whatever the cereal, the presence of RSM decreased FI (-4.5%; $p < 0.05$) and consequently growth (-5%; $p < 0.01$) from 9 to 21 days. FCR began to be affected only during the finisher period (+6%; $p < 0.01$). Compared to wheat, corn seemed to ensure higher growth during the whole experimental period (+2.4% on RSM, NS and +1.8% on SBM, NS), and better FCR only on the grower period (-2%; $p < 0.01$). In Trial2, the starch ATTD did not significantly differ among diets, all values being over 97.5%. The nitrogen ATTD values for the SBM diets were significantly higher than those of the RSM diets (+5% on average with the two cereals). Despite differences up to 83 kcal/kgDM, AMEn values were similar among diets ($P > 0.05$). In these trials, energy as starch ATTD did not seem to have any impact on performance. The decrease in performance observed with RSM may be rather related to the lower nitrogen ATTD. Complementary research is currently ongoing to investigate on this criterion.

PS5 - Non-soy protein sources**PS5-005 Effect of microwaves on the metabolizable energy of green pea (*Pisum sativum*)**B. Iglesias^{2,1}, M. Charrière², M. Gaggiotti³, V. Fain Binda², N. Bagattin¹¹ECANA, UNNOBA, Pergamino, Argentina, ²Sección Avicultura, INTA-EEA Pergamino, Pergamino, Argentina, ³Laboratorio de Forrajes, INTA-EEA Rafaela, Rafaela, Argentina

The feeding cost represents between 55 and 70% of the production costs of chicken meat or eggs. Currently, the poultry sector is facing a new and challenging scenario, the increase in the price of traditional ingredients. Corn and soybeans showed a price increase of 88 and 57% in the last 24 months, respectively. This price increase motivates the need to look for alternative ingredients in order to lower costs. The green pea (*Pisum sativum*) is presented as a viable alternative. Peas are an ingredient with good potential for animal feed, characterized by having a high crude protein content (20-26%), good palatability and low content of anti-nutritional factors. The use of microwaves is not a new technology, however, it is little exploited, so, the aim of this trial was to evaluate the effect of microwaves on the metabolizable energy of green peas. A sample of 200 g of raw green peas was placed on the plate of a 900-watt home microwave and cooked at 70% power for 0, 3, 5, 6, 7, and 9 min, using a completely randomized design with 6 treatments and 3 repetitions each. Moisture (M), crude protein (CP), ureasic activity (UA), protein solubility (PS), acid detergent insoluble nitrogen (ADIN), true metabolizable energy (TME) and coefficient of utilization of gross energy (TME/GE) were determined. The data were subjected to analysis of variance (ANOVA), when the degree of significance was less than 5%, the comparison of means was performed by the test of minimal significant differences; also, lineal regression was used to determine lineal or quadratic effect. As the cooking time increased, the M, UA and PS of the sample decreased linearly ($p \leq 0.05$). Whereas the percentage of CP standardized to 12% H was not affected by the cooking time ($p > 0.05$), NIDA increased significantly just after 9 min of cooking. Regarding the TME, the response was quadratic, with the best results at 5 min of cooking time with an increase of 204 kcal/kg and +4.9 percentage points in TME/GE, compared to peas without heat treatment (0 min). Despite the fact that peas have low levels of anti-nutritional factors, a beneficial effect was found when applying a thermal process using microwaves, and it was established that the best results of TME and TME/GE are achieved with 5 min of cooking at 70% power in a 900-watt home microwave.

PS5 - Non-soy protein sources**PS5-006 Effects of feeding graded levels of sunflower meal on the apparent ileal amino acid digestion of pullets and laying hens**

Á. Mezőlaki¹, L. Pál², L. Wagner², M.A. Rawash^{2,3}, K.G. Tewelde², N. Such², K. Dublec²

¹Agrofeed Ltd., Győr, Hungary, ²Hungarian University of Agriculture and Life Sciences, Keszthely, Hungary, ³Regional Center for Feed and Food, Agricultural Research Center, Giza, Egypt

A digestibility trial was carried out with 10-week-old Tetra SL pullets and 50-week-old laying hens of the same genotype. Besides a corn, wheat and corn starch based basal diet (C), three different diets were composed containing 10 (S10), 20 (S20) and 30% (S30) extracted sunflower meal (SFM) on the expense of corn starch. The diets were isocaloric, but their protein and fibre content increased with the increased SFM ratio. The lower energy content of SFM was compensated with increased sunflower oil supplementation. In order to calculate the ileal amino acid (AA) digestibility, titanium dioxide was used as a marker. The experimental diets were fed in 8 replicate balance cages. After 7 days adaptation period the animals were euthanized, slaughtered and the ileal contents were collected immediately. Two factorial ANOVA was used, with bird age and SFM inclusion rates as main factors. Feeding SFM did not modify the digestibility of amino acids (AA) neither in pullets nor in laying hens. Even 30% inclusion rate of SFM had no negative effect on the AA digestion. On the other hand, the digestibilities of all amino acids were significantly higher in hens, compared with pullets. The apparent ileal digestibility of the first limiting amino acids were: lysine 72.5% and 81.4%; methionine: 85.0% - 89.6%; cystine 73.8% - 83.1%; threonine: 64.2% - 75.1%; valine: 77.2% - 84.7%; isoleucine: 80.0% - 86.3%; arginine: 83.1% - 89.1% for the pullets and laying hens respectively. The results suggest, that using different amino acid digestibility coefficients for the calculation of the ileal digestible AA contents of feedstuffs could improve the accuracy of the prediction in the relation of laying hens and young pullets. According to the determined AA digestibility values, SFM can be used in the pullet and layer diets even at 30% without negative effects on the protein digestibility.

PS5 - Non-soy protein sources**PS5-007 Effects of partial replacement of soybean meal with defatted black soldier fly (*Hermetia illucens*) meal in the diet of laying hens on performance, egg quality, and serum biochemical indices**

P. Zawisza¹, B. Szymczyk¹, A. Arczewska - Włosek¹, K. Szczepanik¹, S. Świątkiewicz¹, J. Calik¹

¹National Research Institute of Animal Production, Kraków, Poland

The aim of the study was to determine the possibility of partial replacement of soybean meal (SBM) with defatted *Hermetia illucens* larvae meal (HIM) in the diet for laying hens, without a negative impact on performance indices, egg quality, and health status. The experiment was performed on 96 caged Bovans Brown laying hens at an initial age of 25 weeks, randomly assigned to 4 experimental groups of 12 replicates (cages) of 2 hens per cage. The hens from the control group received a diet containing 20 % of SBM, without HIM content. In the experimental groups, hens were administered a diet containing a defatted HIM at a level of 5, 10, or 15 % (HIM5, HIM10, HIM15, respectively), at the expense of proportionally decreasing the content of SBM. All diets were isonitrogenous. During the 12-week experiment, the laying performance, the egg weight, the daily mass of eggs per hen, daily feed intake, and feed conversion per egg and per 1 kg of eggs, were determined. Every 4 weeks, 12 eggs per group were taken to examine: albumen height (AH), Haugh unit (HU), yolk content and color, thickness, density, and breaking strength of eggshell. At the 36th week of age, eggs were analyzed for yolk cholesterol (YCh) content, and the blood samples (n=12) were taken to analyze the contents of total protein, albumin, triglycerides, total cholesterol, and its fractions, Ca, P, Mg, Fe; and the activities of alkaline phosphatase, alanine aminotransferase, aspartate aminotransferase, lactate dehydrogenase, amylase, lipase. The laying performance parameters were not affected by the inclusion of any HIM level in the diet (P>0.05). The internal egg and eggshell quality parameters were unaffected (P>0.05) after 4 weeks of HIM administration. After 8 weeks, lower AH and HU were observed in HIM15 (by 15.9 and 8.07%, respectively), and after 12 weeks, more intense egg yolk color was noted in HIM10 and HIM15 groups, when compared to the control group (P≤0.05). The increased serum Ca, and lower YCh contents were indicated in all HIM groups. The dietary HIM inclusion for the period of 12 weeks did not worsen laying performance, permanently negatively affect egg and eggshell quality, or alter liver and pancreas function. HIM did not significantly alter most of the serum biochemical indices but increased the serum Ca content and lowered the yolk cholesterol content. Thus, HIM may be regarded as an efficient, alternative protein source for laying hens.

PS5 - Non-soy protein sources**PS5-008 Influence of partial dietary replacement of soybean with different levels of *Hermetia illucens* meal during grower and finisher phases on live performances and meat quality in broilers**M. Petracci¹, F. Soglia¹, M. Zampiga¹, F. Sirri¹¹Department of Agricultural and Food Sciences, Alma Mater Studiorum - University of Bologna, Bologna, Italy

This study aims at assessing the impact of replacing part of the dietary soybean meal with an *Hermetia illucens* meal (IM) on live performances and quality traits of breast meat in broilers. A total of 1,000 1-day-old Ross 308 male chicks was divided into 3 experimental groups of 7 replicates fed either the commercial corn-wheat-soybean diet (CON) or the same basal diet with a 9 and 18% inclusion of the *Hermetia illucens* proteins (9IM and 18IM, respectively) during both the grower (11-34 d) and finisher (35-42 d) phases. All diets were isoenergetic and isonitrogenous and supplied in mash form. Body weight, daily weight gain, daily feed intake and feed conversion ratio were computed on a pen basis in each feeding phase, while mortality was recorded daily. At slaughter (42 d), 15 breast fillets for each group were collected and used for evaluating pHu, colour, water holding capacity and oxidative status of lipids and proteins. Data were analyzed through One-way ANOVA by considering the level of the dietary inclusion of IM level (0, 9, 18%) as main effect. Overall, replacing the conventional protein source with IM negatively affected the production performances of broilers. In detail, the experimental groups 9IM and 18IM exhibited significantly ($p < 0.001$) lower body weights than CON, with 18IM showing the lowest value (3,205 vs. 3,001 and 2,441 g, respectively). Compared to CON, the 18% inclusion of IM significantly worsened feed conversion ratio (1.939 vs. 1.610 kg/kg, respectively for 18IM and CON; $p < 0.001$). As for breast meat quality, the dietary replacement of the soybean meal with IM only marginally affected the abovementioned parameters. Indeed, if compared with CON, 9IM and 18IM exhibited remarkably lower ($p < 0.05$) pHu values (5.64 and 5.64 vs. 5.79, respectively) that were not associated to impaired technological properties as no differences ($p > 0.05$) were found in drip and cooking losses and oxidation level of protein and lipid fractions. In conclusion, even if meat quality is not affected by the dietary replacement of the commercial corn-wheat-soybean diet with an IM, high level of inclusion is severely limited by the impairment of the production performances. Acknowledgement: This research was undertaken under the NextGenProteins (Transformation of Biomass into Next Generation Proteins for Food and Feed) project funded from the EU Horizon 2020 Research and Innovation Programme, Call H2020-LC-SFS-17-2019, G.A. no. 862704 (<https://nextgenproteins.eu/>).

PS5 - Non-soy protein sources**PS5-009 Innovative laying hens feed: black soldier fly live larvae supplementation. Effects on production performance, plumage status, and egg quality**A. Cattaneo^{1,2}, E. Sezzi³, M. Meneguzzi¹, D. Santori³, S. Cucci³, R. Roccatello², S. Dabou²¹BEF Biosystems s.r.l. , Via Tancredi Canonico 18/c, 10156 Turin, Italy, ²Center Agriculture Food Environment, University of Trento, Via Calepina 14, 38122 Trento, Italy, ³Istituto Zooprofilattico Sperimentale delle Regioni Lazio e Toscana (IZSLT) UOT LAZIO NORD, Strada Bagni 4, 01100 Viterbo, Italy

The use of insects in animal feed, and especially Black Soldier Fly (BSF) larvae, has the potential to reduce demand for soybean production, representing an innovative protein for their nutrition. Considering the poultry sector, it's been since the dawn of time that chickens have been used to eat live insects from the ground; nowadays research on BSF live larvae supplementation in the hens' diet is needed. The present study aims to evaluate the effects of live BSFL on laying hens by means of laying performance, plumage status, egg quality. The study has been performed at the experimental center of IZSLT using live larvae from the company BEF Biosystems for the purpose of valorizing agri-food by-products. A total of 108 Lohman hens (average live weight, LW: 1319.89 ± 93.20 g) were housed from 16 to 32 weeks of age. The birds were distributed in 27 cages (60x90x73cm) and assigned to 3 experimental groups (C, G1, G2; 9 replicate/treatment, 4 birds/cage). The C group (control) was fed commercial feed (Crude Protein (CP) 17,8%; Crude Fiber (CF) 5,4%; cellulose 3,0%; ash 13,2%), while G1 and G2 were supplemented with live BSF larvae (Ash 13,36%; Nitrogen-free extractives 19,47%; CF 11,12%; Fat 19,58%; CP36,47% (% on DM)) provided as 15% and 30 % of expected daily feed intake, respectively. Laying performance, feathering scores, ingestion time of the larvae, egg quality parameters were assessed each month. Has been evaluated egg weights (whole egg, yolk, albumen, shell), equatorial and longitudinal diameters, shell thickness, thick-albumen height and yolk height, yolk diameter, air chamber. Two-way ANOVA repeated measures has been performed, without detecting a significant difference considering the laying performance and feathering score of the birds. The FCR average values registered were 3.17±0.90 (C), 2.69±0.64 (G1), 2.86±0.78 (G2), without significant difference between the groups ($P > 0.05$), while there was a significant difference in larvae ingestion time between the groups ($P < 0.05$). Many egg quality parameters weren't affected by BSFL administration ($P > 0.05$); exception for shell and yolk color ($P < 0.05$), egg weight ($P < 0.05$), longitudinal diameter ($P < 0.05$). In conclusion, given the ability to breed BSF live larvae by enhancing agri-food by-products frequently destined for waste, they represent an advantageous and environmentally sustainable source of protein for the laying hen sector, without compromising productive performance or egg quality.

PS5 - Non-soy protein sources**PS5-010 Microbiological shelf life of Hermetia illucens meal**D. Santori¹, A. Gelli¹, M. Meneguz², S. Mercandino², S. Cucci¹, E. Sezzi¹¹Istituto Zooprofilattico Sperimentale Lazio e Toscana, Rome, Italy, ²BEFbiosystems, Turin, Italy

Insect meal represents a new frontier for sustainable alternative protein of feed, there are numerous studies on nutritional characteristic of this new feed, however there's not literature about shelf life of insects meal. Regulation (EU) 2021/1372 authorised the use of processed animal proteins derived from insects in poultry and pig feed and provided a significant boost to the European insect industry. The production of large quantities of insect meal and their storage make information on the shelf life of the product necessary. In the present work we analysed meal of *Hermetia illucens* subjected to two different treatments, the first one was pre-sterilized at 80°C for 2 hours (Tr.1), the second was treated at 65°C without pre-sterilization (Tr.2) as reported by Regulation (EU) 142/2011. We focused on specific microbiological parameters, namely: *E. coli* (ISO16649-2), Enterobacteriaceae (ISO21528-2), TMC at 30°C (ISO4833), yeasts and moulds (ISO21527-2), *Salmonella* (ISO6579), *Listeria monocytogenes* (ISO11290-1 and 2), *Bacillus cereus* (ISO7932), *Clostridium perfringens* (ISO7937), coagulase positive Staphylococci (ISO6888-2). We also performed analysis on AW (ISO18787) and pH (MFHPB-03:2014). Analysis was repeat 4 times during 12 months. *Salmonella*, *L. monocytogenes*, *B. cereus*, *C. perfringens* and coagulase positive Staphylococci were absent throughout the period in both the treatments. Regarding *E. coli* and Enterobacteriaceae, the two treatments show differences in both initial loads and growth dynamics. Presterilization at 80 degrees for 2 hours ensures lower initial loads for both *E. coli* (Tr.1 : 3×10^1 ; Tr.2 $2,1 \times 10^2$) and enterobacteriaceae (Tr.1 : $8,4 \times 10^2$; Tr.2 : 7×10^4); in terms of growth dynamics, *E. coli* grows faster in 80-degree presterilized flour, while enterobacteriaceae grow faster in non-presterilized flour. In any case, pre-sterilization ensures better bacterial load values. Since *H. illucens* contains unsaturated fatty acids, the products could be susceptible to oxidation so further studies on the oxidation status of stored flours will be needed as well as more studies about shelf life of insect-based ingredients, particularly for whole insect, powders, and insect oils.

PS5 - Non-soy protein sources**PS5-011 Standardized ileal digestible amino acids of single sell protein in broilers**S. Bypanahalli¹, H. Gangavadi², S. Mysore², R. Chikkanna²¹Veterinary College, Karnataka Veterinary Animal and Fisheries Sciences University, Bengaluru, India, ²Veterinary College, Karnataka Veterinary Animal and Fisheries Sciences University, Hassan, Karnataka State, India

An experiment was conducted to determine standardized ileal digestibility of amino acids (SIDAA) in single cell protein (SCP) for commercial broilers. The test diet and nitrogen free diet in mash form were fed to twelve replicate cages each (three birds per cage) for six days prior to digesta collection from the terminal ileum on 32nd day of age. Chromic oxide was added as an external marker at 0.5% of the diet. The SIDAA values in SCP was determined by correcting apparent ileal amino acid digestibility values (AIAAD) for basal ileal endogenous amino acid flow obtained from nitrogen free diet. The SCP employed in the trial was produced by methanotrophs, the primary strain is a *Methylococcus* and it contained (g/kg) Ala - 61.7, Arg - 39.9, Asp - 64.1, Cys - 4.5, Glu - 74.1, Gly - 39.1, His - 22.8, Ile - 32.6, Leu - 58.1, Lys - 49.2, Met - 7.3, Phe - 42.5, Pro - 26.2, Ser - 25.8, Thr - 32.5, Trp - 18.5, Tyr - 27.6 and Val - 39.8 and total protein was 66.3g/kg. The AIAAD values (%) of essential amino acids viz., Arg, His, Ile, Leu, Lys, Met, Phe, Thr and Val were 81.65, 76.60, 62.23, 66.69, 80.79, 81.41, 63.86, 66.14 and 65.78, respectively and SIDAA values (%) were 97.84, 87.84, 81.23, 81.22, 90.84, 88.11, 76.68, 87.25 and 81.55, respectively. The AIAAD values (%) of non-essential amino acids viz., Ala, Asp, Gly, Glu, Ser and Tyr were 63.42, 76.02, 62.58, 75.53, 61.10 and 46.49, respectively and SIDAA values (%) were 75.49, 89.69, 76.31, 90.34, 83.10 and 63.45, respectively. The apparent and standardised ileal digestibility of total protein was 69.28 and 84.09 % respectively. These values can be used for precision feed formulation incorporating SCP as feed ingredient in broiler diets.

PSS - Non-soy protein sources**PSS-012** The impact of replacement of soya bean meal with three rapeseed cake varieties on broiler performance and nutrient digestibilityF. Goodarzi Boroojeni¹, K. Männer¹, D. Boros², J. Zentek¹¹*Institute of Animal Nutrition, Freie Universität Berlin, Berlin, Germany,* ²*Laboratory of Quality Evaluation of Plant Materials, Institute of Plant Breeding and Acclimatization - National Research Institute, Radzików, Poland*

This study investigated the impacts of different inclusion levels of expelled rapeseed cakes (RSC) with various fiber content (canola quality black, brown and yellow rapeseed varieties) in broiler diets on growth, feed efficiency and nutrient digestibility. Six isocaloric and isonitrogenous experimental diets were produced by using three different RSC varieties at 10 and 20 % inclusion levels, as partial replacements for soybean meal. In total, 480 one-day-old broiler chicks were randomly distributed to 48 pens and the diets were randomly assigned to pens (8 pens per diet). Performance variables were recorded weekly and the apparent ileal digestibility (AID) of nutrients was measured at d 35. Data were subjected to ANOVA using the GLM procedure. During the grower period (d 22-35) and entire experiment (d 1-35), body weight gain (BWG) and feed conversion ratio (FCR) of broilers fed brown (BR) and yellow (YL) RSC were better than birds receiving black (BL) RSC ($P \leq 0.05$). However, inclusion levels of RSC had no impact on performance variables, while increasing the inclusion level of RSC in broiler diets reduced AID of P, crude protein (CP), total amino acids (AA), Asp, Thr, Ser, Ala, Leu, Phe, Tyr, Lys, Arg and Pro ($P \leq 0.05$). BR- and YL-RSC diets showed better AID of fat than the BL-RSC diets, while AID of P in the diets with BR- and BL-RSC was better than those with the YL-RSC ($P \leq 0.05$). AID of Glu, Val, Leu, Ile, Lys and total AA was higher in the diets containing BR-RSC compared with the BL- and YL-RSC diets, while AID of Tyr and Phe in the BR-RSC diets was higher than the YL-RSC diets ($P \leq 0.05$). AID of Met in diets with the YL-RSC was lower than the diets containing BL- and BR-RSC ($P \leq 0.05$). In conclusion, increasing inclusion level of RSC from 10 to 20 % in the diets had no negative impact on performance of broilers, while birds receiving diets with lower fiber RSC (BL and YL varieties) performed better than those fed diets with the BL-RSC. However, AID of nutrients in the diets was not completely in line with what was observed for growth performance of birds. Increasing the inclusion level of RSC in broiler diets impaired AID of P, CP and most of the AA, while in general, diets with the BR-RSC showed higher nutrients digestibility compared with diets containing the BL- and YL-RSC. It seems that nutritionists would need to take the variety of rapeseed into account when sourcing and ascribing nutrient digestibility values to different RSC.

PS6 - Unsolved issues in poultry nutrition**PS6-001** Assessment of two dietary models for investigation of the effects of amino acids supplementation into low-protein diets for broiler chickensO. Olukosi¹, H. Philippi^{1,2}¹*Department of Poultry Science, University of Georgia, Athens, United States,* ²*Institute of Animal Science, University of Hohenheim, Stuttgart, Germany*

Two experiments were run concurrently to study two dietary models investigating the effect of amino acid (AA) supplementation on low-protein (LP) diets for broiler chickens. The objective of Exp. 1 was to assess the impact of accounting for N content (crude protein, CP, value) of individual supplemental AA during feed formulation on growth performance and N excretion of broiler chickens. Exp. 2 was to investigate the above question in phytase-supplemented diets. Each experiment utilized 3 diets: positive control (PC) diet adequate in CP and meeting digestible AA requirements and two LP diets supplemented with AA. All the 3 diets met the digestible AA requirement of the breed. Gly and Ser were added to LP diets as non-specific N sources. The N content of the individual AA supplemented into the LP diets was used for diet protein level calculation in one of the diets (LPY) but not in the other (LPN). Each treatment had 8 replicates and 5 birds per replicate. All the birds received nutrient-adequate diets from day 0 to 7 and experimental diets from day 7 to 21. Birds and feed were weighed on days 7 and 21, and excreta were collected over 24 hours from day 20 to 21. In Exp. 1, weight gain decreased ($P < 0.01$), and FCR increased ($P < 0.05$) in the order PC > LPN > LPY. Feed intake was similar for LPY and LPN but lower ($P < 0.01$) than the PC diet. There were no treatment effects on excreta DM, but the total N excreted over 24 hours decreased ($P < 0.01$) in the order PC > LPN > LPY. In Exp. 2, weight gain and feed intake were similar for PC and LPN but greater ($P < 0.01$) in both diets than in LPY. FCR was similar for PC and LPN but lower ($P < 0.05$) in both diets than LPY. There was no treatment effect on excreta DM, but total excreted N was similar for PC and LPN but greater ($P < 0.01$) in both diets than LPY. The analyzed N content of the PC and LPY diets was as expected, whereas the analyzed N in the LPN diet was greater than the expected value. Conclusions from the two experiments are that whether the CP values of the AA supplemented to low-protein diets are accounted for or not during diet formulation impacts the conclusion drawn regarding the effect of AA supplementation on growth performance and N excreted by broiler chickens, and the outcome was more pronounced in diets not supplemented with phytase. In addition, the least excreted N was observed in broilers receiving diets in which CP values of supplemental AA were used in diet formulation.

*PS6 - Unsolved issues in poultry nutrition***PS6-002 Dietary supplementation with sodium butyrate: live performances, carcass traits and myopathy occurrence in female and male broilers**

M. Boskovic Cabrol¹, A. Huerta Palacios¹, A. Trocino¹, M. Birolo¹, F. Bordignon¹, F. Pirrone¹, G. Xiccato¹

¹Department of Agronomy, Food, Natural Resources, Animal and Environment (DAFNAE), University of Padova, Padova, Italy, Padua, Italy

The present study aimed to evaluate the effect of different inclusion levels of sodium butyrate in diets with two fat levels on growth performances and myopathies occurrence in broiler chickens of both sexes. A total of 900 one-day-old chicks (Ross 308) were allocated to 36 pens according to a 2 × 3 × 2 factorial design encompassing two fat inclusion levels (lower fat-grower diet: 6.7%; finisher diet 7.7%; and higher fat-grower diet: 7.7%; finisher diet: 8.9%), three levels of microencapsulated sodium butyrate (0 mg/kg, 150 mg/kg and 300 mg/kg) and two sexes (3 pens per experimental group). As expected, a higher fat diet resulted in greater body weight (P<0.001), average daily gain (P<0.001), and better feed conversion ratio (P<0.001) compared to chickens fed a lower fat diet, whereas feed intake was not affected (P>0.10). The chickens fed a higher fat diet had higher cold carcass weight (P<0.01) and dressing percentage (P<0.05), and greater Pectoralis major yield (P<0.05) in comparison with birds fed a lower fat diet. Sodium butyrate supplementation did not affect growth performance nor slaughter yield and carcass traits (P>0.05). Compared to males, female chickens had lower body weight, weight gain, and feed intake (P<0.001) and worse feed conversion rate (P<0.001). In addition, females had higher dressing percentage (P<0.001), and greater breast and P. major yields (P<0.001) in comparison with males. Furthermore, no interactions between sodium butyrate and fat inclusion level, nor sodium butyrate and sex were observed. At gross examination, regardless of the experimental factors, the occurrence of myopathies was 56.25% for white striping (WS), 24.31% for wooden breast (WB), and 7.64% for spaghetti meat (SM). The occurrence of WB was higher in males than in females (18.75% vs. 5.56%; P<0.01), whereas SM showed an opposite trend (6.94% in females vs. 0.69% in males; P<0.05). Moreover, the high-fat diet increased the occurrence of WS (34.72% vs. 21.53%; P < 0.01) and SM (6.94 vs. 0.69%; P<0.05). Finally, the overall occurrence of WS, WB, and SM were not affected (P>0.05) by the butyrate addition. In conclusion, sex and dietary fat level affected the growth and myopathy occurrence. In contrast, butyrate did not modify performances and breast abnormalities, while effects at the gut level have to be investigated. Funding: The grant of M. Boskovic Cabrol was supported by the DEMyo project (No 101063055) funded by the European Commission under the HORIZON-MSCA-2021-PF-01 call.

*PS6 - Unsolved issues in poultry nutrition***PS6-003 Effect of 125% and 135% arginine diets on growth performance and immunological response to necrotic enteritis in broilers**

S. Fathima¹, W. Al Hakeem¹, B. Shah¹, R. Shanmugasundaram², R. Selvaraj¹

¹University of Georgia, Athens, United States, ²United States National Poultry Research Center, Athens, United States

Legislative restrictions on the prophylactic use of antibiotics in feed led to the reemergence of necrotic enteritis (NE) in poultry, necessitating the need to develop alternatives to in-feed antibiotics. Arginine is an essential amino acid that is the substrate for nitric oxide and ornithine biosynthesis. Arginine can modulate the immune response of birds to the Eimeria challenge by regulating macrophage polarization and subsequent inflammatory pathways. This study evaluated the effects of 125% and 135% L-arginine on the production performance and immunological responses in necrotic enteritis (NE) challenged broilers. A total of 480 day-old chicks were randomly allocated into four treatment groups consisting of 6 replicates each: 1. Uninfected +basal diet 2. NE +basal diet 3. NE +125% arginine diet and 4. NE +135% arginine diet. The basal diets were formulated to meet or exceed Cobb-500 nutrient requirements. NE was induced by inoculating 1×10⁴ sporulated Eimeria maxima oocysts on day 14 and 1×10⁸ CFU C. perfringens on day 19,20,21 of age. All data were analyzed by ANOVA and the means were compared by Tukey's HSD and were considered significantly different at P ≤ 0.05. NE infection significantly increased the feed conversion ratio (FCR) (p< 0.01), intestinal permeability (p= 0.02), jejunal lesion score (p< 0.01), and the ratio of CD4+:CD8+ cells in cecal tonsils (p= 0.02) and decreased the body weight gain (BWG) (p< 0.01), and bile anti-C. perfringens IgA concentration (p= 0.04). Arginine supplementation did not reverse the NE-induced loss in BWG, and intestinal permeability nor did have a significant effect on the NE lesion score of the birds. 135% arginine increased the FCR by 10 points (p = 0.01) at day 35. 125% arginine diet significantly increased the bile anti-C. perfringens IgA concentration by 37.5% (p = 0.02) on day 28. 125% and 135% arginine diets significantly decreased the ratio of CD4+:CD8+ cells in the cecal tonsils on day 28 (p= 0.03) and day 35 (p= 0.01). To conclude, the 125% arginine diet, can be used in combination with other feed additives to partially replace antibiotics in broilers due to its immunomodulatory effects.

PS6 - Unsolved issues in poultry nutrition**PS6-004 Effect of corn particle size and pellet diameter on the particle size in the microstructure of pelleted diets**W. Pacheco¹, S. Bonilla¹¹Auburn University, Auburn, AL, United States

Corn and meal particle size influences pellet quality and broiler performance. The objective of this study was to evaluate the effect of corn particle size and pellet diameter on the average particle size in the microstructure of pellets after particle agglomeration to quantify the degree of grinding that occurs during the pelleting. Corn was ground using a two-pair roller mill to obtain four particle sizes (855, 1,659, 2,043 and 2,534 mm). Ingredients were blended using a twin shaft mixer to produce the meal diets. After mixing, 16 meal samples from each corn particle size were collected for particle size analysis of meal diets. Thereafter, meal diets were steam conditioned at 77°C with a retention time of 45 seconds and pelleted with either a 3.0 or 4.0- mm pellet die. The experiment consisted of a 3 x 4 factorial arrangement (feed form x particle size) with 4 replicates per treatment. Pelleted samples were collected randomly from 4 bags during bagging and then subjected to a methodology previously developed by our research team to separate agglomerated particles after pelleting. After particle separation, particle size was analyzed using the ASABE method S319.4 with the addition of 0.5 grams of sieving agent (silicon dioxide) to prevent particle agglomeration during particle size analysis. Data were statistically evaluated using the GLM procedure of JMP and means were separated by Tukey's HSD with a statistical significance considered at $P < 0.05$. Pellet diameter did not influence the degree of grinding during pelleting ($P > 0.05$). However, diets pelleted with 3 mm die had greater PDI ($P < 0.05$) than diets pelleted with 4 mm die, regardless of the initial corn particle size. As corn particle size increased, particle size of the meal diets increased (936, 1,251, 1,387, and 1,567 μm ; $P < 0.05$). Furthermore, the degree of grinding during pelleting increased as meal particle size increased regardless of the pellet die diameter (936 vs. 598 and 603 μm), (1,251 vs. 755 and 742 μm), (1,387 vs. 913 and 818 μm), (1,567 vs. 877 and 871 μm). The results of this study indicated that pellet diameter did not influence the degree of grinding during pelleting, but higher PDI was obtained with 3 mm pellets. Furthermore, as meal particle size increased, the degree of grinding during pelleting increased.

PS6 - Unsolved issues in poultry nutrition**PS6-005 Effects of eggshell translucency and coloration lightness on eggshell thickness, hatchability and chick weight in broiler breeders**D. Neves¹, L. Orellana², R. Burin¹, J. Krehling², A. Urrutia², L. Almeida^{2,3}, L. Munoz², C. Escobar², P. Soster^{2,4}, B. Chaves-Cordoba², M. Bailey², C. Williams⁵, C. Torres¹, L. Linares¹, M. Rebollo¹, K. Macklin²¹Zinpro Corporation, Eden Prairie, United States, ²Auburn University, Auburn, United States, ³Universidade Federal do Paraná, Curitiba, Brazil, ⁴Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, ⁵Wayne-Sanderson Farms, Oakwood, United States

Several eggshell quality parameters such as shell weight, thickness, strength and density have been demonstrated to impact hatchability. The aim of the current study was to describe possible effects of shell translucency (T score) and coloration lightness (L*value) parameters on shell thickness, hatchability and chick weight. A total of 4320 eggs from 4 commercial Ross 708 breeder flocks, between 50 and 55 weeks of age were provided the same diet and used for this study, where 1080 eggs per flock were selected for T score and L*value. Egg weight and shell thickness were assessed during the egg's enrollment; egg weight, infertile eggs, embryo death, cracked, contaminated and exploders were measured and removed at transfer; hatched/unhatched eggs, culls and chick weight were measured at hatch. For T score, a 3-point subjective scoring system was used as the main categorical parameter based on the amount, size and coverage of spot areas or mottling in the shell (1=low, 2=medium, 3=high). Shell L*value was evaluated using an electronic colorimeter sorting the eggs as light (avg. $L^*=80.7$) or dark (avg. $L^*=76.0$). For shell thickness a noninvasive ultrasound gauge was employed. Data from this experiment was analyzed using the GLIMMIX procedure of SAS (V9.4) and Tukey's HSD test was performed to separate means with significant differences when $P \leq 0.05$. Results suggest that shell color was related to initial egg weight on the day of collection ($P < 0.01$) and at 18d of incubation ($P = 0.02$), in both cases dark eggs were 0.6g heavier than light eggs. Dark eggs had 2.4% lower egg loss at hatch ($P < 0.001$), 3.8% increased hatchability of fertile eggs ($P = 0.003$) and yielded 0.006mm thicker shells ($P = 0.0019$) compared to light eggs. Regarding translucency, egg weight at transfer was 0.8g heavier for T score 1 eggs compared to 3 ($P < 0.04$). Furthermore, T score 1 had 5.8% lower egg loss at transfer ($P = 0.028$), 6.9% higher hatchability of set eggs ($P = 0.07$) and 0.7g heavier chick weight ($P < 0.03$) compared to score 3. However, T score 1 eggs had shells 0.028mm thinner than score 2 and 0.034mm thinner than score 3 ($P < 0.001$). An interaction effect was observed for shell thickness, L*value and T score, where eggs classified as dark with T score 1 had thinner shells compared to dark eggs with score 3 ($P = 0.029$). These results suggest that shell translucency and coloration lightness can be good non-invasive indicators of shell thickness, hatchability and chick weight in breeder flocks.

PS6 - Unsolved issues in poultry nutrition**PS6-006** Evaluation of conditioning temperature and retention time in the hygieniser on *Enterococcus faecium*, true amino acid digestibility, and metabolizable energyW. Pacheco¹¹Auburn University, Auburn, AL, United States

Meat and eggs are universally accepted animal protein sources. However, in the past, they have been linked to Salmonella outbreaks. *Enterococcus faecium* has been used as a Salmonella surrogate in several thermal mitigations in poultry feeds. This study aimed to determine effects of conditioning temperature and retention time in the hygieniser on inactivation of *E. faecium*, true metabolizable energy (TMEn), and true amino acid digestibility (TAAD) using cecetomized roosters. Inoculated diets with *E. faecium* were arranged in a 3 x 3 factorial design with three conditioning temperatures (75, 85, and 95°C) and three retention times in the hygieniser (80, 160, and 240 seconds). An uninoculated meal diet after mixing, was used as control. Inoculated mash feed had *Enterococcus* levels was 5.29 ± 0.20 log cfu/g. Forty Single Comb White Leghorn Roosters were fasted for 30 hours, precision-fed 35 grams, and excreta collection was done for 48 hours post-feeding to analyze TAAD and TMEn. Data were analyzed as a one-way ANOVA using the GLM procedure of SAS software, and means were separated using Tukey's HSD, significance was accepted at $P \leq 0.05$. *E. faecium* levels decreased by all processing temperatures and retention times and there were no detectable *E. faecium* at 85 and 95°C. A temperature of 75°C during conditioning was sufficient to decrease the amount of *E. faecium* by 2 log CFU/g; the hygieniser reduced it by a further 1 log compared to the conditioner, and the pellet mill by an additional 1 to 1.5 log. Conditioning temperature and retention in the hygieniser did not influence TAAD ($P > 0.05$). Diets conditioned at 75°C for 80 seconds contained more than 120 kcal/kg of TMEn relative to the control diet (nonconditioned). These results indicate that although the surrogate *E. faecium* is significantly reduced when using a conditioning temperature of 75°C, that reduction can be increased to > 5 log CFU/g when the conditioning is increased to 85 or 95°C for 15 seconds in the conditioner and retained in the hygieniser for at least 80 seconds. Conditioning temperatures and retention times can be utilized as a tool to mitigate microbial load in feeds and to increase metabolizable energy.

PS6 - Unsolved issues in poultry nutrition**PS6-007** Feeding pullets in stressful conditions: does mash size matter?A. Mens^{2,1}, I. de Jong², E. Parand², R. Kwakkel¹¹Departement of Animal Nutrition, Wageningen UR, Wageningen, Netherlands, ²Wageningen UR Livestock Research, Wageningen, Netherlands

The rearing period of laying hens is important since a pullet needs to develop into a high producing layer. In 18 weeks, all their physical and physiological processes and their gastro-intestinal tract must develop correct. Improper rearing conditions and stressful events could lead to both physical and behavioural problems in the laying period. Adequate nutritional strategies not only supports egg production, but are also important to cope with challenges in early life. It has been suggested that this not only relates to the diet composition and ingredients, but also the physical form of the diet. Thus, this study aimed to test a coarse and fine mash together with a stress during early rearing on growth development of pullets, development of the gizzard/proventriculus, neuro-endocrine parameters and performance of layers until 35 weeks of age. In total, 1,560 one-day-old pullets were divided over 60 identical pens in three climate-controlled rooms. Treatments were arranged according to a 5x2 - factorial design with stress imposed in five different age intervals (wk 1-3, 3-5, 5-7, 7-9) or no stress, and two diet forms (finely or coarsely ground mash) throughout the experiment. The imposed stressor consisted of removal of litter material, perches and pecking blocks and housing on solely slats. The fine diet had a sieve size of 1.5mm (wk 1-4), and 2mm for all subsequent diets, while the coarse diet started with 3 mm (wk 1-4), followed by 5 mm (wk 5-12), and 8mm for the subsequent diets. The coarseness of the mash did not influence early egg production, however increased the FI in wk 31-35 (+54g; $P=0.01$) and egg weight in wk 20-25 (+0.8g; $P=0.002$). Furthermore, early life stress had some effect on egg production. Between wk 26-30, egg production was higher in layers which endured stress between wk 3-5, as compared to the other age intervals (+1.4 %-point; $P=0.02$). Moreover, between wk 31-35, layers enduring stress during wk 7-9 laid fewer eggs as compared to all other treatments (-1.7 %-point; $P=0.02$). The gizzard/proventriculus was better developed throughout the hens lives when feeding the coarse mash ($P<0.001$). Further analyses of neuroendocrine parameters and gut morphometry are pending. In conclusion, the coarseness of mash diet provided in rearing, or the stressful conditions had small effects on layer performance later in life. An obvious effect was found of diet form on gizzard development, indicating a potential effect on gut functionality.

*PS6 - Unsolved issues in poultry nutrition***PS6-008 Investigation into the potential of superdosing phytase to release plant derived phosphorus for broilers from hatch**V. Mulraney¹, D. Scholey¹, H. Warren², E. Burton¹¹Nottingham Trent University, Nottingham, United Kingdom, ²Alltech, Samford, United Kingdom

The majority of dietary phosphorus (P) is primarily stored in the form of phytates and are poorly bioavailable to poultry due to the lack of an endogenous phytate-degrading intestinal enzyme phytase. To combat this common practice is to supplement diets with mineral P. To investigate if mineral P can be completely removed from the diets of broiler from hatch. The trial received a favourable opinion from the University's ethical review group prior to starting. 816 male Ross 308 broilers were fed a specially formulated mash diet. There were 3 diets; High dig P Control; 0.45% digestible P from a mineral source with 500FTU, Low dig P Control; 0.35% digestible P from mineral source with 500FTU & Phytase only P; 0.35% digestible P provided by adding 2000FTU. Birds were offered *ad libitum* access to food & water throughout the trial & housed in groups of 17 per pen from day one with 16 replicates per treatment diet. Birds were euthanized at day 7 (7 birds per pen) and day 21 (6 birds). Calcium (Ca) & P concentration in tibias & d21 litter was measured by using ICP-OMS. Bone strength was tested with a texture analyser post-mortem. A one-way ANOVA with Duncan Post Hoc tests were performed using SPSS (v25). On day 7, there was a significant decrease in BWG & bone strength between the Low dig P Control diets (166g/52.98N) and the Phytase only P diet (109g/47.01N), but, by d21, there was a no significant difference in bone strength between the Low dig P Control (222.21N) when compared to Phytase only P diet (211.46N), although birds fed the High dig P control diet (249.73N) showed significantly stronger bones than both low P diets. There was no significant difference in FCR, FI & Ca & P in tibia bones at day 21 across all three diets but there was a significant reduction in excreted P in the litter of Phytase only P fed birds (0.18g/kg) compared to High dig P Control (9.2g/kg) and Low dig P Control diets (6.6g/kg) and the Phytase only P diet ($p < 0.001$) Removing Inorganic mineral P from broiler diets significantly reduced the amount of P excreted by the birds without any comprise to bone strength or growth in birds aged 21 days.

*PS6 - Unsolved issues in poultry nutrition***PS6-009 Mycotoxin deactivator promotes the intestinal health of broiler chickens co-challenged with salmonella and mycotoxins**D. Preveraud¹, M. Ingberman², B. Castello Branco Beira², N. Simarro-Fagundes³, W. Quinteiro-Filho³¹Adisseo France SAS, Antony, France, ²Imunova Análises Biológicas, Curitiba, Brazil, ³Adisseo Brasil, São Paulo, Brazil

The objective of the study is to evaluate in broilers the impact on intestinal and health parameters of a mycotoxin challenge with the presence of Salmonella infection. For that, 276 one-day-old Ross broilers were acquired from a commercial hatchery. The animals were randomly assigned to 6 different experimental groups of 46 broilers each (1 replication (isolator) per group). The treatments consist of a control group (ctrl), a mycotoxin group (CM), a mycotoxin group receiving a mycotoxin deactivator (CM-MD), a Salmonella group (CS), a co-infection mycotoxin-Salmonella group (CMS), and a mycotoxin-Salmonella group receiving a mycotoxin deactivator (CMS-MD). On the first experimental day, the animals in CM, CMS, CM-MD and CMS-MD groups started to receive the mycotoxins in their diet (added fungi culture containing fumonisins (12,744 ppb), deoxynivalenol (1452 ppb) and T-2 toxin (358 ppb)). On the fourth experimental day, each animal of CS, CMS and CMS-MD groups received 1x10⁸ CFU Salmonella Heidelberg by oral delivery. Then, between d4 to d28, intestinal permeability was evaluated by serum FITC-dextran, ceca content was collected to assess Salmonella spp. counts by Most Probable Number (MPN) and microbiota composition was determined using S16 sequencing. In cecal tonsil, the cytokines gene expression was measured, histomorphology was assessed from jejunum and cecum tissues and liver samples were also collected for lipoperoxidation and histopathology evaluation. Finally, anti-salmonella IgA was quantified in feces. Statistical analysis was performed by two-way ANOVA with Tukey's post-hoc test ($P < 0.05$). Mycotoxin presence in the feed can significantly increase intestinal permeability ($P=0.0157$) and numerically increase pro-inflammatory IL6 cytokine, leading to an higher passage of Salmonella across the epithelium and an activation of macrophages. The mycotoxin deactivator solution based on mineral clays, deactivated yeast, botanicals, antioxidant has shown significant effect on gut permeability (decrease FITC-d), salmonella prevalence (decrease MPN), redox status (decrease LPO), and inflammation (decrease IL6 and increase IL10). In conclusion, this study shows that a moderate fusarium mycotoxin challenge can highly negatively impact the health of the animals and can be a prevalence factor for Salmonella infection as well. An anti-mycotoxin solution with complementary modes of action can protect the birds and promote sensitive biomarkers of intestinal health.

PS6 - Unsolved issues in poultry nutrition**PS6-010 Potential influence of methionine source and level on appetite regulation in broiler chickens**L. Gong¹, T. Mahmood², Y. Mercier², Y. Guo¹¹College of Animal Science and Technology, China Agricultural University, Beijing, China, ²Adisseo France S.A.S, Commeny, France

This study aimed to investigate the effects of methionine (Met) source and level on growth performance, gene expressions of taste receptors, gut hormones, and appetite-related genes of broiler chickens. Two Met sources (DL-Met and OH-Met) and three digestible TSAA / Lys levels i.e., 0.58, 0.74, and 0.90%, corresponding to low, control (Arbor Acre recommended) and high levels, respectively were used in a 2 × 3 factorial design. A total of 720, 1-day-old AA male broiler chicks were randomly assigned to 6 treatments with 10 replicates of 12 chicks. Growth performance was recorded during the study period from 1-14 d. At day 14, one chicken per replicate pen was selected to collect gut and hypothalamus tissue samples for subsequent analyses. Met level but not the source influenced growth performance ($P < 0.05$). Specifically, both low and control groups had higher feed intake than high TSAA group and body weight was inversely related to TSAA level ($P < 0.05$). The gene expressions of umami taste receptors (T1R1 and T1R3) were upregulated in duodenum, jejunum, and ileum by low TSAA group compared with the other levels ($P < 0.05$). In the jejunum, gene expressions of both T1R1 and T1R3 were upregulated by OH-Met supplemented groups compared with the DL-Met group ($P < 0.001$). Gene expression of anorexigenic hormone (CCK) was increased with TSAA doses irrespective of the source in duodenum whereas this dose effect in jejunum was accompanied by a sources effect with upregulation in DL-Met treatment. In the hypothalamus, the appetite-stimulating (AgRP) and appetite-suppressing genes (POMC and MC4R) were upregulated with Met level. MCR4 gene expression was also up-regulated by OH-Met source ($P < 0.05$). We also observed that low TSAA upregulated the mTOR expression significantly compared with the other two Met levels ($P < 0.05$). Distinctly, Met source effect was observed with OH-Met that downregulated mTOR but upregulated the gene expression of AMPK α 1 ($P < 0.05$). In conclusion, our findings showed that the gene expressions related to appetite regulation in the gut and hypothalamus of broilers are regulated by the Met level, wherein low TSAA level could potentially improve L-amino acid sensing in broiler gut. Besides, OH-Met has the potential to influence the sensors of cellular energy levels (AMPK and mTOR) in the hypothalamus. This study provides a new research approach to explore the molecular mechanism of the effects of Met source and level on the growth of broilers.

PS6 - Unsolved issues in poultry nutrition**PS6-011 Pre-hatch feeding of broiler embryos with calcium salt of OH-Methionine: A study of feasibility**J. Dayan¹, T. Mahmood², Y. Mercier², Z. Uni¹¹Department of Animal Science, Faculty of Agriculture, Food and Environment, The Hebrew University of Jerusalem, Rehovot, Israel, ²Adisseo France S.A.S, Commeny, France

Dietary uptake of methionine (Met) is pivotal for broilers development, growth, and production. Pre-hatch supplementation of Met source may provide impetus for muscle development. Therefore, this study aimed to examine whether pre-hatch supplementation of 2-hydroxy-4-(methylthio) butanoic calcium salt (OH-Met), by in ovo feeding (IOF) method, will improve the performance of broiler embryos, hatchlings, and muscle development. A pre-test was carried to select optimum doses of OH-Met for IOF solutions. Based on solubility, osmolality (mmol/kg), and pH levels; OH-Met 1% in 0.5% NaCl (osmolality: 274; pH: 6.05), OH-Met 2.25% in 0.4% NaCl (osmolality: 284; pH: 6.44), and OH-Met 3.5% in 0.2% NaCl (osmolality: 289; pH: 6.34) were selected as IOF solutions. All OH-Met solutions were dissolved perfectly, clear, and stable with no sedimentation. 400 fertile eggs from 39 weeks old breeder flock (Cobb500; weight: 68.3g ± 3.4g) were obtained from a commercial hatchery and distributed into 4 treatment groups with 100 eggs per treatment group. These eggs were incubated under Cobb standard conditions (Temp.: 37.8°C; RH: 56%). At embryonic day (E17), each egg was injected with 0.6ml of IOF solution according to treatment groups. Non-injected eggs served as control. Hatching profile was recorded in a 3-hour interval from E19 until the end of incubation. All the birds were fed a common commercial pre-starter diet ad-lib. Ten birds per treatment group at D0, D3, and D10 post hatch were used to record body weight, breast muscle (BM) weight, residual yolk (RSY) weight and their relative percentages. At D10 post hatch, BM samples were taken for histological analysis using Sirius Red and Fast Green staining. Results verified the feasibility of injecting all doses of OH-Met to broiler embryos at E17 as hatchability was not reduced. Furthermore, the IOF of OH-Met 3.5% had numerically highest hatchability percentage with 98% compared to average of 93% in all other treatments. The BM and RSY percentage, were not significantly different between the treatments. Nevertheless, histological analysis of the BM on D10 revealed smaller fiber size (short diameter) in the OH-Met 3.5% group compared to control ($P < 0.0001$). These preliminary data are suggestive of increased hyperplasia over hypertrophy of the muscle fibers with IOF of OH-Met 3.5%. However, further research is necessary to elucidate the implications of OH-Met 3.5% IOF on long term effect on muscle growth of broiler chickens.

PS6 - Unsolved issues in poultry nutrition**PS6-012** Tailor-made probiotic as alternative to increase intestinal and respiratory integrity of broilers under field conditionsM. Kipper¹, F. Franco², R. Magalhães², M. Sousa², P. Almeida¹¹Elanco Animal Health, São Paulo, Brazil, ²Nutriza Friato, Pires do Rio, Brazil

Low intestinal and respiratory integrity are associated with lower productive performance in broiler. The objective of this study was evaluating a tailor-made blend of *Bacillus subtilis* added to the feed as an alternative to improve these indexes. The assessment was carried out in a commercial facility equipped with 26 mesh boxes (2 m²) spread throughout the building. Each box receives 26 birds and were randomly distributed into 2 treatments: (1) Control, birds with the company's standard diet; (2) Correlink™ (Elanco, Animal Health), standard diet plus 1.5 x 10⁵ UFC/g of feed of *Bacillus subtilis* (ABS747 + ABS1781). Birds had free access to water and feed through the trial. At 31 days of age, 1 bird per box was selected for intestinal and respiratory integrity assessment via HTSi™ (Elanco, Animal Health). Briefly, the birds were euthanized and necropsied to observe the presence or absence of macroscopic changes, including: cellular sloughing, cecal gas, excessive intestinal fluid, excessive intestinal mucus, thin intestines, gizzard erosion, feed passage, airsacculitis, pododermatitis, and yolk retention. The exceptions were pododermatitis and gizzard erosion which were classified in 4 scores and airsacculitis in 5 scores. The results are presented in percentage of affected birds. Intestinal and respiratory integrity were calculated using regressions from the literature and based on lesion scores. The results show an improvement in intestinal integrity (94.8 vs 95.5% - Control vs Correlink™) when using Correlink™. This increase was an outcome of the reduction on the occurrence of the lesions: cellular sloughing (30.8 vs 0.0%), cecal gas (38.5 vs 23.1%), excessive intestinal fluid (61.5 vs 46.2%), thin intestines (15.4 vs 7.7%), gizzard erosion (46.2 vs 38.5%), and feed passage (7.7 vs 0.0%). Excessive intestinal mucus content was increased (61.5 vs 84.5%) in the group with Correlink™. Improvements in respiratory integrity (95.4 vs 96.3%) were also associated with Correlink™ and was an outcome of the reduction in airsacculitis (38.5 vs 30.8%). Lastly, pododermatitis (23.1 vs 15.4%) and yolk retention (7.7 vs 0.0%) were reduced in the group with Correlink™. Results shown that using Correlink™ in broiler feed is an effective strategy to improve intestinal and respiratory integrity indexes, improving the overall birds' health and leading to a greater productivity.

PS6 - Unsolved issues in poultry nutrition**PS6-013** The effects of methionine and threonine supplementation in low protein diets on the performance of broiler chickens challenged with *Eimeria*J. Taylor¹, G. Liu², A. Ajao², T. Applegate², R. Selvaraj², O. Olukosi², W. Kim², E. Ball¹, I. Kyriazakis^{3,1}¹Agri-food and Biosciences Institute, Belfast, United Kingdom, ²University of Georgia, Athens, United States, ³Queen's University Belfast, Belfast, United Kingdom

We aimed to investigate the effects of supplementing methionine (Met) and threonine (Thr) in low protein diets offered to broilers challenged with *Eimeria* spp. All birds were offered the same starter diet from d0-10 of age. Four grower diets were formulated: positive control (PC) with 18.5% crude protein (CP), negative control (NC) with 16.5% CP, NC supplemented with Met (0.97%) or Thr (1.23%). A 4x2 factorial arrangement (4 diets, each with or without a mixed *Eimeria* challenge on d14) was used in the study. Feed intake was measured daily from d0-13 post-infection (pi) and body weight was measured on d0, 4, 7, 11 and 14pi. A repeated measures mixed model with diet, infection and day as fixed factors and their interactions was used to identify the pre-patent (d0-3pi), acute (d4-7pi) and recovery (d8-13pi) periods of infection. ADFI and ADG were calculated over each of these 3 stages and analysed with GLM models with diet and infection as fixed factors and their interactions. Body weight at d0pi was included as a covariate to account for the different growth trajectories of birds on different diets. Infected birds showed a significant reduction in ADFI and ADG during the acute stage of infection ($P < 0.05$). Diet showed no effect on ADFI during any stage of infection ($P > 0.05$) but significantly affected ADG during the pre-patent period ($P < 0.05$). ADG of the birds given NC + Met was significantly reduced compared to those given the PC diet or the NC + Thr. There was no interaction between diet and infection on ADFI or ADG during any stage of infection ($P > 0.05$). In conclusion the results suggest that low CP diets supplemented with Thr or Met do not reduce the effects of a mixed *Eimeria* challenge on broiler performance. This research was conducted under the Adisseo Research Grant 2021.

PS6 - Unsolved issues in poultry nutrition**PS6-014 Variability in the nutrient composition and standardized ileal amino acid digestibility of dried grains with solubles in broilers**I. Andretta¹, H. Rech¹, M. Kipper¹¹Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil

Managing the ingredient variability is a key step to improve profitability and sustainability of animal production. In this context, assessing the variability that exists in the nutritional values of the main feedstuffs is crucial, particularly for co-products. This study investigated the variability on nutrient composition and lysine standardized ileal digestibility (SID) coefficient of dried grains with solubles (DDGS) in broilers. Standard methods for systematic review were used. First, the research question was proposed following the PICo-format (population: broilers up to 42 days old; intervention: DDGS assessment; context: studies developed using a nitrogen-free diet in the methodology). Previous studies published in peer-reviewed journals were considered for the database only if matching the above criteria. The search was conducted in November 2022 in scientific journals available in PubMed, Scopus, and Web of Science. Obtained references (n: 576, from which 359 were duplicates) were assessed carefully considering the information presented in each title (84 removals), abstract (52 removals), and complete article (67 removals). Finally, a database was built using the information collected in 14 studies published from 2008 to 2020. Most of the studies (11) focused on DDGS produced from corn. The selected studies assessed a total of 41 sources of DDGS and confirmed the great variability on the nutritional composition of this ingredient. The crude protein levels in DDGS varied from 18.1 to 53.4% (mean: 29.5%; CV: 23.9%; first quartile [Q1]: 25.6%; median [Q2]: 28.6%; third quartile [Q3]: 53.4%), while the total lysine content ranged from 0.26 to 1.40% in the assessed sources (mean: 0.70%; CV: 32.4%; Q1: 0.54%; Q2: 0.71%; Q3: 0.79%). The SID lysine digestibility coefficient also varied greatly among the sources of DDGS (mean: 56.2%; ranging from 26.0 to 80.9%; CV: 24.6%; Q1: 46.9%; Q2: 58.7%; Q3: 68.9%), highlighting the importance of tools for adjusting the nutritional matrices of co-products that are as variable as DDGS for optimizing broiler diets. Despite the progress in recent years, there is a lack of rapid assessment tools considering the variability of DDGS sources for broilers and avoiding waste that impacts the environmental and economical sustainability.

PS6 - Unsolved issues in poultry nutrition**PS6-015 β -mannanase as an alternative to increasing the layer hen's productivity**C. Carvalho¹, I. Andretta¹, G. Galli¹, N. Camargo¹, M. Kipper²¹Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil, ²Elanco Animal Health, São Paulo, Brazil

This study was developed to evaluate the effect of a β -mannanase (Hemicell™ HT, Elanco Animal Health) supplementation on the performance of laying hens and cleanliness of produced eggs. Hyline W36 laying hens housed in commercial aviaries with 14 thousand birds were evaluated. Twenty cages (with four laying hens each) were randomly selected and allocated for each treatment. Control animals were fed the farm's conventional diet. The 2nd treatment received the control feed with the inclusion of β -mannanase (300 g/t). The birds had free access to water and feed. The experiment started at 36 wks. of age and data collection was carried out at 40, 44, and 48 wks. Performance and cleanliness were measured with eggs collected in the last 3 days of each period. Eggs were classified as clean when no dirt was found; small dirt eggs presented spots up to 1 cm²; and large dirt were those with spots greater than 1 cm². Means were compared by ANOVA and considered different at 5% of significance. The egg-laying rate increase ($P < 0.05$) with β -mannanase at the wk. 40 (85,3 vs 93,7%), wk. 44 (73,3 vs 96,7%), and on average (84,9 vs 94,33%). Lower productivity in this period was associated with subclinical cases of necrotic enteritis not associated with bird mortality in both treatments. At wk. 48, egg-laying rate (91,0 vs 92,6%) was not different between treatment ($P > 0.05$). Egg weight increased ($P < 0.05$) with β -mannanase at wk. 44 (61,3 vs 63,1%), 48 (64,1 vs 65,2%), and on average (62,5 vs 63,6g). At the wk. 40, egg weight (62,0 vs 62,3%) was not affected ($P > 0.05$) by the treatment. The CV of egg weight reduced ($P < 0.05$) with β -mannanase at wk. 44 (7,2 vs 5,6%), 48 (7,1 vs 5,4%), and on average (6,7 vs 5,6%). At wk. 40, the CV of egg weight (5,9 vs 5,9%) was not affected ($P > 0.05$) by the treatment. Using β -mannanase increased ($P < 0.05$) the cleanliness of eggs in all periods evaluated. At wk. 40, the β -mannanase increased clean eggs (82,2 vs 93,5%) and reduced eggs with small (14,3 vs 5,9%) and large dirt (3,6 vs 0,6%). The same was observed at the wk. 44, when the β -mannanase increased clean eggs (72,6 vs 93,8%) and reduce eggs with small (21,5 vs 4,8%) and large dirt (5,9 vs 1,5%). Finally, at 48 wks., the β -mannanase still increased the frequency of clean eggs (85,4 vs 93,8%) and reduced eggs with small (10,0 vs 3,8%) and large dirt (4,6 vs 2,5%). Using β -mannanase increases productivity by improving laying rate, egg weight, and uniformity, while increasing the frequency of clean eggs.

PS7 - Other topics**PS7-001 1,25(OH)2D3-glycosides from the plant *Solanum glaucophyllum* alter gene expression in broiler at 21 and 42 days of age**K. Bühler¹, L. Payling², M. Acman², L. Romero², J.D. van der Klis¹¹*Herbonis Animal Health GmbH, Augst BL, Switzerland*, ²*Anh-innovation, Loule, Portugal*

Waxy-leaf nightshade (*Solanum glaucophyllum*, SG) naturally contains 1,25-dihydroxycholecalciferol in a glycosidic form (G-1,25(OH)2D3). The glycosides are cleaved in the intestinal tract before the free 1,25(OH)2D3 is absorbed. Subsequently, 1,25(OH)2D3 interacts with signalling pathways and the expression of certain genes not only related to calcium (Ca) metabolism but also to various other physiological functions. Current research on the influence of vitamin D in livestock focuses on the expression of selected genes. In this study, the effects of SG fed to broilers were evaluated for the whole broiler genome. A total of 1,536 male Ross 308 AP broilers in 48 pens (12 replicate pens) were fed a corn-soybean meal diet, supplemented either with 0, 0.5 or 1.0 µg G-1,25(OH)2D3 per kg of feed from d1 to d21 (T1-T3), or 1.0 µg G-1,25(OH)2D3 per kg of feed from d1 to d42 (T4). At timepoints 21 d and 42 d, 2 birds from 8 pens of T1 and T4, each, were sacrificed. Samples from liver, jejunum and kidney were collected and prepared for subsequent mRNA extraction and sequencing. The sequenced data were aligned with Kallisto to the *Gallus gallus* reference genome (version GRCg6a). For differential gene expression, data were normalised and analysed with DeSeq2. Pathway analysis was done using the available Reactome pathway database as reference annotation. For statistical analysis, RNA integrity number (RIN), treatment, age and the interaction treatment x age were included in the model. Overall quality of the extracted mRNA was good. Twelve out of 64 kidney samples had to be excluded from further analysis due to low mRNA quality (RIN <7). According to treatment, there were 23 differentially expressed genes (DEGs) in liver, 109 DEGs in jejunum and 7 DEGs in kidney (p-adjusted <0.0001). The activated pathways involved changes in Ca transport and homeostasis and innate immune system. In conclusion, this study confirmed effects of vitamin D also reported in other species such as immune system activation. It could also be shown that with the addition 1.0 µg G-1,25(OH)2D3 to the diet, feedback mechanisms of the Ca metabolism react in a physiological way to the external source of 1,25(OH)2D3. A challenge of this study was that pathways relating to vitamin D metabolism in chickens are poorly annotated and that the reference genome used showed considerable gaps. Whilst the most recent reference genome is improved, it still requires alignment with protein and pathway databases.

PS7 - Other topics**PS7-002 A review: beneficial effects of saponins and polyphenols in *Quillaja saponaria* and *Yucca schidigera* combination product**V. Stanev¹, L. Gomez¹, S. Bonaspeti¹¹*Phibro Animal Health Corporation, Teaneck, NJ 07666, United States*

Quillaja saponins are known to stimulate specific humoral, but most of all cell-mediated specific immune response to different pathogens, while polyphenols from *Yucca* and *Quillaja* have antioxidant and anti-inflammatory properties. Thus, *Quillaja*+*Yucca* combination products are commonly used to improve intestinal health, birds' resistance to different intestinal pathogens and performance in high-challenge situations. Here we would like to make an overview of the effects of *Quillaja* and *Yucca* product (QY) containing 3% minimum of triterpenoid saponins in low- or moderate-pathogen challenge situations. When used in different floor pen studies QY significantly improved intestinal morphometrics demonstrated by an increase in villi height - control 946b µm, QY at 250 g/t 989a µm, QY at 500 g/t 1020a µm (Bafundo, Männer & Duerr, 2021). It provided a significant improvement of the intestinal barrier function, thus mitigating the Leaky Gut Syndrome measured by reduced intestinal permeability for fluorescein isothiocyanate-dextran (FITC-d method) control 0.268a µg/ml, QY at 250 g/t 0-42d 0.209b µg/ml, QY at 250 g/t 28-42d 0.235ab µg/ml and QY at 250 g/t 35-42d 0.237ab µg/ml (Stefanello et al., 2022). The improved intestinal morphometrics and reduced Leaky Gut Syndrome are complemented by improved absorption of nutrients expressed by improved apparent fecal digestibility of crude protein (control 53.9c%, QY at 250 g/t 57.1b%, QY at 500 g/t 60.0a%), crude fat (control 80.0c%, QY at 250 g/t 81.8b%, QY at 500 g/t 84.1a%), and crude ash (control 18.1c%, QY at 250 g/t 20.5b%, QY at 500 g/t 22.9a). In the same study all these corresponded to significant improvement in zootechnical performance: body weight at 35 days (control 2249c g, QY at 250 g/t 2274b g, QY at 500 g/t 2322a g), feed conversion ratio at 35 days (control 1.38c, QY at 250 g/t 1.36b, QY at 500 g/t 1.32a) and production efficiency index at 35 days (control 447c, QY at 250 g/t 469b, QY at 500 g/t 492a) when product was used in broilers without intestinal pathogen challenge. *Values without common letters in the superscripts differed significantly at P < 0.05.

PS7 - Other topics**PS7-003 A scoring system to measure biosecurity compliance in commercial indoor and free-range poultry production**A. Amalraj¹, H. Van Meirhaeghe², N. Caekebeke³, R. Creve³, I. Chantziaris¹, J. Dewulf^{1,3}¹Faculty of Veterinary Medicine, Department of Internal Medicine, Reproduction and Population Medicine (DI08) Ghent University, Merelbeke, Belgium, ²Vetworks BV Knokstraat 38 B-9880 Aalter Belgium, Aalter, Belgium,³Biocheck.Gent B.V, Ghent, Belgium

The objective of the study was to develop and validate a weighted risk-based scoring tool to measure biosecurity in breeder, turkey, duck, free-range layer and free-range broiler production in a standardized and reproducible manner. Questionnaires were drafted each with (turkey=102, duck=108, breeders=119, free-range broiler=100 and free-range layer=126) questions regarding the implemented biosecurity measures and full points gained only when a measure is applied correctly. Answers to the questions get converted to scores ranging from 0 (total lack of biosecurity) to 100 (full application of biosecurity). The Biocheck.UGent™ scoring system works on the principle of avoiding efficient disease transmission. Therefore, the different measures were prioritized and weighed on the basis of their relative importance for the prevented transmission. The score per question is multiplied by a weighting factor. The sum of the weighted scores of the questions within a subcategory will be the subcategory score. The scores for external and internal biosecurity were obtained by taking the weighted averages of all subcategories included. Biosecurity levels were measured in poultry farms from 7 European countries (Belgium, the Netherlands, Poland, France, Spain, Italy and Hungary) using Biocheck.UGent tool (<https://biocheckgent.com/en>). For participating turkey farms of Italy (n=5) (82% vs 83%), Spain (n=4) (78% vs 88%), Hungary (n=7) (56% vs 61%) and Belgium (n=3) (66% vs 79%) external biosecurity scores were lower than internal biosecurity. The breeder farms of Belgium (n=3) scored lower for external than internal biosecurity (69% vs 74%) whereas in Netherlands (n=4) (86% vs 80%) and Hungary (n=2) (85% vs 83%) it was vice versa. More specifically breeder farms scored highest for subcategories “cleaning and disinfection” (81%) and “disease management” (86%) and lowest for “organization of the farm and supply of materials” (46%). The mean scores of duck farms (n=5) showed higher scores for external biosecurity than internal biosecurity (75% vs 61%). The scoring system allows a standardized way of evaluating biosecurity, allows benchmarking the farms and in providing farm-specific advice for improvements. Use of these tools in the major poultry producing regions will help to map the biosecurity levels and identify high risk areas. Research funded by the H2020, under the grant agreement number: 101000728 (NetPoulsafe Project)

PS7 - Other topics**PS7-004 An Algae-Clay based Mycotoxin detoxifier reduces the bioavailability of a mix of Mycotoxins in broiler chickens in a toxicokinetic study**M. Gallissot¹, S. Rutjens², M. Rodriguez¹, M. Devreese²¹Olmix Group, Brehan, France, ²Department of Pathobiology, Pharmacology and Zoological Medicine, Laboratory of Pharmacology and Toxicology, University of Ghent, Ghent, Belgium

A toxicokinetic study was performed to determine the effects of an algae-clay based mycotoxin detoxifier on the oral absorption of the mycotoxins deoxynivalenol (DON), ochratoxin A (OTA) and aflatoxin B1 (AFB1) in broiler chickens. The study included 16 male broiler chickens (Ross 308) of approximately 1.6 kg BW. After an acclimatization period of one week, the broiler chickens were fasted for 12 h and then administered a single oral bolus with either the mycotoxins (n = 8) or the mycotoxins in combination with the detoxifier (n = 8) (2.0 mg AFB1/kg BW, 0.5 mg DON/kg BW, 0.25 mg OTA/kg BW, 2.5 g detoxifier/kg feed), administered in a parallel study design. Blood samples of the 16 broiler chickens were taken at different time points between 0 h (before administration) and 24 h (post administration, p.a.). The analysis of deoxynivalenol-3-sulphate (DON-3S, DON main metabolite), OTA and AFB1 in plasma was performed using UHPLC-MS/MS. The following parameters were calculated: area under the curve from time zero to the last point above the LOQ (AUC0→t), maximal plasma concentration (Cmax) and time at maximal plasma concentration (Tmax). Results showed that, using the oral bolus model, the mycotoxin detoxifier significantly altered the AUC0→12h of DON-3S in broiler chicken (P=0.012). The relative oral bioavailability ((average AUC0→t mycotoxin + detoxifier / average AUC0→t mycotoxin) * 100) of DON-3S when administered with the detoxifier was 60.1%. For OTA, the detoxifier decreased the absorption of OTA as indicated by a significantly decreased AUC0→24h (P<0.001). Consequently, the relative oral bioavailability of OTA when administered with the detoxifier was lowered as well, namely 55.7%. For AFB1, the detoxifier affected the absorption of AFB1 with a significantly decreased AUC0→8h (P<0.001), Cmax (P<0.001) and a significantly delayed Tmax (P=0.025). Consequently, the relative oral bioavailability of AFB1 when administered with the detoxifier was 35.9%. Therefore, it can be concluded that the tested algae-clay based mycotoxin detoxifier reduces the oral absorption of multiple mycotoxins orally administered to broiler chickens in a single oral bolus model.

PS7 - Other topics**PS7-005 Analysis of egg productivity, blood parameters and pre-laying behavioral characteristics of good layers and poor layers**W. Lee¹, H. Kim¹, E. Hong¹, J. Son¹, H. Kim¹, H. Kang¹¹Poultry Research Institute, National Institute of Animal Science, Pyeongchang, Korea, Republic of

Laying hens generally start laying eggs from 20 to 22 weeks of age, but egg production decreases due to breeding management, feed quality, and disease outbreaks. For this reason, laying hens can be divided into the good class (laying rate of 80% or more) and the poor class (laying rate of less than 50%) according to the laying rate. According to the survey, the ratio of poor laying hens in laying hens farms is 1-6%, which means that they usually eat feed but do not lay eggs, resulting in economic loss. However, only a few cases have investigated their characteristics comparison and classification methods. We conducted to investigate egg productivity, blood parameters and behavioral traits. In order to select the poor layers, the egg production rate of the laying hens population was observed for 2 weeks. A total of twelve 45 weeks laying hens were used, with 6 good layers and 6 poor layers. The treatments were designed with good layers (GL) and poor layers (PL) in two treatments, and three replicates per treatment, two hens per replicate were placed. As productivity, egg production rate, egg weight, egg mass, feed intake, and FCR were measured and expressed as average during whole period. Blood was collected twice in the morning and night at the end of the test, and differences in components according to laying were compared. Observation behavior is a sitting behavior, which is a frequent behavior before laying egg. During the test, thermal imaging camera was installed for each replicate to record the behavior, and the sitting behavior was observed from 1 hour before the laying time. In result, GL showed a difference in egg production rate, egg mass, and FCR than PL ($p < 0.05$), but feed intake was similar. In blood analysis, GL showed high levels of triglycerides and LDH, but PL showed high levels of ALT. The ratio of calcium to phosphorus by time period was similar in both treatments. The sitting behavior of the GL group was observed an average of 4 times for 1 hour before laying egg, and a total of 24 mins of sitting behavior was observed. In conclusion, GL and PL consumed similar amounts of feed, but showed significant differences in productivity. Blood characteristics were similar except for some items. Observation of the sitting behavior of laying hens before laying is judged to be a good method for selecting layers with low or no egg production. This study is expected to contribute to achieving efficient rearing management.

PS7 - Other topics**PS7-006 Basal energy requirement and partitioning according to the visceral mass tissues in laying pullets**R. Riveros¹, G. Varella¹, R. Lucas¹, A. Fialho¹, B. Balbino¹, L. Pereira¹, N. Sakomura¹¹Animal Science Department, School of Agricultural and Veterinarian Sciences (FCAV), São Paulo State University (UNESP), Jaboticabal, Brazil

It is necessary to consider the energy used by the tissues to determine the energy utilization in poultry. The visceral mass is correlated with their functionality and energy demand. This work aimed to determine the basal energy expenditure in visceral mass in laying pullets. 380 one-old-day laying pullets Lohmann LSL were allocated in groups of ten birds per cage (80 x 90 cm) and maintained under thermoneutral conditions. A periodical assay (8) was conducted every three wks (from 1 to 22-old-wks). For each assay, 24 birds with similar BW to the population's average were selected and allocated in four open-circuit respirometry chambers. Each assay measured the gas exchange parameters (oxygen consumption, VO₂ and CO₂ production, VCO₂) under fasting conditions for 24h to calculate the fasting heat production (FHP). After the measurement, two birds per chamber were slaughtered to weigh visceral organs (free-feather body weight, carcass, gut, liver, gizzard, and heart). A linear regression was fitted between FHP and BW^{0.75} (not including the constant on the model) to determine maintenance (kJ/kg^{0.75}). Multiple regression analyses were performed to partition the energy expenditure into components (feather and feather-free body weight) and visceral components (carcass, breast, liver, heart, and gut). All statistical analyses were performed in Minitab v.19 and considered a 95% of confidence. The energy for maintenance for laying pullets was 89.2 kcal/BW^{0.75}. The partition of energy for maintenance into feathers was not significative ($P = 0.352$), also for free-feather body weight was significative (< 0.001). These results suggest that the birds use the energy to maintain the free-feather tissues and not for the keratinized (feathers). The partition of basal energy into visceral components, the carcass ($P = 0.305$), liver (0.325), and breast ($P = 0.717$), were not significant. However, the heart ($P = 0.039$) and gut ($P < 0.001$) organs were significant. That is related to the metabolic activity of these organs requiring continuous energy demand under fasting conditions to maintain homeostasis, transport the essential nutrients, and maintain the cell renovation and tonicity of enterocytes. In conclusion, not all tissues from the whole body require energy for maintenance. The heart and gut are the main tissues that demand energy to maintain homeostasis, at constants of 6.13 and 2.03 kcal to maintain a gram of mitotic and enteric tissues.

PS7 - Other topics**PS7-007** Changes in the expression of selected peptides regulating the metabolism of depending on birds breed

E. Pruszyńska-Oszmerek¹, N. Leciejewska¹, M. Hejdysz², M. Sassek¹, D. Szczepankiewicz¹, K. Mielnik¹, S. Kaczmarek², A. Lukomska³, P. Kołodziejki¹

¹Department of Animal Physiology, Biochemistry and Biostructure, Poznań University of Life Sciences, Poznań, Poland, ²Department of Animal Nutrition, Faculty of Veterinary Medicine and Animal Science, Poznań University of Life Sciences, Poznań, Poland, ³Department of Preclinical Sciences and Infectious Diseases, Faculty of Veterinary Medicine and Animal Science, Poznań University of Life Sciences, Poznań, Poland

In recent years, more and more metabolically active peptides have been discovered that are able to significantly regulate the carbohydrate-lipid metabolism of humans and animals, including birds. One of them is the relatively recently described spexin (SPX) - agonist of galanin receptors, liver-expressed antimicrobial peptide 2 (LEAP2) - an endogenous inhibitor of ghrelin-induced GH secretion and irisin - adipomyokine being a communicator between muscle and fat tissue. The aim of the research was to determine changes in the expression of peptides regulating carbohydrate-lipid metabolism in hens of various types, such as laying or multipurpose type of hens. Birds at nine weeks old (n=10 males per group) from eight different poultry breeds (laying type: Brakla, Greenlegged Partridge, Araucana, Leghorn; general type: Marans, Sussex, Faverolles, Italian hen) were used in the experiment. Birds were housed according to the technical information for Hy line Brown hybrids. They were fed a corn-soy mixture containing 20% of total protein, and the value of metabolic energy was 3050 kcal. Changes in the expression of SPX and LEAP2 at the mRNA (using Real-Time PCR) and protein (using Western blot and immunohistochemistry and/or fluorescence) levels in tissues involved in the regulation of carbohydrate and lipid metabolism (fat tissue, muscle, and liver) were investigated. The concentration of these peptides in the blood serum was measured using ELISA tests. Moreover, commercially available colorimetric tests were used to determine the metabolic status of the animals. We found that the expression of investigated peptides at the mRNA level in selected tissues as well as the concentration of these peptides in blood varied in different breeds of poultry. Moreover, the changes were correlated with the type of birds use. One of the most interesting results were reverse changes in mRNA expression of genes for SPX and LEAP2 in the muscle tissue of birds. In the muscle of laying birds, a lower level of SPX mRNA and a higher level of LEAP2 mRNA were observed compared to the general type of birds ($P < 0.05$). These results suggest that these peptides may play an important role in the metabolism of chickens, which could be a potential source of interest as a target for the development of poultry breeds. Funding source: National Science Centre (NCN) in Poland project no: 2021/41/B/NZ5/00446

PS7 - Other topics**PS7-008** Competitive exclusion to secure pullets' production: impact on microbiota establishment, relative abundance of Enterobacteriaceae and Enterococcus sp. in a large field trial

C. Achard¹, M. Castex¹, M. Ligabue¹, A. Sacy¹

¹Lallemand SAS, Blagnac, France

The pullets rearing period is a critical phase that greatly influence the future health and performances of layers. The early colonization by opportunistic pathogenic bacteria, such as *Enterococcus faecalis* is a major threat for the health of a flock. AviGuard®(Lallemand) is a microbial community derived from healthy adult chicken, which efficiently limit colonization by undesirable bacteria, such as *Salmonella*, *E.coli* and *Clostridium perfringens*, when administrated in hatched birds. The effect of this competitive exclusion product has also been documented in a context of infection by vancomycin-resistant *Enterococci* in chicks and ducklings (Zaini et al., 2000). The aim of this study was to assess the effect of the competitive exclusion (CE) product in a commercial pullet production set up. At hatch, half of the pullets were sprayed with AviGuard®. The two groups of 60 000 pullets each were then raised in the same barn divided in two separated areas. At d8 and d33 of age, 10 birds in each group were sacrificed. Immune organs and digestive tract segments were collected, weighted and measured. Microbial DNA was extracted from cecal content and from scrapped mucosa. High-throughput sequencing of the 16S rRNA gene V4-V5 regions was performed on Illumina MiSeq sequencer. Sequences were processed using DADA2 pipeline. At d33, the duodenum was longer (+10%, $p < 0.05$) and the bursa of Fabricius was heavier (+190%, $p < 0.001$) in the CE group, which could suggest a better intestinal development and a faster immune maturation. These effects were associated with a significant modulation of the cecal microbiota of the pullets by AviGuard® at d8 and d33. The relative abundance of several taxa containing known undesirable bacteria was decreased in the ceca of Aviguard treated pullets. Enterobacteriaceae median abundance decreased overall from 0,05% to 0,01% with AviGuard®. Higher levels of *Enterococcus* were detected at d33 than at d8 and the relative abundances were lower in AviGuard® group (0,064% vs 0,002% at d8 and 0,42% vs 0,18% at d33, median values). The application of Aviguard at early stage of the chick development may reduce the opportunistic pathogenic bacteria in the gut and reinforce the innate immune system, conferring direct protective effects early in life. The combination of a well-developed microbiota and immune system may result in more robust broiler chickens with higher resilience against health challenges, such as invading pathogens.

PS7 - Other topics**PS7-009 Deposit of Fumonisin in broiler tissues and reduction with an algae-clay based mycotoxin detoxifier**M. Gallissot¹, D. Tardieu², M. Matard-Mann¹, M. Rodriguez¹, P. Guerre²¹Olmix Group, Brehan, France, ²ENVT, Université de Toulouse, Toulouse, France

Fumonisin are mycotoxins found worldwide for which maximum levels are recommended in animal feed. In poultry, the toxicity of these compounds occurs at low doses by liver damage and decreased performance. The toxicokinetics of fumonisins are characterized by a poor oral absorption and a rapid elimination from the plasma. It was thus long considered that fumonisins (FB) don't accumulate in animals. Nevertheless, recent studies in poultry demonstrated that the hepatic half-elimination of fumonisin B1 (FB1) was up to several days suggesting that fumonisins can accumulate in animal tissues. Based on this latest research the aim of this study was to evaluate fumonisins deposit in broiler tissues and to evaluate the effect of feeding an algae-clay based mycotoxin detoxifier (AC) on this accumulation. Twenty-one-day old broilers were slaughtered after being fed a diet with 20 mg FB1+FB2/kg (considered as nontoxic) and supplemented with or without the 0.450 kg AC/T of feed for 4 or 9 days prior to slaughtering. No sign of toxicity was observed on performances at this level of FB in feed, but increased concentrations of Sa and So over time in the liver were measured after 9 days of exposure to FB (P<0.05). A time-dependent accumulation resulting from 4 to 9 days of exposure of FB1 was measured in the liver with concentrations of respectively, 20.3 and 32.1 ng FB1/g at these two exposure periods (P<0.05). Even if FB1 levels were very low in breast muscles, an accumulation could also be observed after 4 and 9 days of exposure with concentrations of 0.036 and 0.072 ng FB1/g, respectively (P<0.05). When feeding the AC, a significant reduction of FB1 accumulation was measured in the liver and muscle by respectively 42 and 53% after 9 days of exposure (P<0.05). Broilers fed the AC also showed a decrease in sphinganine (Sa) and sphingosine (So) contents in the liver compared to the levels of Sa and So measured in broilers fed FB alone after 9 days exposure (P<0.05). To conclude, this study highlights that fumonisins can accumulate in animals' tissues and that the inclusion of an algae-clay based mycotoxin detoxifier reduces this accumulation.

PS7 - Other topics**PS7-010 Determination of protein and amino acid composition of poultry ileal digesta by near-infrared spectroscopy**A. Cruz-Conesa^{2,1}, I. Ruisánchez², A. Pérez-Vendrell¹, J. Ferré²¹Institute of Agrifood Research and Technology, Animal Nutrition, Mas Bové, Constantí, Spain, ²Universitat Rovira i Virgili, Faculty of Chemistry, Department of Analytical and Organic Chemistry, Tarragona, Spain

Modern poultry feed formulations tend to be based on amino acid content instead of protein content. In addition, the most cost-effective formulation that results in the highest nutrient digestibility is of interest. Therefore, there is a growing interest in determining the available amino acid contents rather than totals, and to formulate the optimal diet based on them. The digestibility coefficients of protein and amino acids are usually obtained in in vivo trials that require feeding the birds with different diets of well-known composition and analyzing a large number of ileal digesta contents. The determination of protein and mainly amino acids require costly wet analytical methods. This work present, for the first time, the use of near infrared spectroscopy (NIRS) combined with multivariate calibrations to determine protein content and up to 17 amino acids in poultry ileal digesta. The NIR spectra were registered between 850 and 2499.5 nm and pretreated by the first derivative. Partial least squares regression (PLSR) was used to obtain the prediction models. Protein, 11 out of 17 amino acids (glycine, alanine, valine, leucine, isoleucine, phenylalanine, tyrosine, aspartic acid, glutamic acid, threonine, proline) and the total of amino acids were good predicted with a coefficient of determination of prediction (R²P) higher than 0.80 and a coefficient of variation of prediction (CVP) lower than 10%. For lysine and methionine, proper coefficients of determination (R²P≈0.82) but high prediction errors (CVP≈15%) were obtained. This situation prevents to be considered for quantitative analysis, but they could be useful for semi-quantitative or screening analyses. Finally, 4 out of 17 amino acids (cysteine, arginine, serine and histidine) were all poorly predicted (R²P<0.70, CVP>10%). The presented results demonstrated that NIRS is a reliable tool for assessment of variation in protein and amino acids in poultry ileal digesta, reducing the cost of digestibility studies and contributing in this way to expedite the obtaining of ileal digestibility coefficients of protein and amino acids of feedstuffs and diets.

PS7 - Other topics**PS7-011 Dietary organic acids ameliorate high stocking density stress-induced intestinal inflammation through the restoration of intestinal microbiota in broilers**D. Dai¹, G. Qi¹, H. Zhang¹, Y. Han², Y. Wu², J. Wang¹¹Institute of Feed Research of Chinese Academy of Agricultural Sciences, Beijing, China, ²Trouw Nutrition Research & Development Centers, Amersfoort, Netherlands

High stocking density (HSD) stress has detrimental effects on growth performance in intensive animal production. To investigate the effects and potential mechanisms of organic acids (OA, a blend of free and buffered short-chain fatty acids combined with medium-chain fatty acids including formic acid, ammonium formate, acetic acid, propionic acid, caproic acid, caprylic acid, decanoic acid, and lauric acid) on broilers exposed to HSD, growth performance, intestinal barrier and intestinal microbiota, and microbial metabolites were evaluated in the current study. A total of 528 one-day-old male Arbor Acres broilers were randomly allocated into 3 treatments with 12 replicates per treatment including 10 birds for normal stocking density and 17 birds for HSD. The dietary treatments were as follows: 1) Normal stocking density + basal diet; 2) HSD + basal diets; 3) HSD + OA. We found that increased levels of serum corticosterone, lipopolysaccharides, interleukin-1 β , tumor necrosis factor- α , and down-regulated mRNA expression of ZO-1 were induced by HSD stress, which cause compromised growth performance of broilers ($P < 0.05$). Notably, OA significantly reduced levels of serum corticosterone, lipopolysaccharides, interleukin-1 β , and tumor necrosis factor- α , while up-regulated interleukin-10, mRNA expression of ZO-1, and improved growth performance ($P < 0.05$). Moreover, OA could down-regulate the mRNA expression of TLR4 and MyD88 to inhibit the NF- κ B signaling pathway ($P < 0.05$). Additionally, HSD stress significantly decreased the abundance of Bacteroidetes and disturbed the balance of microbial ecosystems, whereas OA significantly increased the abundance of Bacteroidetes and restored the disordered gut microbiota by reducing competitive and exploitative interactions in microbial communities ($P < 0.05$). Meanwhile, OA significantly increased the content of acetic and butyric acids, which showed significant correlations with intestinal inflammation indicators ($P < 0.05$). In summary, dietary OA ameliorated intestinal inflammation and growth performance of broilers through restoring the disordered gut microbial compositions and interactions induced by HSD and elevating short-chain fatty acid production to inhibit the TLR4/NF- κ B signaling pathway. These findings demonstrated the critical role of intestinal microbiota in mediating the HSD-induced inflammatory responses, contributing to exploring nutritional strategies to alleviate HSD-induced stress in animals.

PS7 - Other topics**PS7-012 Digesta phase divergently separated in foregut of laying hens fed with fine or coarse oat hulls**M.F. Habibi^{1,2}, R. Kwakkel¹, S. de Vries¹¹Animal Nutrition Group, Wageningen University and Research, Wageningen, Netherlands, ²Faculty of Animal Science, Universitas Gadjah Mada, Yogyakarta, Indonesia

The inclusion of fine or coarse dietary fibre in a diet may determine the behaviour of digesta in the foregut of chickens. Evidence showed that coarser dietary fibres result in longer retention times in the gizzard. It is still unknown, however, how digesta phases are separated in different gut segments, when varying particle sizes of dietary fibre are included. Due to the grinding process, it is hypothesized that digesta is separated into larger (coarse fibre) and smaller particles (fine solids), and a liquid phase in the gizzard. A total of 244 29-wk-old laying hens were assigned to fine or coarse 15g/kg oat hull (OH) diets, which contained 3 g/kg TiO₂ and 2 g/kg Co-EDTA as presumed continuous markers of fine solid and liquid digesta fractions. At d 34, 35, or 36, birds were administered an oral pulse dose of 44 mg Cr-mordanted OH and 102 mg Yb as presumed markers of coarse fibre (CoF) and fine solid digesta fractions, respectively. Birds were subsequently euthanized at 13 timepoints (30-1440 min) after marker administration to obtain digesta from crop and proventriculus+gizzard (PG). The collected digesta was used to determine the mean retention time (MRT) of every fraction by calculating an inverse of passage of digesta in crop and PG. Digesta phase separation was calculated by the normalization between MRT_{fine solids} and MRT_{liquids}, and MRT_{CoF} and MRT_{fine solids}. MRT of fine solid digesta varied between 85.3-114.8 min in the crop and 29.1-56.8 min in the PG, while liquid digesta varied between 41.1-44.8 min in the crop and 10.2-15.0 min in the PG. MRT of CoF varied between 113.0-197.5 min in the crop and 32.4-46.7 min in the PG, while MRT of fine solid varied between 119.0-174.0 min in the crop and 22.0-34.5 min in the PG. More digesta phase separation was observed in PG vs crop (~55% vs ~37-43% between fine solids and liquids; and ~17-18% vs ~6% between CoF and fine solids). Moreover, digesta phase separation measured between fine solids and liquids was larger than between CoF and fine solids. No interactions between dietary treatments and phase separation were found, except diets with coarse OH caused a larger separation between solid and liquid digesta in the crop compared to fine OH (+4.9%, $P=0.007$). The results indicate that solid and liquid digesta pass through the crop and PG differently, with most phase separation occurring in the PG. OH are selectively retained in the PG, but do marginally separate from other solids in the crop.

PS7 - Other topics**PS7-013 Effect of an innovative precision biotic on laying hens' welfare**F. Leone¹, S. Lolli², E. Folegatti², L. Ferrari¹, G. Grilli³, V. Ferrante¹¹Università degli Studi di Milano - Dept. Environmental Science and Policy, Milano, Italy, ²DSM Nutritional Products, Segrate, Italy, ³Università degli Studi di Milano - Dept. Veterinary and Animal Sciences, Milano, Italy

The object of the research was to determine the effects of Symphiome™ in laying hens on the welfare of animals improving intestinal well-being allowing a general improvement of behavioral reactivity. The study was conducted on a commercial farm. 16,000 beak trimmed Lohmann Brown kept in an aviary system were monitored from 48 weeks to 79 weeks of age. The hens were divided into two sheds: A, treated (T) supplemented with Symphiome™ in the diet (900 g/T); B control (C). Productive data were recorded weekly. Moreover, at weeks 48, 55, 60, 66, 72 and 79 both egg quality and behavioral data were evaluated. At each sampling point, 60 eggs per shed were collected and analyzed to assess egg quality. The whole and different component of eggs were weighed. The thickness of the shell was measured with a digital caliber; the yolk color was measured using the Digital YolkFan Pro (Nix/DSM); finally, the egg breaking strength was measured using the Egg Force Reader™ (Orka). The avoidance distance test (ADT) and the novel object test (NOT) were performed to study the human-animal relationship and animal reactivity, (Welfare Quality®, 2019). Moreover, 100 hens per shed were weighed and the feathers in different regions of the body and foot pad were scored (Welfare Quality®, 2019). The T group had a significantly higher persistence of egg deposition than the C group, starting from week 71 ($p < 0.01$). Mortality in the T group was lower than in the C group (2.93% versus 4.31%). Symphiome™ shifts the microbial metabolic functions to produce desired metabolites and reduce undesirable metabolites, consequently, this favours beneficial bacteria and reduces pathogens enhancing gut health through precision microbiome and improving resilience to enteric stress. The condition of the feathers was better in the T group than in the C group at weeks 48, 55, 66 and 79 ($p < 0.001$). In this study, the FPD score was higher in the C group than in the T group (mean score 0.34 ± 0.07 vs 0.27 ± 0.04). A positive effect was found on the reactivity of the animals: the response to the tests was better in T hens that were more curious about the NOT and kept smaller distances from the operator in ADT than the C group. These findings seem to confirm the initial hypothesis of the study that an improvement in intestinal health may have a positive impact on the reactivity of the animals and on feather pecking, with a positive impact on the welfare.

PS7 - Other topics**PS7-014 Effect of feed deprivation on intestinal integrity**S. Osho¹, V. Stanev¹, L. Gomez¹, K. Saddoris-Clemons¹, B. Humphrey¹, M. Garcia¹¹Phibro Animal Health Corporation, Teaneck, NJ 07666, United States

Selective permeability is a major function of the intestinal mucosa, which should allow absorption of low molecular weight compounds (e.g. glucose, amino acids, fatty acids and glycerol, minerals and water) and prevent the penetration of high molecular weight compounds such as protein molecules or complexes and nucleic acids (toxins, allergens or whole microorganisms) into the blood circulation. Tight junctions are crucial multi-protein complex cellular structures, linking together neighboring epithelial cells of the intestinal mucosa, involved in the regulation of paracellular permeability and intestinal barrier function. In inflammatory reactions triggered by pathogens, dysbiosis, toxins, feed change, feed deprivation and/or heat stress, intestinal barrier function is compromised and high molecular compounds penetrate through the mucosa referred to as a Leaky Gut Syndrome. The objective of this study was to characterize the effect of feed deprivation on intestinal inflammation and barrier function assessed by the dynamics of different cytokines (interleukin-1 β and interleukin-17) and tight junction proteins (claudin-1) expression in the intestinal mucosa, as well as mucosal permeability for high molecular compounds such as fluorescein isothiocyanate-dextran (FITC-D). Forty-eight 7-day-old Ross708 male broilers were randomly allotted to one of two treatments (6 replicate cages; 2 birds per cage) in a randomized complete block design and fed corn-soybean meal-based diets ad libitum. After 14 d of feeding, feed was either withdrawn or provided ad libitum (CON) for 24 h. After 22 h of feed withdrawal, all birds were orally gavaged with 8.4 mg FITC-D per kg BW. Two hours later blood and jejunal scrapings were collected for serum FITC-D measurement and gene expression, respectively. Feed withdrawal increased serum FITC-D 6.5-fold compared to CON ($P < 0.05$) demonstrating increased intestinal permeability for high molecular compounds, thus impaired intestinal barrier function (Leaky Gut Syndrome) associated with the feed deprivation. Compared to CON, feed withdrawal increased claudin-1 2-fold and interleukin-1 β 1.84-fold and reduced interleukin-17 5.2-fold ($P < 0.05$), indicating altered tight junction function and inflammatory state. Alleviating the Leaky Gut Syndrome and intestinal inflammation associated with feed deprivation and other harmful stimuli has important implications on intestinal integrity and immunity.

PS7 - Other topics**PS7-015 Effect of monovalent and glycoside ionophore-nicarbazin combination products at typical and 35% increased dose in control of coccidiosis**V. Stanev¹, L. Gomez¹¹Phibro Animal Health Corporation, Teaneck, NJ 07666, United States

Due to the synergistic and complementary effect of ionophores and nicarbazin, combination products are the backbone of anticoccidial programs worldwide, providing enhanced efficacy, at reduced dose of the individual components, thus increased safety margins and reduced risk of resistance development. However, reduced efficacy is not uncommon. This study explores the hypothetical improved efficacy of ionophore+nicarbazin combination products when used at a higher than typical dose. Treatments of glycoside and monovalent ionophore-nicarbazin products at typical and 35% increased dose (in ppm) were: 1) semduramicin+nicarbazin at 18sem+48nic (SEM+NIC), 2) 24sem+64nic (SEM/NIC+35), 3) narasin+nicarbazin at 50nar+50nic (NAR/NIC) and 4) 70nar+70nic (NAR/NIC+35). Treatments were provided from 0 to 28 days of age, followed by an ionophore (semduramicin at 22.5ppm) from 29 to 42 days of age and were compared to an infected untreated control (IUC). Each treatment was replicated 10 times with 30 male Cobb500 broilers per pen. Birds were challenged by oral gavage with a contemporary isolate containing *E. acervulina*, *E. maxima* and *E. tenella* at 18 days of age. The efficacy of the treatments was assessed based on coccidiosis lesion scores at 24 days of age according to Johnson and Reid (1970) coccidiosis scoring system and zootechnical performance from 0 to 28 days. Both products provided significant reduction of *E. acervulina* lesions at both respective doses (IUC 1.27 a; NAR/NIC 0.03 b; NAR/NIC+35 0.10 b; SEM/NIC 0.23 b; SEM/NIC+35 0.20 b). Neither of the products significantly reduced *E. maxima* lesions (IUC 1.53 a; NAR/NIC 2.27 b; NAR/NIC+35 2.07 b; SEM/NIC 2.33 b; SEM/NIC+35 2.17 b) and only SEM/NIC+35 significantly reduced *E. tenella* lesions (IUC 0.93 a; NAR/NIC 0.90 a; NAR/NIC+35 0.60 ab; SEM/NIC 0.30 ab; SEM/NIC+35 0.20 b). Body weight gain at 28 days was significantly improved by both SEM/NIC and SEM/NIC+35 compared to IUC, but not by NAR/NIC, nor NAR/NIC+35 (IUC 1402g a; NAR/NIC 1440g a; NAR/NIC+35 1419g a; SEM/NIC 1502g b; SEM/NIC+35 1518g b). Same for feed conversion ratio at 28 days (IUC 1.432 b; NAR/NIC 1.377 ab; NAR/NIC+35 1.417 b; SEM/NIC 1.339 a; SEM/NIC+35 1.345 a). There was no relevant improvement when using either of the two products at 35% higher than typically registered dose. Thus, use at a higher dose did not bring an additional benefit and is not recommended. Note: Values without common letters differed significantly at $P < 0.05$.

PS7 - Other topics**PS7-016 Effect of the addition of crude fibre concentrate in the feed on the number of colony-forming units of selected cecal bacteria and pH of broiler chicken faeces and litter**J. Urban¹, M. Michalczuk¹, A. Lange², D. Bieñ¹, A. Matuszewski¹, A. Jaroszek³, S. Jaworski²
¹Institute of Animal Sciences, Warsaw University of Life Sciences, Warsaw, Poland, ²Institute of Biology, Warsaw University of Life Sciences, Warsaw, Poland, ³RETENMAIER Polska Sp. z o.o., ul. Bitwy Warszawskiej 1920 r. 7b., Warsaw, Poland

The aim of this study was to determine the effect of the addition of crude fibre concentrate in the feed on the number of colony-forming units of selected cecal bacteria and pH of broiler chicken faeces and litter. The study material consisted of 990 male chicks of the Ross 308 line divided into 3 groups in 5 replicates each - control - (C), experimental 1 - (A1), experimental 2 - (A2). The differentiating factor was the addition of ARBOCEL® crude fibre concentrate in the feed for the experimental groups (group A1: Starter - 0.4%, Grower 1 - 0.8%, Grower 2 - 0.8%, Finisher - 0.2%; group A2: Starter - 0.6%, Grower 1 - 1.0%, Grower 2 - 1.2%, Finisher - 0.4%). The chickens were maintained under standard conditions according to the Ross Flock Management Guide (2018). On the 35th day of rearing, a 2 g cecal fragment was collected post-mortem from 18 chickens (6 from each group). The collected intestinal fragment with contents was shaken in 20 mL of 0.9% NaCl for 24 hours. A series of tenfold dilutions of the material was then prepared and cultures were performed in triplicate on MRS media (to determine the number of lactic acid bacteria) and ENDO media (to determine the number of Enterobacteriaceae). Weighed 5 g of faeces collected from birds from 9 boxes (3 replicates from each group) and 5 g of litter were taken from three boxes from each group and poured over 20 ml of distilled water, then mixed thoroughly. The prepared mixtures were left for 15 minutes. After this time, pH was measured using an ELMETRON CP-401 pH meter with an IJ44C glass electrode and temperature sensor (Elmetron, Poland). Measurements of the pH of each litter and faeces sample were performed three times. The number of colony-forming units of Enterobacteriaceae did not differ ($p \geq 0.05$) between the control and experimental groups. For lactic acid bacteria, the number of colony-forming units was higher ($p \leq 0.05$) in the groups fed feed with crude fibre concentrate. The pH of faeces and litter were characterised by lower values ($p \leq 0.05$) in the experimental groups. For both the number of colony-forming units of lactic acid bacteria and the pH of faeces and litter, there were no differences ($p \geq 0.05$) between the experimental groups. The addition of crude fiber concentrate in the feed increased the number of lactic acid bacteria in the cecal content and lowered the pH of the faeces and litter.

PS7 - Other topics**PS7-017 Effects of a blend of fatty acids esters on health status, microbiota and broiler performance**C. Techer¹, J. Castier¹, N. Bernard¹, L. Chossat¹¹Mixscience, Bruz, France

The increasing public concern about the use of antibiotics in commercial poultry production has changed the ways in which producers manage animal health and performance, and the search for alternatives remains a challenge with considerable interest in the poultry industry. This study was conducted to determine the effects of a blend of fatty acids esters on gut microbiota, immune parameters and performance of broiler chicken compared to a growth promoting factor. A 35 days study trial was conducted with 1008 Ross 308 male day old broiler chicks assigned randomly to 4 treatments comprising 5-6 replicates with 48 birds per replicate. The 4 groups included animals receiving: 1) basal diet with no antibiotic (G1), 2) basal diet + 125/125/100 ppm of growth promoting factor (enramax 8%) for the starter/grower/finisher feeds, respectively (G2), 3) basal diet (T1) + 500 ppm of a blend of fatty acid esters (G3), 4) basal diet (T1) + 1000 ppm of blend of fatty acids esters (G4). Significant effects on animal performance, on immune biomarkers such as alpha 1-acid glycoprotein ($p < 0.05$), were observed for the G2 compared to G1. Even if lower effects on performance were observed for G3 and G4 compared to G2, level of immune biomarkers and microbiota profile were comparable, suggesting that supplementation can reduce the pro-inflammatory status of animal and, thus, can play an important role within the reduction of antibiotics in poultry farms.

PS7 - Other topics**PS7-018 Effects of an antioxidant containing phenolic compounds from olive on oxidative state in broilers and efficacy against feed rancidity**J. Estévez¹, A. Viñado¹, M. Sadurni², L. Castillejos², A.C. Barroeta², M. Verdú³, S. Carné¹¹Industrial Técnica Pecuaria S.A. (ITPSA), Barcelona, Spain, ²Servei de Nutrició i Benestar Animal (SNIBA), Bellaterra, Spain, ³Department of Animal Nutrition and Feed Industry, bonÀrea Agrupa, Guissona, Spain

Some authors have described in vivo effects of technological antioxidants. However, natural antioxidants are scarce and economically inaccessible for feed. This study aimed to evaluate the efficacy of Protekto, a product containing phenolic compounds from olive, such as hydroxytyrosol, as a technological antioxidant in broiler feed; and also to assess its effects as physiological antioxidant for birds. An experiment of 42 days with 3,024 1-day old female broilers (Ross 308), distributed in 24 pens (126 birds/pen) was performed. Each pen was randomly assigned to one of two treatments (12 replicates/treatment), both with the same basal diet. The control group (T1) did not contain any antioxidant added to the diet. The treated group (T2) was fed with a diet including 3000 g/t of Protekto, without any other added antioxidant. The antioxidant efficacy in feed ($n=5$) was evaluated through determining peroxide value (PV) by potentiometry, and total xanthophylls (TX) by spectrophotometry and HPLC, at days 0, 30 and 90 post manufacturing, as well as through the Rapidoxy test at t0. To assess the effect on the oxidative status of the chicken, malondialdehyde (MDA) by thiobarbituric acid reactive substances (TBARS) method was analyzed in plasma from blood samples collected at day 42 from 1 animal/pen ($n=12$). The antioxidant reduced PV at t0 and t30 by 25% and 37% vs. control ($P < 0.01$), respectively, and numerically reduced PV at t90 a 13% ($P=0.13$). These results indicate a higher stability of the feed with the antioxidant. The level of TX was significantly higher (12-16%) from t0 to t90 ($P < 0.001$). As xanthophylls are highly susceptible to oxidation, a lower reduction in feed means a better oxidative stability, agreeing with PV. In Rapidoxy, the feed samples containing antioxidant showed a longer induction period (6%; $P < 0.05$), evidencing again a higher oxidative stability versus control. Besides technological efficacy, the antioxidant also induced a clear trend to decrease MDA of plasma by 13% ($P=0.055$), suggesting a better oxidative status of the animals supplemented with 3000 g/t of Protekto. In conclusion, the antioxidant including olive phenolic compounds constitutes an effective strategy to protect feed against oxidation. Protekto also shows a positive effect on the oxidative state of animals; further studies will be conducted to assess effects on meat quality and animal performance. Study financed by FEDER funds. Project COMRD16-1-0033.

PS7 - Other topics

PS7-019 Efficacy of different ionophore-nicarbazin combination products in coccidiosis challenge modelV. Stanev¹, B. Maertens², L. Gomez¹¹Phibro Animal Health Corporation, Teaneck, NJ 07666, United States, ²Poulpharm BVBA, Izegem, Belgium

This study investigated the efficacy of different ionophore-nicarbazin combination products using 400 male, day old, Ross308 birds divided into wired floor battery cages (5 birds each) in 8 groups: 1) Uninfected Untreated Control (UUC); 2) Infected Untreated Control (IUC); 3) Monensin 50ppm+nicarbazin 50ppm; 4) Salinomycin 50ppm+nicarbazin 50ppm (SAL+NIC); 5) Narasin 50ppm+nicarbazin 50ppm (NAR+NIC); 6) Maduramicin 3.75ppm+nicarbazin 40ppm (MAD+NIC); 7) Semduramicin 15ppm+nicarbazin 40ppm (SEM+NIC low) and 8) Semduramicin 18ppm+nicarbazin 48ppm (SEM+NIC high), with 10 replicates per treatment. Birds were individually weighed at day 14 and provided feed supplemented according to the allocation. At d16 all birds, with the exception of the UUC group, were individually gavaged with 1ml of a mixed coccidia inoculum containing 130 000 *E. acervulina*, 22 000 *E. maxima* and 8 000 *E. tenella* sporulated oocysts from a recent field isolate originating from the Netherlands. All remaining feed was weighed at d23. Half of the birds from each group were individually weighed, sacrificed and lesion scored at d22 and the remaining birds followed the same protocol at d23. Results were statistically analyzed, and efficacy of the treatments was based on oocyst shedding, intestinal lesion scoring, body weight, weight gain, feed intake and feed conversion. All products provided an improvement of DWG compared to IUC. Highest improvement was recorded in the SEM+NIC high group, which was the only group not differing from UUC, meaning completely alleviating the effect of the challenge. The least effect was recorded in the NAR+NIC treatment, where DWG was significantly lower than all other combination treatments. Feed intake was impaired in all treatments, with the exception of both SEM+NIC low and high groups where it was not different from the UUC. All treatments improved FCR compared to IUC, with highest improvement in the SAL+NIC group. Lesion scores in all treatments except NAR+NIC were significantly reduced compared to IUC. Highest reduction was recorded in SEM+NIC high which was significantly better than all other treatments, except for SAL+NIC. None of the products significantly reduced *E. acervulina* lesions compared to IUC. *E. maxima* lesions were significantly reduced in SEM+NIC high, SAL+NIC and MON+NIC compared to IUC and only NAR+NIC did not significantly reduce the lesions of *E. tenella*. None of the combination products reduced oocyst shedding in comparison to IUC.

PS7 - Other topics

PS7-020 Energy utilization in broiler breeders during the laying phase through a multivariate approachN. Sakomura¹, R. Riveros¹, G. Teofilo¹, R. Camargos¹, B. Balbino Leme¹, M. Macari¹¹Animal Science Department, School of Agricultural and Veterinarian Sciences (FCAV), São Paulo State University (UNESP), Jaboticabal, Brazil

The dynamic of how energy is used in broiler breeders could help to define the energy requirements. This study aimed to describe the energy partition in broiler breeders based on multivariate analysis, considering the reciprocity of the efficiency of energy utilization. 60 Cobb 500 broiler breeders were used from 29 to 65-old wks. Periodically (every four wks) six birds were selected according to their body weight and egg production. During eight days previous to measurements, the birds were adapted to a specific amount of feed: (G1) a recommended amount according to the guideline, (G2) 25% above G1, and (G3) 25% below G1. The measurement periods were four days (3d under fed condition and 1d under fasting) in an open-circuit of respirometry chambers to collect the oxygen consumption (VO2) and CO2 production (VCO2). The excreta were collected, as well as the body weight and feed intake were recorded daily. The metabolizable energy (ME) was obtained from the difference between gross energy intake and excreted, and the heat production (HP) and fasting heat production (FHP) from VO2 and VCO2. The energy retention (ER) was calculated as MEi-HP, and it was fractioned as energy retained as protein (ERp) and fat (ERf), where ERp was estimated from nitrogen balance calculation (protein retained times 23.4 kJ/g of protein). The ERf was calculated by subtracting the ERp from ER. The data were analyzed by multivariate analyses, according to the model: $MEi = (1/km) * FHP + (1-km) * ((1/kp) * ERp + (1-1/kp) * ERf)$, where km is the efficiency for maintenance and kp the efficiency for energy retention as protein. This model is based on the complementarity (1-km) is referred to as the fraction of energy that is not destined to maintenance, thus, for retention also the efficiency of energy retained as fat is described as (1-kp), assuming that the rate of fat deposition is complementary to protein deposition. The statistical analyses were performed using R software and by a non-linear procedure of the SSnlm package. The results showed that the multivariate model fit significantly for all parameters ($P < 0.001$), the km was 0.485 ± 0.019 and the kp was 0.584 ± 0.042 . From kp, the efficiency for energy retention as fat was 0.616. It was concluded that broiler breeders during the laying phase, had higher efficiency for fat deposition than for protein and the efficiency of energy utilization for maintenance was 0.48.

PS7 - Other topics**PS7-021 Evaluation of the effect of MCFA on the expression of avian beta-defensin genes during a Salmonella infection in broiler chickens**

D. Hermans¹, J. De Smet², J. Vervloesem¹, S. Radwan¹, V. Jacquier¹, S. Vartiainen³, J. Vande Ginste¹

¹Nutrition Sciences, Drongen, Belgium, ²Poulpharm BV, Izegem, Belgium, ³Alimetrix Ltd, Espoo, Finland

Medium chain fatty acids (MCFAs) are - next to their positive effect on the host level as an energy source - mainly known for their direct antimicrobial activity. MCFA may, however, also indirectly contribute to better health and disease resistance by modulating immune cells. In this experiment, we investigated if a specific MCFA blend could influence the expression of avian β -defensin genes during a Salmonella infection in broiler chickens. A total of 144 male Ross 308 birds were used for this study. Animals received drinking water and feed ad libitum throughout the entire study. Salmonella-negative chickens (sentinels) were randomly distributed per 20 birds to 6 isolator units. Half of the sentinel birds received a standard control diet, the other half with 600 gram/ton MCFA added on top. Seeder birds were housed separately and orally inoculated with 109 CFU of a virulent Salmonella Enteritidis strain (SE U.09.76) at 3 days of age and received a standard control diet. At 8 days of age, 4 Salmonella-positive birds (seeders) were put into each isolator to assure a gradual Salmonella transmission to the sentinels. At 20 days of age, all birds were euthanized and from the sentinels, small pieces (0.5 x 0.5 cm) were collected from the oesophagus, duodenum (tip of the loop) and spleen. Samples of each isolator were randomly pooled (n = 5 samples/isolator) and grouped per treatment (n = 3x5 samples/treatment). The relative gene expression levels of AvBD1, AvBD7 and AvBD9 were analyzed with qPCR by normalizing the expression against housekeeping genes RPL10 and TBP. Data were analyzed by ANOVA, using the general linear model procedure of R. The statistical model included the fixed effect of treatment. Differences were considered significant at $p < 0.05$, and in that case, were followed by a Tukey multiple comparison test. Next to a numeric ($p > 0.05$) increase for AvBD1 in the duodenum for the group receiving MCFA, a significantly increased AvBD9 expression was observed in the spleen of sentinel birds receiving MCFA ($p = 0.038$) compared to the negative control group, which shows the potential of these molecules to infer also systemic effects in poultry. An MCFA-induced expression of AvBD9 in chicken immune cells has already been shown in vitro. These data show that dietary MCFA can influence the expression pattern of avian β -defensins during a Salmonella colonization in broiler chickens, through which they could be a valuable tool in controlling Salmonella in poultry.

PS7 - Other topics**PS7-022 Growth and slaughter performance of four slower growing hybrids**

S. Mueller¹, J. Demierre², R. Zweifel¹

¹Aviforum Foundation, Zollikofen, Switzerland, ²IP-SUISSE, Lausanne, Switzerland

For the conventional chicken fattening in Switzerland, fast-growing hybrids are generally used. But currently, the use of slower growing hybrids is increasingly discussed. This, because a slower growth is intended to improve animal welfare. Therefore, the aim of the present study was to evaluate growth and slaughter performance of four slower growing broiler hybrids such as Redbro (RB), Rustic Gold (RG), JA987 (JA) and Ranger Classic (RC). The 4x1350 birds were kept in 20 m² compartments of 270 birds each. All birds received the same standard broiler diet divided into three phases (starter: 12.6 MJ metabolisable energy, 210 g crude protein/kg, grower: 13.0 MJ metabolisable energy, 195 g crude protein/kg, finisher: 13.2 MJ metabolisable energy, 180 g crude protein/kg). Body weight and feed intake were determined weekly. Average daily gain (ADG) and feed efficiency (g feed/g gain) were calculated. Litter quality and welfare parameters such as footpad lesions and hock burns were assessed. The RB and RG broilers were fattened for 42 d, JA and RC for 44 d. Data were subjected to ANOVA using SAS 9.4 and were analyzed considering diet as fixed effect. For multiple comparisons of the Least Square means the Tukey-Kramer option was used. Statistical significance was set to $p < 0.05$. The body weight development of three hybrids (JA, RC and RG) was very similar. The hybrid RB was heavier ($P < 0.05$) than the other three hybrids from d 7 to d 35. At the end of the fattening period, body weight of JA broilers was at a similar level with RB but still, RB was numerically the heaviest broilers. Consequently, ADG was greatest ($P < 0.05$) at RB with 54.5 g/d, all other hybrids had a similar ADG (49.8 g/d to 51.1 g/d). Feed efficiency was best ($P < 0.05$) for RG with 1.55, followed by RB (1.58) and RC (1.62). Feed efficiency for JA was most unfavorable with 1.71. The litter was mostly very dry with only little encrustation for all hybrids. Thus, footpad lesions and hock burns were found only very few (0% and maximal 6%, respectively). Dressing percentage was numerically greatest for JA broilers (71.5%) and lowest for RB (66.8%) with RG and RC in between (69.6 and 69.3%, respectively). To conclude, the growth and slaughter performance of all four hybrids was similar. The slower growing hybrids had a positive effect on the parameters litter quality, footpad health and hock burn occurrence.

PS7 - Other topics**PS7-023** How chestnut tannins have the potential to influence performance and metabolism of broiler chickens

K. Buyse^{1,2}, A. De Grande¹, E. Delezie¹, L. Goethals³, N. Van Noten¹, G. Janssens², M. Lourenço¹

¹Animal Science Unit, Institute for Agricultural, Fisheries and Food Research, Melle, Belgium, ²Department of Veterinary and Biosciences, Faculty of Veterinary Medicine, Ghent University, Merelbeke, Belgium, ³Sanluc International NV, Gent, Belgium

Nowadays, the broiler industry makes use of high yielding animals characterized by low feed conversion ratios and high growth rates. This can cause a series of metabolic stress responses. The industry has been searching for solutions for these metabolic challenges, among other plant extracts, especially chestnut tannins (CT) as natural antioxidants. However, the exact working mechanisms and effects on metabolism of CT on broilers still needs to be elucidated. A trial was performed using three doses of CT [(500 mg/kg (T500), 1,000 mg/kg (T1000) and 2,000 mg/kg (T2000)] and a control group (0 mg/kg (T0), during the entire rearing period. Performance was assessed during the whole rearing period, and at two ages (D28 and D35) markers for oxidative stress (superoxide dismutase (SOD), malondialdehyde (MDA) and ferric reducing antioxidant power (FRAP)) in muscle and intestinal tissue, and in plasma; were measured as well as acylcarnitines and free amino acids in plasma. In addition, creatine kinase (CK), lactate dehydrogenase (LDH) and aspartate aminotransferase (AST) were determined in serum samples at both ages. As seen in previous studies, animals of the T2000 group achieved a lower body weight than the other groups ($p=0.012$). However, when tannins were added in the feed CK (D28: $p=0.026$; D35: $p=0.045$) and AST (D28: $p=0.021$; D35: $p=0.063$) significantly decreased, indicating less muscle damage. Muscle SOD increased in the T1000 group compared to the other treatments (D28: $p=0.031$). In contrast, muscle MDA was highest in the T2000 group (D28: $p=0.088$; D35: $p=0.014$). Based on the profiles of plasma acylcarnitines and free amino acids, significant shifts occurred in the energy metabolism in the presence of CT. There was an indication that the broilers switched between dietary fat and protein as energy source. We can then hypothesize that CT have a multivalent potential to change (anti-oxidative) metabolism in a positive or negative way, depending on the dosage. However, the dose response effects were not linear and overall effects on performance depend on the summation of the effects of tannins. The discrepancy between the results for the two ages emphasizes the importance of metabolic age in judging effects of additives.

PS7 - Other topics**PS7-024** Improvement of broilers uniformity through the use of a led light on feeders

L. Galosi¹, R. Falconi^{2,1}, I. Mearelli², L. Biagini¹, A. Roncarati¹

¹School of Biosciences and Veterinary Medicine, University of Camerino, Matelica, Italy, ²Fileni Group, Cingoli, Italy

Among the management problems that continuously affect broiler production, the request to reduce the non-uniformity size of growing animals is one of the key-factors to ensure the success of farming. This study aimed to assess the use of a light emitting diode (LED) and its effect on the productive performances of broiler chickens. LED light lamps, over the final feeder, to attract broilers to feed in this section, were tested, evaluating the performances in productive conditions. In this way, coming to be emptied more quickly, this device allowed a greater filling along the entire feeding line in comparison with farms without LED lights. A total of 87,200 ROSS 308 chickens, with the same body weight (mean $g\ 41 \pm 3$), were housed in two shed (Shed 4, Shed 5), with the same environmental conditions. Females are housed in the first part of each shed, and males in the second part. When the females are removed for slaughtering, all the shed is dedicated to the males. In Shed 5, the feed distribution devices were equipped with an LED light (FlexLED GLO lamp, Big Dutchman), located on a single feeder at the end of each feeding line. Weekly, 100 males and 100 females for each shed were weighed by means of an electronic scale (BAT1, VEIT Electronics, Moravany, CZ), provided with a software for the mean body weight calculation. At the end of the growth cycle of females and males in each shed, flock uniformity rate was evaluated according to the formula $[100 - (\text{standard deviation} / \text{mean body weight of chicken}) * 100]$. Data concerning body weight at different sampling times, were submitted to analysis of variance (ANOVA) using SPSS 25 (Version 25.0, Armonk, NY, USA) and the differences between the means were considered significant at $p < 0.01$ using the Student-Newman-Keuls (SNK) test. The final mean body weight never showed significant differences in the females (29 days: $g\ 1345$ in Shed 4; $g\ 1359$ in Shed 5) and in the males (43 days: $g\ 2771$ in Shed 4; $g\ 2793$ in Shed 5). Nevertheless, the uniformity was improved in females and males raised in Shed 5 (F 75.2% and M 54.1%), where feeders were equipped with LED devices, compared to the conventional feeders of Shed 4 (F 65.7% and M 48.5%). The LED light applied to the feed distribution line demonstrated its utility in the improvement of the size uniformity.

PS7 - Other topics**PS7-025 Incremental dietary Ca content downregulates intestinal expression of Ca transporters and claudins in a microbial phytase-independent manner**Y. Hu^{3,2,1}, J. van Harn², W. Hendriks³, J. van Baal³, A. Dijkslag⁴, M. van Krimpen², P. Bikker²¹De Heus Animal Nutrition B.V., Ede, Netherlands, ²Wageningen Livestock Research, Wageningen, Netherlands, ³Wageningen University & Research, Wageningen, Netherlands, ⁴ForFarmers, Lochem, Netherlands

We previously found that incremental dietary calcium (Ca) content reduced apparent distal ileal Ca and phosphorus (P) digestibility, which was greater in the phytase supplemented diets. Hereby we hypothesized that incremental dietary Ca content reduces intestinal gene expression of Ca and P transporters and claudins, with a greater impact in the microbial phytase supplemented diets. Eighteen hundred day-old male Ross 308 broilers were randomly assigned to one of eight experimental diets in a 4x2 factorial design including four Ca/rP ratios (1.3, 1.8, 2.3 and 2.8) and two microbial phytase levels (0 vs 1000 FTU/kg). Dietary rP was fixed at 3.2, 2.5 and 2.2 g/kg in the starter (day 0-10), grower (day 10-29) and finisher (day 29-36) period, respectively, which was 80% of the recommendation of CVB (2018). On day 21-23, one broiler per pen was euthanized to collect mucosa from mid duodenum for analysis of expression of Ca and P transporters and claudins using RT-PCR. Results indicated that irrespective of microbial phytase inclusion (no interaction effect), incremental dietary Ca/rP linearly increased serum Ca concentration but reduced duodenal mRNA expression of Ca transporters CaSR, CaBP-D28k and PMCA1 and Ca-pore-forming claudins CLDN-2 and CLDN-12 ($P < 0.001$). Incremental dietary Ca/rP also linearly reduced serum P concentration in the phytase free diets but not in the phytase supplemented diets ($P < 0.001$) and lowered duodenal mRNA expression of P transporters NaPi-IIb, PiT-2 and XPR1 independent of microbial phytase ($P = 0.052$, 0.071 and 0.028 , respectively; no interaction effect). Dietary phytase inclusion increased ($P = 0.026$) NaPi-IIb but reduced ($P = 0.029$) CLDN-2 expression. In conclusion, an incremental dietary Ca/rP ratio downregulates duodenal expression of Ca-related transporters (CaSR, CaBP-D28k and PMCA1) and Ca-pore-forming claudins (CLDN-2 and CLDN-12) in a phytase-independent manner.

PS7 - Other topics**PS7-026 Intestinal morphology and performance of European quails submitted to post-hatch fasting for different periods**T.J. de Oliveira¹, H. Marques da Silva¹, A.V. de Sousa², G. Firmo Marinho², L. Bezerra Batista², A.L. de Barros Moreira Filho², C.J. Bruno de Oliveira¹, P.E. Naves Givisiez¹¹Departament of Animal Science, College for Agricultural Sciences, Federal University of Paraíba (CCA/UFPB), Areia-PB, 58397-000, Brazil, ²Department of Animal Science/CCHSA, Federal University of Paraíba, Bananeiras, PB, Brazil

Intestinal morphology and performance were assessed in European quails submitted to post-hatch fasting for 24 and 48 hours to mimic the time lapse between hatching and placement in the poultry house. European quails ($n=180$) were distributed in three treatments with five replicates of 12 animals: immediate access to food (OH), fasting for 24h (24H) or 48h post-hatch (48H). Jejunum was sampled at 7, 14 and 21 d from five birds/treatment for histometric analysis using hematoxylin-eosin staining. Villus height, crypt depth, villus: crypt ratio, and villus area were measured. Ten measurements per variable per bird were used to calculate a mean value per bird. Body weight, feed intake, weight gain and feed:gain ratio were assessed at 21d. Analysis of variance was carried out in a completely randomized design with three treatments and five repetitions. Means were compared by Tukey's test at 5%. Fasting did not affect any variables at 7d, nor crypt depth (CD) at 14 and 21 days of age and villus: crypt ratio (VCR) at 21days. At 14 days, villus height and villus area decreased in 24H (VH: 525.3 μm ; VA: 36311.9 μm^2) and 48H (VH: 483.6 μm ; VA: 32532.9 μm^2) birds when compared to OH birds (619.6.3 μm and 44705.4 μm^2). Villus: crypt ratio was lower in 48H quails compared with OH (10.65 vs 13.19 $\mu\text{m}/\mu\text{m}$, respectively); 24H birds had intermediate VCR values (11.72 $\mu\text{m}/\mu\text{m}$) that were not different from OH or 48H birds at 14 d. At 21 d, VH and VA were smaller in 48H birds (VH: 503.9 μm ; VA: 35364.6 μm^2) than OH (VH: 633.0 μm ; VA: 46175.0 μm^2) and 24H quails (VH: 643.4.9 μm ; VA: 46474.4 μm^2). The negative effects on morphology may affect nutrient absorption and, consequently, performance of birds. Body weight was decreased in 48H quails (143.6 g) compared to 24H (159.4) and OH (167.9 g), as well as feed intake (291.0, 320.3 and 337.4 g, respectively) and weight gain (134.3, 150.2 and 158.0 g, respectively). Feed:weight ratio at 21d was not affected by fasting (overall mean 2.14). Considering that birds submitted to longer periods of fasting (48 hours) seem to recover later than birds fasted for 24 hours, fasting for long periods should be avoided in European quail production. In conclusion, early post-hatching feeding is recommended in European quails to prevent negative effects on intestinal morphology and performance. Funding: FAPESQ (#3148/2021), UFPB (#PVN13255-2020, #PVO15360-2022), and CAPES (Finance code 001 and PPrint #88881.311776/2018-01)

PS7 - Other topics**PS7-027 Intestinal permeability and goblet cell count of broilers fed with prebiotic associated or not with antibiotics**

H.H. de Carvalho Mello¹, A.P. de Freitas Martins¹, H. Sales de Campos², J.H. Stringhini¹, M. Barcellos Café¹, A.G. Ferreira Dias¹, J.C. Lopes Brasileiro¹, R. Rodrigues dos Santos¹

¹Departamento de Zootecnia, Escola de Veterinária e Zootecnia, Universidade Federal de Goiás, Goiânia, Brazil, ²Instituto de Patologia Tropical e Saúde Pública, Universidade Federal de Goiás, Goiânia, Brazil, Goiânia, Brazil

The aim of the study was to evaluate the effects of prebiotic associated or not with antibiotic on broiler intestinal permeability, and goblet cells count. A total of 1440 one-day-old male Cobb 500 chicks with 42g + 2.1g average weight were distributed in a completely randomized design, with four treatments and ten replications, totaling 36 birds per experimental unit. The treatments used were a basal diet without prebiotics and antibiotics (BD), a basal diet with antibiotic (AB), a basal diet with prebiotic (PRE), and a basal diet with antibiotic and prebiotic (AB+PRE). To do so, 55 g/ton antibiotic zinc bacitracin and 250 g/ton prebiotic *S. cerevisiae*-derived mannan-oligosaccharides and beta-glucans were used. Eight chickens at 28 days of age and five chickens at 42 days of age per treatment were used for intestinal permeability testing. The birds were inoculated orally, directly into the esophagus, with FITC-d (3-5 kDa; Sigma Aldrich Co™) diluted in saline at 4.16 mg/kg, with the aid of a feeding tube. After 2 hours of inoculation, 2.0 mL blood was collected. Serum levels of FITC-d were measured at 485nm excitation and 528nm emission wavelengths, using a spectrofluorometer. For goblet cell count of intestinal mucosa, six birds per treatment were euthanized by cervical dislocation at 21 and 42 days of age for the collection of intestinal fragments. Five-cm samples were taken from small intestine segments (duodenum, jejunum, and ileum). To prepare slides, these segments were fixed in a 10% buffered formaldehyde solution for 24 hours. After fixation, they were stored in 70% alcohol, and stained with Alcian Blue for goblet cell count. Images for reading were acquired in a 2.5x and 20x objective using a Leica DM 4000B optical microscope coupled to a microcomputer. The images were analyzed using Image J software. To count goblet cells, an area of 7mm² per fragment was considered. The intestinal permeability analysis showed no difference at 28 days old and a tendency of lower permeability in broilers fed PRE at 42 days old. At 42 days of age, the association AB + PRE had a higher amount of goblet cells but without differentiating from prebiotic treatment and basal diet. In conclusion, the use of prebiotics, associated or not with antibiotics, affects the goblet cells count at 42 days old. The use of PRE seems to affect the intestinal permeability of the broilers, needing further studies.

PS7 - Other topics**PS7-028 Investigation of the active metabolites of *Bacillus subtilis* DSM 29784 and their effects in broiler chickens**

N. Vieco-Saiz¹, S. Kruse², F. Pierre³, G.E. Morlock², R. Ducatelle⁴, F. Van Immerseel⁴, E. Pinloche¹

¹Adisseo France SAS, Center of Excellence and Research in Nutrition, Commentry, France, ²Institute of Nutritional Science, Chair of Food Science, and Interdisciplinary Research Centre for Biosystems, Land Use and Nutrition, Justus Liebig University, Giessen, Germany, ³Adisseo France SAS, Antony, France, ⁴Ghent University, Faculty of Veterinary Medicine, Mellebeke, Belgium

Bacillus subtilis DSM 29784 (Bs29784) is a probiotic strain with demonstrated effects on animal performance (Rhayat et al, 2017) and intestinal health (Keerquin et al, 2021). These beneficial effects have been linked with the production of hypoxanthine, nicotinic acid and pantothenate (Choi et al., 2021). However, the exact mechanisms by which Bs29784 confers these health benefits via its secreted metabolites remains unclear. Using a combination of cellular biology and intestinal fermentation simulations, we aimed to study the key functions of these metabolites on intestinal health and gut microbiota. We used a caco-2 cell model to assess the proliferation using PrestoBlue™. Level of inflammation was evaluated by measuring TER and pro-inflammatory cytokine release (IL6/IL8) after 2h incubation with the treatment followed by 4h incubation with cytomix (TNFα/IFN-γ/IL-1β). Ileal and caecal contents of 28d chicken were used for the intestinal fermentation. Gaz pressure, pH, SCFAs, NH₃, lactate were analyzed. Bacterial community changes were analyzed by 16s NGS (Illumina). Finally, high-performance thin-layer chromatography (HPTLC) was used to visualize differences in the metabolite profile of the probiotic Bs29784 compared to seven other bacteria of the genus *Bacillus* with high genetic similarity. We observed that all the metabolites increased cellular proliferation. Panthotenate improved TEER. Following cytomix stimulation, hypoxanthine and panthotenate lessened the drop of TEER and hypoxanthine significantly decreased IL6 production. On the intestinal fermentation simulations, panthotenate stimulate butyrate production and increased *Bifidobacterium* in the Ileum. Hypoxanthine and panthotenate increased cecal butyrate which is correlated with higher frequencies of butyrate producers or butyrate-production stimulators such as *Bifidobacterium*, *Butyricoccus* and *Intestinimonas*. Nicotinic acid increased SCFAs and propionate. Furthermore, all metabolites increased microbiota diversity. The HPTLC approach highlighted the presence in high quantity of radical-scavenging metabolites such as, lipopeptides, glycopeptides, glycolipopeptides, as well as antimicrobial metabolites (surfactin) and other physiologically active metabolites. Finally, these results strengthen the understanding of the effect of Bs29784 on the host and support its probiotic effect enhancing animal resilience.

PS7 - Other topics**PS7-029 Microbiota modulation with *Pediococcus acidilactici* CNCM I-4622 supplementation in laying hens during the late phase of the production cycle**C. Achard¹, A. Sacy¹, E. Chevaux¹, F. Barbe¹, M. Ligabue¹, M. Castex¹¹Lallemand SAS, Blagnac, France

In this study, 52 layers of 41 weeks old Novogen were enrolled for 10 weeks in individual cages, comparing a control diet with a diet supplemented with the probiotic strain *Pediococcus acidilactici* CNCM-I 4622 (Bactocell®) at a dose of 2×10⁹ cfu/kg of feed the first three weeks, then at 10⁹ cfu/kg. The performances were analyzed using a random intercept slope mixed model with Treatment and Time as fixed effects. Fresh feces were collected for microbiota analysis at mid-course. Microbial DNA was extracted from feces and the hypervariable V4-V5 regions of the 16S rRNA gene were targeted for sequencing. High-throughput sequencing was performed on a MiSeq sequencer. Sequences were processed using FROGS pipeline to generate an OTU abundance table. Taxonomic annotation of the OTUs was performed using the SILVA SSU database (version 138) with BLAST+ and completed using RDP algorithm. There was a trend for higher egg weight (+3%; p=0.09) while the percentage of downgraded eggs (-89%; p=0.05) and the laying rate adjusted for marketable eggs (+4%; p=0.03) were respectively significantly decreased and increased in the probiotic group. As a consequence, the exported egg mass (+7%; p=0.01) and the FCR (-8.6%; p=0.05) were significantly improved in the probiotic group. The microbiota analysis allowed to identify 15 different phyla, 85 families and 193 genera. The dominant phyla in all samples were Firmicutes (89%±12%), followed by Bacteroidota (7.7%±10.6). Other minor phyla included Actinobacteriota, Fusobacteria and Proteobacteria. We observed a high variability in fecal microbial composition, with Firmicutes:Bacteroidota ratio ranging from 9999:1 to 55:45. Lactobacillaceae (43% ±27%; p=0.05) was the major family, mostly represented by *Lactobacillus*, *Ligilactobacillus*, and *Limosilactobacillus* genera, followed by Peptostreptococcaceae family (13% ±13%). Of note, *Enterococcus* genus exhibited a low mean relative abundance (1.4% ±5%). Alpha diversity was higher in the probiotic group, and the relative abundances of 4 phyla and 8 families were significantly modulated. Interesting negative correlation were evidenced between the relative abundance of Lactobacillaceae and the alpha-diversity. This correlation was even stronger when considering unknown Clostridia UCG-014/*Lactobacillus* log ratio. This suggests that lower level of Lactobacillaceae may have allowed the development of a more diverse microbiota in this specific case, and the probiotic supported it.

PS7 - Other topics**PS7-030 Modern laying hens: has the deposition rate of carotenoids in egg yolk changed?**M. Umar-Faruk¹, V. Gigaud²¹DSM Nutritional Products, Village-Neuf, France, ²DSM Nutritional Products, La Garenne-Colombes, France

Carotenoids are a class of natural fat-soluble compounds, mainly de novo synthesized by plants. The major drive to use carotenoids in animal production is their ability to confer different color hue to animal products, as it's an important characteristic involved in food selection. In addition, carotenoids are essential antioxidants that play an important role in reproduction and associated with various physiological functions. Therefore, carotenoid is commercially used not only for pigmentation but also poultry breeder performance and table egg quality improvement. Since the first isolation of natural carotenoids in 1817, more than 700 different carotenoids have been characterized, but four of them are used in commercial poultry production, namely canthaxanthin, apo-ester, lutein/zeaxanthin, citranaxanthin and capsanthin/capsorbin. One of the most important factors to consider is the source of the carotenoids and the differences on effectiveness, in terms of rate and speed of transfer and the amount capable of being deposited in the target tissue. The deposition rate of carotenoids is the prerequisite to the final color of the target tissue. If this factor was already assessed in previous publications (Bauernfeind, 1981, Hammershoj 2010, Sirri 2007, Fru 2006, Fru 2007) the objective of this study was to update and highlight the differences on deposition rate in egg yolk of modern laying hens among carotenoids sources. Seven internal studies between 2016 and 2018 using the same design were used and combined to determine the average of carotenoids deposition rate with a total of 251 values. Among the used carotenoids, this overview confirms the highest deposition rate for apo-ester with 46.2%, followed by canthaxanthin with 31.9%, then lutein-zeaxanthin with 19.4%, citranaxanthin 12.72%. The least deposition is found with capsanthin and capsorbin with 5.25%. From the above recent information, carotenoids continue to be the major source of bio-pigmentation of animal derived products. Apo ester and canthaxanthin are still the highly deposited carotenoids with Capsanthin/Capsorbin being the least. There is no huge evolution in terms of carotenoids deposition in modern layers.

PS7 - Other topics**PS7-031 Near-infrared spectroscopy to predict the carbohydrate and lignin contents of a variety of feedstuffs included in poultry diets**

A. Cruz-Conesa^{2,1}, K. Bach Knudsen³, S. Joan Noel³, A. Pérez-Vendrell¹, J. Ferré², I. Ruisánchez²

¹Institute of Agrifood Research and Technology, Animal Nutrition, Mas Bové, Constantí, Spain, ²Universitat Rovira i Virgili, Faculty of Chemistry, Department of Analytical and Organic Chemistry, Tarragona, Spain, ³Department of Animal and Veterinary Science, AU Viborg research center Foulum, Aarhus University, DK 8830 Tjele, Denmark

Carbohydrates (CHO) are the principal constituents of the diets given to poultry around the world. They supply the largest part of the energy to the animal, despite the fact only monosaccharides, disaccharides and starch are absorbed by the bird. Oligosaccharides (OS), resistant starch, non-starch polysaccharides (NSP) and lignin compose the so-called dietary fiber that it is not absorbed. The soluble fraction of fiber is mainly fermentable and causes benefits to the gastrointestinal tract while the insoluble is not and therefore lead to a decrease in nutrient and energy digestibility. The CHO fraction and its composition is highly variable among feed ingredients but also amongst the different varieties of the same ingredient. To improve the nutrient utilization and to formulate animal diets that are more efficient it is necessary to characterize the CHO fraction of the ingredients. In addition, with the growing use of supplementary enzymes, such as xylanase, b-glucanase or mannanase to mitigate the anti-nutritive effect of fiber the determination of the CHO components is essential. To make a full account of the CHO and lignin constituents, several wet chemical enzymatic, chromatographic and gravimetric methods need to be employed, which are expensive and time-consuming. Near-infrared spectroscopy (NIRS) overcomes these limitations because it is a rapid, non-destructive, multi-parametric technique and requires minimal sample preparation. In this work, around 300 samples of animal feedstuffs, consisting of cereals, cereal co-products, protein-rich and fiber-rich feedstuffs were used to develop and validate near-infrared (NIR) partial least square regression (PLSR) models. Spectral pretreatment optimization, sample selection and outlier detection were considered for each model. Robust predictions ($R^2P > 0.90$) were obtained for digestible carbohydrates (sugars and starch) and for most of the total or insoluble components of dietary fiber (lignin, NSP, cellulose, b-glucan, non-cellulosic polysaccharides (NCP), arabinose, xylose, galactose, rhamnose and uronic acids). The OS, fructans were well predicted in cereals ($R^2P = 0.94$) and linearity ($R^2CV > 0.70$) was also found for a-galactosides (raffinose, stachyose and verbascose) in protein-rich feedstuffs. The obtained results were in general very satisfactory and demonstrate that NIRS is a reliable tool to characterize the carbohydrate fraction of a variety of feedstuffs.

PS7 - Other topics**PS7-032 Post-hatch fasting effects on performance and digestive organs of Japanese quails**

D.S. Gomes¹, T.J. de Oliveira¹, A.V. de Sousa², E.F. da Silva Cabral², J.L. de Araújo Morais², Á. S. Gomes Santana², A.L. de Barros Moreira Filho², P.E. Naves Givisiez¹

¹Departament of Animal Science, College for Agricultural Sciences, Federal University of Paraíba (CCA/UFPB), Areia-PB, 58397-000, Brazil, ²Department of Animal Science/CCHSA, Federal University of Paraíba, Bananeiras, PB, Brazil

This study evaluated how post-hatch fasting for 24 and 48 hours affects performance, and weight and length of different digestive organs of Japanese quails. In order to mimic the time lapse between hatching and placement in the poultry house, as-hatched Japanese quails were distributed in three treatments with five replicates of 12 birds: immediate access to feed (0H), fasting for 24 h (24H) or 48 h post-hatch (48H). Body weight, feed intake, weight gain and feed:gain ratio were assessed at 21 days of age (d). Organs were sampled at 7 and 21d (five birds/treatment) to record the weight of small intestine, large intestine, proventriculus, gizzard and liver, and small intestine length. Analysis of variance was carried out in a completely randomized design with three treatments and five repetitions and means were compared by Tukey's test at $P < 0.05$. At 21d, body weight (BW, g), feed intake (FI, g) and weight gain (WG, g) were lower ($P < 0.05$) in 48H quails (BW: 79.8a, 76.3a and 73.3b; FI: 259.4a, 254.4a and 239.3b; WG: 72.1a, 68.8a and 65.7b, for 0H, 24H and 48H birds, respectively). Feed:gain ratio (g/g) was similar between treatments (0H: 3.6a; 21H: 3.7a; 48H: 3.6a). Performance was also negatively affected in 24H quails, although not significantly when compared with 0H birds. Therefore, birds would probably recover after 21 days if a 24-h fasting post-hatch is necessary before allocation in the poultry house. Poorer performance probably results from changes in intestinal integrity and morphology that may affect nutrient absorption. Small intestine length was not affected by fasting at 7 or 21d. At 7 d, organ weight was smaller in 48H quails when compared to 24H and 0H, except for the gizzard. The differences were not seen at 21d, except for the small (SI) and large intestine (LI) weights. SI weight (g) was smaller in 48H and intermediate values were seen in 24H quails (0H: 4.1a; 21H: 3.6ab; 48H: 3.3b), whereas LI weight (g) was smaller in 48H and intermediate values were seen in 0H birds (0H: 1.3ab; 21H: 1.5a; 48H: 0.9b). Finally, gizzard (g) was smaller in 48H birds (0H: 3.6a; 21H: 3.6a; 48H: 2.7b). The performance of Japanese quails is negatively affected by post-hatch fasting for 48 hours at least until 21d and therefore, feed should be provided to Japanese quails preferably not later than 24 hours after hatch. Funding: FAPESQ (#3148/2021), UFPB (#PVN13255-2020), and CAPES (Finance code 001 and Print #88881.311776/2018-01)

PS7 - Other topics**PS7-033 Protective effect of a yeast β -glucan on broiler chickens exposed to a diet naturally contaminated with deoxynivalenol**V. Marquis¹, J. Schulthess¹, R. Raspoet¹, F. Molist², R.R. Santos²¹Phileo by Lesaffre, 137 rue Gabriel Peri 59700 Marcq-en-Baroeul, France, ²Schothorst Feed Research, Department of Research and Development, Meerkoetenweg 26, 8218 NA Lelystad, Netherlands

Among mycotoxins, deoxynivalenol (DON) is one of the most prevalent, occurring worldwide in feed. DON-contaminated feed may be responsible for adverse effects, having impact on animal health and production. In poultry, chronic exposure to low levels of DON results in impaired performance and subclinical alterations, increased susceptibility to pathogens and infectious diseases, all resulting in economic loss. Preventive measures can reduce feed contamination but are not effective in removing all mycotoxins from the diet. The use of additives, therefore, which are able to deactivate mycotoxins, avoiding their absorption in the intestine, or supporting gut health during exposure, can minimize economic losses caused by mycotoxins. The study evaluated the effectiveness of a yeast fraction, enriched in β -glucans, on the performance, gut health, liver function, and bacterial translocation in broilers fed a DON-contaminated diet. A total of 234 one-day-old male Ross broilers, divided into 3 treatments with 6 replicates each, were fed a corn/soybean-based control diet, or corn/soybean diets which were naturally contaminated with DON (~3,000 ppb) either or not supplemented with a yeast β -glucan (β -G) (125g/ton) over a period of 28 days. Dietary exposure to DON did not affect production performance. However, DON exposure significantly decreased jejunum villus height, and crypt depth when checked on day 13, an effect which was countered by the yeast β -G supplement. On day 28, the jejunum VH:CD ratio was significantly higher in broilers fed the DON-contaminated diet, supplemented with yeast β -G, whereas the ileal villus area was significantly decreased in broilers fed a DON-contaminated diet, regardless of supplementation. Dietary contamination reduced expression of PEPT1 and GLUT on day 13 and upregulate LEAP2 suggesting an impaired protein absorption. On day 28, the upregulation of XOR, IFN γ , IL8, IL10, and IL12 suggest oxidative stress and inflammation were present. A significant increase in the translocation of *E. coli* to the liver was also observed. These negative effects were minimized by dietary supplementation with the yeast β -G. In conclusion, the results of this study indicate that the consumption of circa 3,000 ppb DON impairs jejunum villus height, crypt depth, and villus area, leading to intestinal oxidative stress and inflammation, with bacterial translocation. The addition of yeast β -glucan to the diet was beneficial to the broilers in the study.

PS7 - Other topics**PS7-034 Recent European trends of intestinal health in broilers**M. vereecken¹, B. Dehaeck¹, w. schelstraete¹, s. bekaert¹, m. marien¹¹Huvepharma, Antwerp, Belgium

Data was obtained by 87 independent field veterinarians operating in 5 different European countries (Belgium, France, Poland, UK, and Spain) scoring 7356 flocks (46514 birds). The data was entered in Aviapp® (the health and performance monitoring platform of Huvepharma®). Only data from users which share data with the platform were selected. The age of scoring ranged between 14 and 42 days. No other selection was performed. To accommodate for the data heterogeneity, the coccidiosis data was analysed using an ordinal logistic regression incorporating a random effect term for user, farm and country nested within the year of observation. The age effect was modelled using a base spline using three degrees of freedom interacting with the year of observation (fixed effects). For the other outcomes (dysbacteriosis, gizzard erosions, footpad dermatitis), linear mixed models were used incorporating a fixed effect for each month and random effects for users, farm, country, and age of scoring. The peak score of *E. acervulina* was seen at 25.7 days in 2021 (peak score 0.62) and at 25.0 days in 2022 (peak score 0.63). For *E. maxima*, the peak score was seen at 32.2 days in 2021 (peak score 0.24) and at 30.7 days in 2022 (peak score 0.16). For *E. tenella*, the scores were very low in general with the peak seen at 32.1 days in 2021 and at 29.2 days in 2022. In both years the peak score was 0.04. *E. acervulina* was the predominant species and lesions decreased in the second half of 2022 (as for *E. maxima*). Dysbacteriosis scores were also evaluated in 2021 and 2022. Starting in April 2022, an increase of the monthly average dysbacteriosis scores was seen in comparison with the monthly averages in 2021. Furthermore, from 2021 onwards, a significant increase in gizzard erosions was seen with average scores of 0.25 (1st half 2021), 0.30 (2nd half 2021), 0.33 (1st half 2022) and 0.39 (2nd half 2022). Interestingly, a positive correlation was found between the monthly average dysbacteriosis scores and the monthly average gizzard erosions scores in 2022 (correlation coefficient 0.46). In 2021, this correlation coefficient was much lower at 0.14. The stronger positive correlation in 2022 might indicate a common cause, e.g. less availability of good quality raw materials. In conclusion, from 2021 to 2022, coccidiosis was better controlled but intestinal health in general was a bit poorer, as indicated by increased dysbacteriosis scores.

PS7 - Other topics**PS7-035 Setting foundations: Manganese amino acid complex supports eggshell membrane architecture and eggshell quality**C. Torres¹, D. Neves², A. Aljamal², J. Wang³, H. Zhang³¹Zinpro Corporation, Eden Prairie, United States, ²Zinpro Corporation, Minneapolis, United States, ³Feed Research Institute, Chinese Academy of Agricultural Sciences, Beijing, China

Manganese (Mn) is vital in the metabolism of glycosaminoglycan (GAG) and uronic acid (UA), key components for proper development of the eggshell organic matrix. The effect of Mn supplementation in layer diets on eggshell structure and quality were investigated. A total of 324 Hy-line Brown layers were randomly assigned into 3 dietary treatments with 6 replicates, each containing 18 birds. From 21 to 46 weeks, layers were fed a Control corn-soybean basal diet (21.95 mg Mn/kg) or the basal diet supplemented with 40 mg/kg Mn as sulfate (MnSO₄) or 40 mg/kg Mn as amino acid complexed (MnAAC). Eggshell ultrastructure, GAGs and UA content were measured at 34 and 46 weeks of age. Eggshell thickness and breaking strength were evaluated at the end of every 4 weeks. Data were analysed using a one-way ANOVA and LSD was employed to compare the means when differences were significant at $p < 0.05$. Total egg production 23 - 46 week period was greatest with MnAAC supplementation followed by MnSO₄ ($88.4 \leq 90.8 \leq 92.9$ %, $p = 0.016$ Control, MnSO₄, MnAAC respectively). The GAG content in calcified eggshells was not influenced by dietary Mn supplementation whereas uric acid content was increased at both ages. With regards to eggshell membrane, Mn supplementation increased the content of uric acid ($3.72 \leq 4.06 < 4.67$ mg/g, 46 weeks, $p = 0.007$ Control, MnSO₄, MnAAC respectively) and GAGs ($2.11 < 2.31 < 2.40$ mg/g, 46 weeks, $p = 0.06$, Control, MnSO₄, MnAAC respectively) at 46 weeks of age. The Control group gave rise to larger and abnormally arranged mammillary layer. The thickness of the mammillary layer was 10.6% greater and its width was 11.7% greater in the Control group relative to MnAAC group; hens fed with MnSO₄ had intermediate figures and not significantly different from the other treatments. Total eggshell thickness (effective + mammillary layer) was not affected by Mn supplementation; however, the MnAAC group increased effective layer thickness and effective layer thickness to mammillary layer ratio compared to other treatments. Furthermore, the MnAAC group had eggshells with decreased mammillary cone resulting in greatest resistance to break compared with other treatments ($31.7 \leq 34.3 \leq 36.94$ N, $p = 0.005$, Control, MnSO₄, MnAAC, respectively). Dietary MnAAC improved eggshell quality and mechanical property by increasing organic matrix content in the membrane and calcified eggshell resulting in improved eggshell ultrastructure and breaking strength.

PS7 - Other topics**PS7-036 Short chain fatty acids and their impact on gut health parameters**S. Rengman¹, S. Tawde², A. Tacconi², H. Zhang³¹Perstorp AB Sweden, Malmö, Sweden, ²Perstorp Waspik BV, Waspik, Netherlands, ³Feed Research Institute, Chinese Academy of Agriculture Sciences, Beijing, China

Short chain fatty acids are nowadays commonly accepted as feed additives to support animal production and reduce the negative impact of different challenges. They have been proven to support gut health by positively impacting the epithelial cell function, increasing mucus production, promoting intestinal cell integrity, and supporting mucosal immune functions. Butyric acid is probably the most investigated both in humans as well as in animals. Much less is however known for valeric acid. In this study the effects of a combination butyric acid and valeric acid ester with a minimal addition of carvacrol has been investigated to assess its effects on gut health parameters and their correlation to performance in male Arbor Acre broiler chickens. For this research a total of 1,440 one-day-old chicks were divided to 4 treatments. The control group was fed a standard diet while experimental groups received the same diet supplemented with different dosages of the test product. Performance parameters, intestinal morphology parameters and intestinal barrier protein expression were analyzed at days 14, 28 and 42 and intestinal immunity indexes were analyzed at days 28 and 42 of the trial. Results showed that chicken fed the test product at all dosages had significantly better FCR compared to control group. Intestinal morphology parameters in jejunum and ileum did not show significant differences on day 14, 28 and 42 for two of the treatments. However, one treatment showed significantly higher villi length and villi to crypt ratio in the jejunum on day 42 of the trial. The test product significantly decreased levels of TLR2, TLR4, IL-1 β , IL-6 and TNF- α in jejunal mucosa. At the age of 42 days TLR4, IL-6 and TNF- α levels in jejunal mucosa were greater in two of the treated. On day 28 of the trial two treatments were found to have significantly upregulated jejunal ZO-1 and occludin expression. The third treatment had higher occludin expression. At 42 days one of the treatments showed significantly higher expression of ZO-1 and occludin, while the third treatment showed upregulation of the expression of ZO-1, claudin and occludin. The use of a combination of esterified butyric and valeric acid, in all three dosing strategies trialled, had a positive impact on gut health parameters. The improvement in gut health was positively reflected in the animals performance.

PS7 - Other topics**PS7-037** Supplementation with *Saccharina latissima* extract affects early growth rate and antibody levels, but not microbial composition in broiler chicksE. Ivarsson¹, H. Wall¹, M. Boyner¹, L. Sun¹, G. Cervin², H. Pavia², E. Watrang³¹Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden, ²Department of Marine Sciences, University of Gothenburg, Uppsala, Sweden, ³Department of Microbiology, National Veterinary Institute, Uppsala, Sweden

The study aimed to investigate if feeding an extract rich in laminarin from the algae *Saccharina latissima* (AE) to broiler chicks affects body weight, antibody levels or microbial composition in young chickens. An experiment was conducted where 255 chicks were hatched on-farm and distributed into 24 pens and fed two diets, control (C) and a diet supplemented with AE to provide 290 ppm laminarin per kg feed. Chicks were individually weighed at days 3, 7, 14. At days 7 and 14, two birds per pen were killed and caecal digesta was collected for microbiota analysis. In addition, blood samples were drawn at days 3, 7 and 12 and sera were analysed for total IgY concentration and titers to infectious bronchitis virus (IBV) with ELISA methodology. DNA was extracted from the caecal samples and sequenced using the Illumina NovoSeq 6000 PE250 platform. Growth performance and antibody data sets were analysed with Proc Mixed in SAS, while microbiota data was analysed with mixed effects linear models with the packages lme4, lmerTest, pbktest and emmeans in R. The results showed that at days 3 and 7, chicks fed AE had a higher body weight ($p < 0.05$) than chicks fed C. However, on day 14 no differences ($p > 0.05$) in body weight were observed. The total amount of IgY and titers to IBV were highest on day 3 and subsequently declined throughout the experimental period. Expressed as proportions of day 3 levels within individuals, results showed that chicks fed AE had higher IgY values days 7 and 12 ($p < 0.05$) than chicks fed C (26 vs. 21%) while for IBV titers, the chicks fed C had higher values ($p < 0.05$) than chicks fed AE (46 vs 38%). In the current study chicks were not exposed to IBV. Hence, antibodies to IBV were solely maternally derived, while the total amount of IgY also comprised antibodies produced by the chicks. Results thereby indicate that the AE chicks both metabolised their maternal antibodies and commenced their own IgY production faster compared to C chicks. For caecal microbiota, principal coordinate analysis showed differences in generalized UniFrac distance matrix between days 7 and 14, however no differences due to feeding AE were observed. The amplicon sequencing variant (ASV) with highest relative abundance at day 7 was *Escherichia-Shigella_d46e*, whereas at day 14 the most abundant ASV was *Eisenbergiella_2799*. In conclusion, supplementation with AE promotes early growth and antibody production, but does not affect the caecal microbial composition.

PS7 - Other topics**PS7-038** The effect of water-soluble probiotics during feed transition period on animal performance of broiler under commercial conditionsN. Yacoubi¹, U. Riesen¹¹Evonik Operations GmbH, Hanau- Wolfgang, Germany

Water-soluble probiotics are often applied to quickly react to upcoming stress situations in the flock - but they can negatively impact the formation of biofilm in the water lines. For this reason, formulations that reduce the formation of biofilms while remaining efficacious are required. The new formulation is an effervescent tablet loaded with a natural, fast-growing *Bacillus amyloliquefaciens* CECT 5940 (5E+8 CFU/L), ensuring a fast dissolution rate (10 min in average) as well a homogenous distribution of the spores in water without additional stirring. In this study, we tested the efficacy of the new formulation under field conditions in a commercial farm. The farm, located in the UK, was composed of 6 identical houses of 36,500 Ross 308 birds each. All houses received the same commercial wheat-soybean meal based diet that follows breeder recommendations. The different houses were randomly allocated to the different treatments: 3 control houses (C) and 3 houses received the tablets in water (P). One tablet was dissolved in a 20 L stock solution and then supplemented to the drinking line at a concentration of 2%. The birds received the probiotic for 3 days after hatch and during the feed change for approximately 12 hours/day for 3 days. Animal performance: feed and water consumption, average body weight (Av BWG), feed conversion ratio (FCR) and mortality were recorded daily during the entire rearing period. Data were submitted to one-way analysis of variance ($\alpha = 0.05$). Results showed that applying the probiotic resulted in an increased Av BWG by 34g compared to the control houses ($P < 0.01$). Hock-burn and pododermatitis scores were improved by approximately 5% in all 3 treatment houses and less factory rejects (-0.1% ~1095 Birds). During the study, each two houses (C and P) suffered badly from chronic yolk sac infection. On day 3, high mortality of 3.39% was reported in house C and the veterinarian made the decision to medicate with antibiotics. The P house had lower mortality (0.82%) and no antibiotic treatment was required. The probiotic had a protective effect on the birds and mitigated the losses on house P, avoiding the necessity for antibiotic treatment. The economic evaluation showed a positive return on investment (ROI) of 5,98. In conclusion, the new probiotic effervescent tablet, allowed an easy and quick application via water supply during stress period. It resulted in a better animal performance, less medication and improved animal welfare.

PS7 - Other topics**PS7-039 The influence of the addition of various cereal on the metabolic and hormonal profile of broilers - the role of SPX and LEAP2**

P.A. Kolodziejwski¹, E. Pruszyńska-Oszmalek¹, N. Leciejewska¹, L.S. Bassi², M. Sassek¹, D. Szczepankiewicz¹, K. Mielnik¹, A. Lukomska³, M. Hejdysz², S. Kaczmarek²

¹Department of Animal Physiology, Biochemistry and Biostructure, Poznań University of Life Sciences, Poznań, Poland, ²Department of Animal Nutrition, Faculty of Veterinary Medicine and Animal Science, Poznań University of Life Sciences, Poznań, Poland, ³Department of Preclinical Sciences and Infectious Diseases, Faculty of Veterinary Medicine and Animal Science, Poznań University of Life Sciences, Poznań, Poland

The use of various cereals (dominating maize, barley or oat) in the compound feed may affect the metabolic and hormonal profiles of broilers, including hormones regulating food intake, which is indirectly reflected in the increase or decrease of production efficiency. Recently, two peptides have been described whose role in food intake as well as in the regulation of metabolism seems to be significant. The first of them is spexin (SPX), which is an inhibitor of food intake and liver-expressed antimicrobial peptide 2 (LEAP2), which is an endogenous ghrelin receptor antagonist. The main objective of this study was to determine whether the administration of diets based on the addition of various cereals affects the expression and secretion of these peptides in the gastrointestinal tract and in tissues involved in glucose metabolism. The experiment was performed using blood and tissues obtained from 30 broilers (Ross 308, 14 days old) fed with 3 dietary treatments (maize, barley, oats-based pelleted diets). The animals were kept in accordance with the manual for Ross 308 (Aviagen). We determined changes in mRNA and protein expression levels of SPX and LEAP2 in the different parts of the gastrointestinal tract: duodenum, jejunum, and ileum as well as in the pancreas. For this purpose, the Real-Time PCR technique (for mRNA) and Western blot and/or immunohistochemistry and/or fluorescence (for protein expression) were used. Moreover, ELISA kits were used for the determination of SPX and LEAP2 concentrations in blood serum. We found that adding different cereals can modulate mRNA and protein expression of SPX and LEAP2 in tissues and the concentration of these peptides in blood serum. We showed, among others, an increased relative level of mRNA expression of genes encoding SPX and LEAP2 in the pancreas in the group of birds receiving maize compared to birds fed on a diet based on barley or oat ($P < 0.05$). This observation may suggest a direct or indirect role of these peptides in regulating pancreatic metabolism by different nutrients. Funding sources: National Science Centre (NCN) in Poland project no: 2021/41/B/NZ5/00446; and by the statutory funding of the Faculty of Veterinary Medicine and Animal Science Poznań University of Life Sciences (506.558.05.00, 506.558.04.00, and 506.533.04.00), financed by the Polish Ministry of Science and Higher Education.

PS7 - Other topics**PS7-040 The role of hatching systems and biological factors on broiler flock homogeneity**

M.Z. Akram¹, E.A. Sureda¹, L. Comer¹, N. Everaert¹

¹Nutrition and Animal-Microbiota Ecosystems, Department of Biosystems, KU Leuven, Leuven, Belgium

Despite improved genetics and farm practices, yet significant variations exist in bodyweight (BW) within broiler flocks, which adversely impacts flock homogeneity. This study investigated if biological factors such as gastrointestinal tract (GIT) development, gut fermentation and permeability impact weight gain among birds, originating from two hatching systems (HS, HH, hatch in hatchery and HOF, hatch on-farm). The 454 Ross 308 male broiler chicks for each HS were housed in a barn for 38 days. For HOF, 18th day incubated eggs were placed in the pre-heated barn allowing the chicks immediate access to feed and water post-hatching. On day (d) 7, chicks were split into low (L, $n=147$) and high (H, $n=140$) BW groups, creating a two-factorial design (HS $\times$ BW) with four groups (HH-L, HH-H, HOF-L, and HOF-H). The groups were compared for growth traits, GIT and visceral organ development, caecal fermentation, intestinal morphology and permeability, and the data were analyzed using two-way ANOVA. HOF chicks had higher BW at hatch ($P < 0.001$), and greater ileal crypt depth ($P = 0.018$) on d 7 than HH chicks. HS effect disappeared after first week of rearing, however BW effect persisted until the end of trial. High BW groups had 17% higher feed intake and 11% higher average daily gain, which led to a difference in BW of 25% by the end of the trial. Whereas low BW groups had lower FCR than high BW groups in the finisher phase ($P = 0.049$). High BW birds had 20, 6.3 and 15.1% shorter relative small intestine (SI) lengths on d 7, 14, and 38, respectively, and 10.2% heavier relative SI weights during first two weeks compared to low BW broilers. Low BW broilers exhibited 10.32% higher relative heart weight during first two weeks, and 16.3% and 32% heavier relative stomach and bursa of fabricius weights on d 38, compared to high BW broilers. Duodenal villus heights (VH) were increased on d 7 and 38 and ileal VH on d 7 and 14 in high BW birds ($P < 0.001$). The low BW groups had lower short-chain fatty acids and higher branched-chain fatty acids on d 14 than high BW groups ($P < 0.001$). Low BW birds' elevated plasma FITC-d levels on d 38 indicated an increased gut permeability. Thus, our findings indicate that the HOF system only influenced broiler performance until d 7. The differences observed in gut morphology (VH), digestive and ancillary organ development, gut permeability, and cecal fermentation between high and low BW broilers all contributed to the maintained difference in BW.

PS7 - Other topics**PS7-041 Visualisation of essential trace element incorporation in laying hen tibia by correlative elemental imaging**

F. Penen¹, I. Henriquez Valido², M.A. Subirana², S. Faucher³, P. Senechal³, P. Moonen^{3,4}, S. Mounicou², A. Monteiro¹, D. Schaumlöffel²

¹Animine, Annecy, France, ²Université de Pau et des Pays de l'Adour, E2S UPPA, CNRS, IPREM, Pau, France,

³Université de Pau et des Pays de l'Adour, E2S UPPA, CNRS, DMEX, Pau, France, ⁴Université de Pau et des Pays de l'Adour, E2S UPPA, CNRS, Total, LFCR, Pau, France

Leg problems in commercial poultry systems represents one of the greatest welfare problems facing the production industry. In old layer hens, bone fractures can be even more common, affecting between 20 to 90% of birds. It has been shown that trace mineral (TM) supplementation influence bone development. However, their incorporation within the bone structure remains indefinite. Our objective was to evaluate the effect of Zn and Mn supplementation for old hens on bone strength and to visualise and understand their incorporation into bones. 936 Leghorn type laying hens (26 hens x 12 repeats x 3 treatments) were fed from week 57 to week 80 with three different diets: (NC) control diet without TM supplementation; (Zn) NC supplemented with 90 ppm of Zn from potentiated ZnO (HiZox®, Animine) and (Mn) NC supplemented with 110 ppm of Mn from purified Mn2O (ManGrin® Animine). After slaughtering, tibias were collected and kept at -20°C. Bone strength was measured with a compression machine (MTS Synergie 200). A direct observation of the bones was performed by X-ray micro scale computed tomography (μCT), in order to determine the areas of interest for TM localization. Based on μCT data, tibia sections were collected, dehydrated and resin embedded to be analysed by elemental imaging techniques (laser ablation; LA-ICPMS). HiZox® and ManGrin® supplementations improved bone resistance (92.6 N and 92.0 N, respectively) compared to control (44.6 N). Tibia structure was visualized by X-Ray μCT and cortical, trabecular and medullary tissue volumes were estimated: compared to control, Zn and Mn supplementation increased cortical bone volume by 25%, at the expense of trabecular volume, which was decreased by 40%. LA-ICPMS imaging allowed to determine the spatial distribution of Zn and Mn, as well as Fe and P. First results in Mn supplemented diets showed that inside the bone, P is mainly found in cortical tissue whereas Fe was located in medullary tissue. Zn and Mn were collocated in trabecular and cortical tissues. In the later, the inner part of cortical tissue is higher concentrated in metals than the outer part. Moreover, osteons were particularly rich in Zn, Mn and Fe. To the best of our knowledge, it is the first time that the elemental spatial distribution in laying hen bones is presented. Tibia fracture resistance could be correlated with metal localization. Chemical imaging in negative control and Zn supplemented chicken bones is in progress.



AUTHOR'S INDEX



A

Abdelaal N.	359	Almeida P.	382	Bailey M.	375	Bedecković D.	92, 184, 188
Abdelqader A.	133, 270	Almeida Paz I.C.L.	157	Bakhshalinejad R.	138	Bedford M.	147, 340, 345, 353
Ablanedo A.	306	Alrubaye A.	277	Balbino B.	276, 391, 405	Bedford M.R.	45, 185
Accetta F.	205	Alves da Silva E.F.	169, 187	Balbino Leme B.	276, 405	Beirão B.	287
Achard C.	393, 414	Amalraj A.	388	Ballarin C.	332	Bekaert s.	419
Acman M.	386	Amaral T.L.	346	Ball E.	283, 383	Bekkere G.	325
Adams C.	282	Amaya E.	164	Ball M.	253	Bellato A.	280
Addeo N.F.	182	Amerah A.	171	Barbalho R.	213	Bello A.	131, 162, 211, 297, 315
Adedokun S.	165, 312	Ampe B.	88	Barbe A.	196	Bergagna S.	135
Adefioye R.	312	Andretta I.	243, 384, 385	Barbe F.	414	Berghaus R.	268
Ader P.	343	Angel C.R.	134, 163	Barbi J.	298, 347	Berman H.	203
Agashe J.	153	Angel R.	15, 134, 163, 174, 201	Barbosa Macedo M.V.	187	Bernard N.	402
Ahmad Hanafi S.	247	Antonissen G.	248	Barcellos Café M.	412	Bertin A.	314
Ahmadi H.	321	Antoszkiewicz Z.	219	Bargen J.	336	Berti Sorbara J.	132
Ahmad M.	339	Aoun M.	258, 302	Bargo F.	223	Berti Sorbara J.O.	156
Ahmad N.	261	Applegate T.	100, 253, 283, 383	Barnard L.	150, 269, 308	Bezerra Batista L.	411
Aizpurua O.	273	Araújo L.	213	Barroeta A.C.	230, 403	Bhanja S.	153
Ajao A.	283, 383	Arczewska - Włosek A.	365	Bartkiene E.	194	Biagini L.	280, 409
Ajao A.M.	253	Arévalo Sureda E.	270	Bartos Á.	328	Biasato I.	244, 266
Akbari Moghaddam Kakhki R.	136, 221, 304	Arsenault R.	129, 251	Bashir Y.	329	Bień D.	401
Akram M.Z.	425	Asiamah C.A.	103	Bassi L.S.	424	Bierinckx K.	335
Alberdi A.	273	Atallah E.	182	Bastianoni S.	18	Bikker P.	193, 410
Alencar J.A.	130	Atanasov A.	177	Bastos Stefanello T.	291, 292	Birolo M.	148, 332, 372
Alfonso-Avila A.R.	208	Attili A.R.	280	Batista J.	241	Biselo V.	130
Alfonso-Carrillo C.	136, 221, 285, 304	Aumiller T.	181	Batista J.M.M.	358	Biswas A.	153
Al Hakeem W.	373	Aureli R.	259, 299, 352	Batonon-Alavo D.I.	192, 196, 228	Blanc F.	258, 302
Ali M.	105, 330	Aye Cho T.Z.	107	Bautil A.	345, 353	Blanch M.	209
Aljamal A.	277, 290, 420	Azain M.	312	Bayir H.	218	Blanco O.	238
Alkhtib A.	359	B		Bayraktaroglu A.G.	303	Blavi L.	167
Almeida L.	157, 375	Bach Knudsen K.	416	Bebin K.	178, 314, 319	Blokker B.	164
		Bagattin N.	363	Beckers Y.	278	Blonk H.	140

Bonaspeti S.	387	Caekebeke N.	388	Cayzac A.	204	Consuegra J.	102, 255
Bonato M.	213, 287	Café M.B.	241	Ceccantini M.	322, 323	Cordeiro D.A.	346
Bongiorno V.	244	Cai H.	278	Cervin G.	422	Corentin H.	333
Bonilla S.	374	Calenge F.	258, 302	Cesar De Paula Dorigam J.	246	Cornescu G.M.	284, 288
Bordignon F.	148, 332, 372	Calik A.	218	Ceylan N.	232	Cornescu M.G.	318
Boros D.	370	Calik J.	365	Chadwick E.	264	Corniaux A.	233
Bortoluzzi C.	236, 259	Camargo N.	385	Chalvon-Demersay T.	98, 267, 309	Cortes J.	244
Boskovic Cabrol M.	332, 372	Camargos R.	405	Chanaksorn N.	146	Coudron C.	244
Bošnjak-Neumüller J.	189	Campo-Sabariz J.	186	Chantziaris I.	388	Courtin C.	345, 353
Boudry C.	291, 292	Candela M.	101	Chaora N.	238	Cowieson A.	156
Bournazel M.	305	Cantor D.	227	Charrière M.	363	Cozannet P.	103, 239
Bouvarel I.	201	Capern L.	262	Charriere M.V.	310	Creve R.	388
Bouvet R.	275, 309	Cappone E.E.	244	Chatelle C.	299	Cruz-Conesa A.	395, 416
Bovera F.	182	Carcano P.	146	Chaves-Cordoba B.	375	Cucci S.	367, 368
Boyner M.	422	Cardoso Bicego K.	276	Chee S.	316	Cufadar Y.	152
Bozinovski S.	139	Cardoso D.	158, 218	Chen S.	278	Cui G.	224
Braconi N.	140	Carlson S.	290	Chen W.	224	D	
Brink M.	172, 349	Carné S.	301, 403	Chevaux E.	199, 414	Đukić Stojčić M.	307
Brito dos Santos M.R.	169, 256	Cartoni Mancinelli A.	154	Chiattelli D.	154	Dabou S.	367
Brugaletta G.	95, 110	Carvalho C.	385	Chikkanna R.	112, 369	Dahal B.M.	214
Bruno de Oliveira C.J.	169, 187, 256, 411	Castaneda C.	213	Chiofalo V.	205	Dai D.	396
Bühler K.	386	Castellana D.	140	Choct M.	294	Danel J.	362
Bukowska P.	254	Castellini C.	148, 154	Cholewinska E.	263	Da Silva Cabral E.F.	417
Burin R.	277, 290, 375	Castello Branco Beira B.	379	Chossat L.	402	Das P.	329
Burton E.	3, 311, 359, 378	Castello Branco Beirão B.	260	Chrystal P.	227	Dauksiene A.	194
Bussière F.	98	Castex M.	393, 414	Ciacchiariello M.	238	Davin R.	108
Buyse K.	408	Castier J.	402	Cismileanu A.	284, 288	Dayan J.	381
Bypanahalli S.	112, 325, 369	Castillejos L.	230, 403	Cisneros F.	234	de Araújo Morais J.L.	417
C		Castillo A.	67	Clemons C.	197	de Araújo W.J.	256
Cabanas-Ojeda J.	105, 330	Castro C.	147, 351	Comer L.	425	De Baets R.	248
		Cattaneo A.	367	Condy T.	305	De Barros Moreira Filho A.L.	169, 187, 411, 417

De Brito A.B.	346	Devillard E.	322, 323
Debruslais A.	311	Devreese M.	389
De Carvalho Mello H.H.	412	De Vries S.	198, 397
De Cesare A.	95, 101, 110	Dewez M.	324, 331
De Freitas Martins A.P.	412	De Wildt C.	326
De Grande A.	88, 172, 202, 249, 349, 408	Dewulf J.	388
Degroote J.	93, 246	Dhakar S.	216, 217
De Gussem M.	257, 269	Dhara A.	272
Dehaeck B.	419	Dhara A.K.	261
De Jong I.	377	Dias A.G.F.	358
De Jong I.C.	99	Diaz E.	135
De Kreij A.	162	Díez D.	168
De Laet M.	355	Dijkslag A.	193, 203, 410
Delezie E.	88, 172, 202, 248, 249, 349, 408	Di Rosa A.R.	205
De Mesquita Souza Saraiva M.	256	Dittoe D.	271
Demierre J.	407	D. Mansilla W.	96
Denoual P.	97	Do Carmo A.S.	241
Deo C.	153	Dodovski A.	139
De Oliveira J.	98, 411, 417	Dokou S.	189
De Oliveira N.F.	346	Do Monte Pessoa Felix L.R.	256
De Oliveira T.J.	411, 417	Donaldson C.	355
De Paulo L.M.	358	Doreswamy R.	112
De Rauglaudre T.	206, 207	Dorigam J.C.D.P.	151
Dersjant-Li Y.	131, 162, 211, 315	Drazbo A.	150
Desbruslais A.	300, 348	Dridi S.	239
Deschepper K.	249	Duangnumsawang Y.	149, 337
De Sloovere B.	257	Duarte L.A.	346
De Smet J.	406	Dublecz K.	237, 328, 364
De Sousa A.V.	169, 187, 411, 417	Ducatelle R.	36, 413
De Souza Camargos R.	276	Duclos M.	313
De Souza Vieira M.	291, 292	Duong T.	281

Durán R.	297	Ferrante V.	398
Dusel G.	308, 338, 360	Ferrari L.	398
Duvnjak M.	92, 143, 188	Ferreira Dias A.G.	412
E		Ferré J.	395, 416
Ebbing M.A.	327	Ferrer R.	186
Eckel B.	272	Ferrocino I.	266, 280
Eeckhaut V.	36	Feuerstein D.	88, 183, 338, 357
Eising I.	265	Fialho A.	391
Ekesi S.	277	Fickler A.	294, 343, 357
Elolimy A.	317	Fidiarakis P.	236
Enting H.	171	Filoni L.	280
Escobar C.	375	Fiorilla E.	135, 244
Espinosa de los Monteros Peñafiel M.	230	Firman J.	211
Estévez J.	301, 403	Firmo Marinho G.	411
Estévez M.	73	Folegatti E.	398
Estevinho J.	229	Fontaine S.	98, 206, 275
Evans C.	257	Ford M.	165, 312
Evelyn D.	76	Forte C.	135
Everaert N.	202, 425	Fournel S.	206, 207
F		Fournis Y.	197
Fagundes N.	130	Francesch M.	343, 357
Fagundes N.S.	298, 347	Franco F.	382
Fain Binda V.	310, 363	Franco-Rosselló R.	285, 304
Falconi R.	409	Frehen-van Calmthout E.	210
Fan M.Z.	138	Fu Y.	145
Farkas V.	237	G	
Faroongsarng D.	245	Gabarrou J.F.	235
Fathima S.	373	Gaggiotti M.	363
Faucher S.	426	Gai F.	244
Fenske K.	173, 295	Gallardo C.	168
Fernandes Filho I.C.	346		

Galli G.	385	Godoy G.	130
Gallissot M.	389, 394	Godwin I.	227
Galosi L.	280, 409	Goethals L.	408
Gangavadi H.	325, 369	Golzar Adabi S.	152
Ganguly B.	325	Gomes D.S.	417
Gao M.	279	Gomes G.A.	105, 261, 330
Garcia-Launay F.	97	Gomes Santana Á. S.	417
Garcia M.	399	Gomez L.	387, 399, 400, 404
García-Ruiz A.	136, 221	Gong G.	158
García-Ruiz A.I.	96, 144, 231, 285, 304	Gong L.	191, 380
Garcia-Vara A.	186	Gonzalez-Ortiz G.	185
Gariglio M.	135, 244, 266	Gonzalez-Sanchez D.	348
Gasco L.	266	González J.	324, 331
Gayrard C.	220	Gonzalez Ortiz G.	147, 340, 345, 351
Gelli A.	368	Gonzalez Sanchez D.	300, 311
Geraert P.	107	Gonzalo E.	94, 309
Ghane A.E.	162	Goodarzi Borojani F.	149, 337, 370
Gharib-Naseri K.	274	Goossens E.	36
Ghimire A.	214	Goossen T.	102, 158, 166, 255, 260
Ghimire S.	217, 222	Gouveia A.	358
Giacometti F.	101	Grbeša D.	92, 143, 188
Giannenas I.	189	Grilli E.	129, 250, 251, 271
Gibbs K.	252, 257	Grilli G.	398
Gierus M.	327	Gruzauskas R.	194
Gigaud V.	234, 415	G S N.	112
Gilani S.	297	Guerre P.	394
Gillespie D.	165	Guhe M.	173, 295
Giorgino A.	135	Guivernau M.	273
Giovagnoni G.	251	Gül E.T.	152
Glawatz H.	80	Gundersen Storkås C.	91
Godbout S.	207	Gunjević V.	92, 143, 188

Guo Y.	191, 279, 380	Huang Y.	224
Gutierrez B.	151	Huang Z.	226
H		Huerta A.	148, 372
Habibi M.F.	198, 397	Huerta Palacios A.	372
Halдар S.	162, 261, 272	Humphrey B.	399
Hall L.	294	Hussain M.	273
Hamelin C.	178	Hu Y.	193, 224, 410
Han Y.	396	I	
Harig P.	360	Iaconis C.	259
Hasan A.	277	Ibáñez M.A.	209
Hautekiet V.	232	Ibrahim A.	90
Heerkens J.	99	Ibrahim R.	360
Hejdysz M.	109, 156, 354, 392, 424	Idrus Z.	247
Hendriks W.	193, 258, 302, 410	Iglesias B.	310, 363
Henriquez Valido I.	426	Immerseel F.V.	36
Herisson C.	344	Indio V.	95, 101, 110
Hermans D.	406	Ingbergman M.	287
Hernandez J.	176	Ingberman M.	260, 379
Hervo F.	174, 313	Inoue A.	157
Hetland H.	216	Itani K.	217, 222, 339
Hickmann F.	243	Ivarsson E.	422
Hillen B.	257, 297	J	
Hincelin C.	323	Jacquier V.	406
Hirst A.	359	Jadhav S.	153
Hirtenlehner S.	247	Janječić M.	184
Hofacre C.	268	Janječić Z.	92, 184, 188
Holthausen A.	150, 269	Jankowski J.	263
Hong E.	390	Jansen C.	134, 210
Honnenahalli M.	112	Jansen van Rensburg C.	134
Horta F.	331	Jansman A.	106, 160, 203
Horváth B.	237		

Janssens G.	408	Khaskheli A.A.	137, 181
Jansseune S.	258, 302	Khongthong S.	245
Jaroszek A.	401	Kiarie E.	138
Jaworski S.	401	Kiarie E.G.	161
Jenn P.	299	Kidd M.T.	54
Jensen J.	350	Kierończyk B.	58, 212, 296
Jessus L.	97	Kiess A.	213
Jha R.	26, 360	Kim E.	294
Ji L.	224	Kim H.	390
Jlali M.	89, 322, 323	Kim W.	383
Joan Noel S.	416	Kim W.K.	253, 283
Jofré A.	273	Kipper M.	243, 358, 382, 384, 385
Johnson C.	129, 251, 271	Kiš G.	92, 143, 184, 188
Jones M.	165, 268	Kjosevski M.	139
Józefiak D.	58, 212, 296, 337	Kljak K.	92, 143, 177, 188
Jozwik A.	177	Kluenemann M.	100, 282
K		Klünemann M.	220
Kaczmarek S.	109, 156, 354, 392, 424	Klupsaite D.	194
Kaliaperumal T.	342	Knorr Jensen S.	195
Kaliniewicz J.	219	Knudsen K.E.B.	40
Kalyoncu M.	303	Koedijk R.	96
Kamphon M.	159	Kogut M.H.	273
Kang H.	390	Kołodziejski P.	156, 392
Karadas F.	235	Kolodziejski P.A.	424
Karimi M.	167	Konieczka P.	150, 219, 263, 289
Katagiri Dalmoro Y.	291	Kos I.	184
Kazcmarek S.	222	Kozlowski K.	150
Kazue Sakomura N.	276	Kraitavin W.	245
Kenny M.	80	Kralik Z.	92
Khaksar V.	89	Krauze M.	263
Khanal P.	214	Krehling J.	264, 375

Kröger I.	272	Léonard L.	174
Kruse S.	413	Leone F.	398
K T.	329, 342	Lerner S.	157
Kullori G.	153	Leskovec J.	242, 307
Kumar A.	274, 351	Létourneau-Montminy M.	89, 174, 201
Kuttappan A. V.	197		206, 207, 208, 313
Kwakernaak C.	104, 315, 320	Levart A.	190, 242
Kwakkel R.	111, 198, 210, 377, 397	Levrouw L.	104, 320
Kyriazakis I.	35, 253, 283, 383	Lewis E.	161
L		Li C.	278
Labeeuw E.	269	Ligabue M.	199, 393, 414
Ladirat S.	317	Li L.	159, 375
Laghi L.	95, 110	Linares L.	375
Lagos V.	104, 315, 320	Lindemann M.	312
Lahaye L.	291, 292	Lipiński K.	219
Lambert W.	94, 98, 140, 160, 171, 206, 207, 267, 275, 309	Liu G.	253, 278, 283, 383
Lammers A.	258, 302	Liu S.	49, 131, 227, 340
Lange A.	401	Livingston K.	141, 142
Launay C.	362	Li W.	15
Leciejewska N.	392, 424	Li X.	224
Le Cour Grandmaison J.	140, 171	Li Z.	151
Le Dain C.	305	Ljøkjel K.	217
Leduc A.	259	Llamas-Moya S.	281
Lee W.	390	Lolli S.	398
Legawa A.	316	Lopes Brasileiro J.C.	412
Leleu S.	88, 172, 249, 349	Lo Presti V.	205
Lele V.	194	Lorenzo M.I.	164
Lemâle O.	102, 158, 255, 326	Lourenço M.	408
Lemme A.	173, 295	Lozano-Cruz P.A.	105, 330
Lemos de Moraes M.	291, 292	Lucas R.	391
		Lückstädt C.	175

Luis Gonzalez Sanchez A.	270, 286	Mantzios T.	189	Melo J.	310	Mozuriene E.	194
Luitel H.	214	Manyelo T.G.	155, 225	Menconi A.	100	Mueller S.	407
Lukomska A.	392, 424	Marchal L.	131, 211, 315	Meneguz M.	367, 368	Mullenix G.J.	54
Lumpkins B.	281	Marecaille C.	306	Menoyo D.	209	Mulraney V.	378
Lv Z.	226, 279	Margetyal C.	362	Mens A.	106, 377	Munoz L.	375
M		Maria V.	316	Mercandino S.	368	Munțiu Rusu M.I.	284, 288
Mabelebele M.	155, 225	Marien M.	419	Mercier Y.	191, 192, 196, 204, 228, 380, 381	Musigwa S.	103
Mabunda G.	225	Marques da Silva H.	411	Mereu A.	252	Mustafa M.M.	235
Macari M.	276, 405	Marquis V.	418	Meuter A.	157, 262	M Y Meijer M.	181
Macelline S.	49	Martim.Venegas R.	186	Mezőlaki Á.	364	Mysore S.	369
MacElline S.	340	Martin N.	140	Michalczuk M.	401	Mysore S.	325, 369
Macelline W.H.D.S.P.	131, 227	Mascarell J.	301	Michel V.	102, 255	N	
Macklin K.	264, 375	Mascarenhas A.G.	241	Michiels J.	93, 224, 246, 248, 334	Næss G.	214
Madkour M.	317	Mashahiri S.	321	Mielnik K.	392, 424	Nampalle M.	153
Maertens B.	404	Matache C.	288	Mikulski D.	263	Narasimhappa J.	112
Maertens J.	133, 270, 286	Matard-Mann M.	394	Militello D.	130	Narcy A.	89, 174, 201, 208, 313
Magalhães R.	382	Mathlouthi N.	336	Millecam J.	200, 269	Naser El Deen S.	61
Maguregui E.	168	Matton B.	200	Mireaux M.	178, 314	Navarro M.	137
Mahayri T.M.	182	Matuszewski A.	401	Mishra B.	26	Naves Givisiez P. E.	187
Mahieu A.	258, 302	Mazólaki Á.	328	Möddel A.	272	Naves Givisiez P.E.	169, 256, 411, 417
Mahmood T.	191, 192, 196, 204, 228, 380, 381	Mazurkiewicz J.	296	Moeyersons S.	202	Nebbia P.	280
Maina A.N.	161	Mazur-Kuśnirek M.	219	Molist F.	418	Nemec Svete A.	190
Majdeddin M.	93, 246	McAuliffe J.	252	Moniello G.	182	Neteland m.	91
Mallmann B.	158	Mearelli I.	409	Montanhini Neto R.	355	Neves D.	277, 290, 375, 420
Manceaux C.	275	Méda B.	97, 206, 207, 313	Monteiro A.	179, 180, 426	Ng'ambi J.W.	155
Manfreda G.	101	Meijer M.	137	Moonen P.	426	N'Guetta E.	254
Mani R.	342	Mejia-Abaunza N.	105, 330	Morales R.	301	Nguyen H.	274
Männer K.	370	Mekonnen Y.	101	Morlock G.E.	413	Niknafs S.	137, 147, 181, 351
Manohar K.	342	Mélanie M.	314	Morshed M.	227	Noblet J.	107
Mansbridge S.	177	Mello H.	241	Mostert L.	252	Nollet L.	152, 334, 356
Mansilla W.D.	144, 231	Mellouk A.	102, 255	Mounicou S.	426	Nowaczewski S.	109, 354

O

Ocasio Vega C.	223
Ognik K.	263
Oliveri C.	95, 110
Olukosi O.	283, 371, 383
Olukosi O.A.	179, 180, 185, 253
Oppers R.	210
Ording Reierstad S.E.	91
Orellana L.	375
Osho S.	399
Oviedo-Rondón E.O.	30, 105, 298, 330, 347
Ozbek S.	218, 322, 323

P

Pace G.	205
Pacheco W.	374, 376
Pajic M.	189
Pál L.	237, 328, 364
Panaite T.	284, 288
Panaite T.D.	318
Panheleux M.	240, 241
Papadopoulos G.	189
Parand E.	377
Pascual A.	148, 332
Pascual Guzmán A.	332
Pasquali G.	294, 343, 357
Pastor A.	245
Patil Y.	220
Patrizi N.	18
Patsias A.	189
Paul P.	141, 142
Pavia H.	422

Payling L.	386
Pečjak Pal M.	242
Pellikaan W.	111
Penen F.	426
Pereira L.	391
Pérez de Rozas A.	273
Pérez-Vendrell A.	361, 395, 416
Perić L.	307
Perrin G.	165
Pertiwi H.	93
Perz K.	109, 354
Pescatore A.	165, 312
Petracci M.	95, 110, 366
Pezier T.	98
Phaiboon A.	146
Philippi H.	179, 180, 371
Phuc J.	170
Picart C.	356
Pierre F.	413
Piewngam P.	245
Pinard van der Laan M.	258, 302
Pineda L.	316
Pinloche E.	413
Pirgozliev V.	92, 177
Pirpanahi M.	303
Pirrone F.	148, 372
Piscitelli R.	95, 154
Piva A.	129, 250, 251, 271
Plumstead P.	297
Plumstead P.W.	134, 163
Poeikhampha T.	159

Polo J.	285
Potthast C.	247
Poulsen K.	336
Predescu N.C.	318
Preveraud D.	260, 379
Preynat A.	89, 323
Prirgozliev V.	188
Profiti M.	135
Pruszyńska-Oszmalek E.	392, 424
Purón Hernández D.	292
Q	
Qi G.	145, 396
Quero P.	356
Quinteiro-Filho T.	260
Quinteiro-Filho W.	379

R

Radaelli G.	332
Radwan S.	406
Rahajeng A.	316
Raj J.	189
Raju C.	329
Ralph J.	80
Raspoet R.	418
Rassamidatta K.	146
Ravichandran S.	335
Rawash M.A.	328, 364
Rawski M.	212, 296
Raybaud C.	305
R Bedford M.	351
Rebollo M.	277, 290, 375
Rech H.	384

Regnier C.	314
Reis M.	201
Rengman S.	421
Rezaei Far A.	61, 170
Rezar V.	190, 242, 307
Rhoads D.	277
Richard F.	178, 319
Ricke S.	271
Riemensperger A.	247
Riesen U.	423
Rigo Monteiro A.	233
Rijsselaere T.	249
Rinttilä T.	281
Ristovski T.	139
Riveros Lizana R.	276
Riveros R.	276, 391, 405
Robert F.	240, 241
Robino P.	280
Roccatello R.	367
Rochell S.J.	239
Rodehutscond M.	90, 179, 180, 183
Rodrigues dos Santos R.	412
Rodríguez-Gallego E.	273
Rodriguez M.	389, 394
Rodriguez R.	133, 270
Rodriguez-Sanchez R.	133
Roekngam N.	245
Romeo A.	233
Romero L.	386
Roncarati A.	280, 409
Rose S.	177

Rossi G.	280	Sărăcilă M.	318
Rosso D.	350	Saraswathy S.	144
Rother E.	173, 295	Saremi B.	200
Rothstein S.	321	Sassek M.	392, 424
Rouffineau F.	204	Sauerwein H.	308
Roulleau X.	306	Saviani C.	236
Roura E.	137, 147, 181, 351	Savini F.	101
Rousseau X.	261	Savvidou S.	189
Ruangpanit Y.	146	Schaumlöffel D.	426
Ruini A.	18	Schelstraete W.	419
Ruisánchez I.	395, 416	Schiavone A.	67, 135, 244, 266
Rutjens S.	389	Schmidt Bassi L.	156
S		Scholey D.	311, 359, 378
Saad M.	230	Schroyen M.	145
Sacakli P.	218, 303	Schuh-von Graevenitz K.	308, 33, 360
Sacy A.	199, 393, 414	Schulthess J.	418
Saddoris-Clemons K.	399	Sebola N.	225
Sadri H.	308	Sebola N.A.	155
Sadurní M.	230, 403	Segobola P.	164, 236, 259, 265
Sakkas P.	240, 241, 319	Segura-Wang M.	164, 259
Sakomura N.	201, 391, 405	Seibt K.	308
Sala R.	230	Sekarlangit K.	316
Sales de Campos H.	412	Selle P.	49, 131, 227
Sales G.F.C.	256	Selvaraj R.	253, 283, 373, 383
Saliez N.	362	Senechal P.	426
Salobir J.	190, 242, 307	Seon A.	132
Sandvang D.	262, 337	Serraino A.	101
Santamaría Brito R.	292	Sevillano F.	209
Santori D.	367, 368	Sezzi E.	367, 368
Santos R.R.	99, 418	Shah B.	373
Sanz Garcia R.	291, 292	Shanmugasundaram R.	373

Shariatmadari F.	321	Souza F.	213, 287
Shastak Y.	303	Spaepen R.	335
Shelke V.	329	Srichana P.	107
Shourrap M.	317	Srikanthithasan K.	135
Shoveller A.K.	138	Stamatopoulos K.	352
Siebert W.	7, 90, 183	Stanev V.	387, 399, 400, 404
Sihi Arora S.	261	Starkute V.	194
Silva Santos D.	187	Star L.	99
Simarro-Fagundes N.	260, 379	Steenfeldt S.	40, 195
Simitopoulou M.	215	Stefanello c.	130, 282, 291
Singh B.	264	Steiner T.	245
Sirri F.	95, 110, 154, 167, 366	Steinhoff F.	217
Sizmaz Ö.	303	Stepniowska A.	263
Skjoet-Rasmussen L.	262	Stöhr N.	360
Smagiel R.	263	Stokvis L.	108
Smeets N.	133, 270, 286	Strifler P.	237, 328
Smink W.	293	Stringhini J.H.	346, 358, 412
Smith A.	104, 156, 217, 222, 305, 320, 339	Stuper-Szablewska K.	212
Soglia F.	110, 366	Stylianaki I.	189
Sokale A.	268	Subirana M.A.	426
Solano-Garcia M.A.	208	Such N.	328, 364
Solà-Oriol D.	285	Such N.A.	237
Sol C.	324, 331	Sun L.	158, 422
Soler S.	199	Sureda E.A.	425
Somers I.	311	Svečnjak Z.	92, 143, 188
Sommerfeld V.	179, 180, 183	Svihus B.	91, 156, 216, 217, 222, 339
Son J.	390	Swaggerty C.	129, 251, 271
Sorbara J.	236, 259, 352	Świątkiewicz S.	365
Soriano M.	168	Szczepanik K.	365
Soster P.	375	Szczepankiewicz D.	392, 424
Sousa M.	382	Szymanski Ł.	289

Szymczyk B.	365	Torshizi R.V.	321
T		Toscan A.	130, 298, 347
Tacconi A.	421	Tovborg M.	350
Tamassia L.	236	Traineau M.	362
Tan X.	147	Trautwein J.	338
Tardieu D.	394	Trela J.	296
Tarradas J.	273	Trocino A.	148, 332, 372
Tawde S.	421	Tsiouris V.	189
Tayeb I.T.	235	Tugnoli B.	250, 251
Taylor J.	229, 253, 283, 383	Tyler N.	W238
Taylor-Pickard J.	229	U	
Techer C.	402	Umar Faruk M.	132, 164, 234, 415
Tedeschi dos Santos T.	261	Uni Z.	381
Teofilo G.	405	Untea A.E.	318
Tesouro A.	168	Urban J.	401
Tesseraud S.	98	Urrutia A.	375
Tewelde K.G.	328, 364	V	
Teyssier J.	239	Van Baal J.	193, 258, 302, 410
T. Ferreira N.	341	Vandaele M.	246
Theapparat Y.	245	Vande Ginste J.	406
Thiery P.	298, 347	Vande Maele L.	172, 349
Thoby J.	305	Van den Borne J.	111
Timoharju T.	281	Van den Brand H.	137
Tiwari S.	214	Van der Aa A.	172, 349
Tiwari U.	214	Van der Eijk C.	293
Toghyani M.	49, 227, 340	Vanderghinste P.	345
Tomović V.	307	Van der Klein S.	257
Tongyani M.	131	Van der Klis J.D.	386
Torres C.	277, 290, 375, 420	Van der Meulen J.	160
Torrey S.	138	Van der Vaart S.	265
Torshizi M.A.K.	321	Van der Veken W.	232

Van Eerden E.	265	Vermeulen K.	254, 270, 286
Van Harn J.	99, 170, 193, 203, 410	Vernooij J.C.M.	99
Van Hoeck V.	133, 270	Vervenne-Zetteler P.	289
Van Immerseel F.	413	Vervloesem J.	406
Van Kerschaver C.	246	Vidal J.K.	298, 347
Van Krimpen M.	106, 193, 410	Vieco-Saiz N.	102, 255, 413
Van Kuijk S.	316	Vieira Rios H.	291, 292
Van Liefferinge E.	246	Vila B.	361
Van Meirhaeghe H.	388	Vilariño M.	362
Van Noten N.	246, 408	Villatoro Hernandez J.	257
Van Vilsteren A.	289	Villca B.	361
Van Vuure C.	108	Villegas A.M.	100
Van Wikselaar P.	160	Viñado A.	301, 403
Varella G.	391	Vingerhoets T.	111
Vartiainen S.	406	Vista AB	45
Värzaru I.	318	Vlerick L.	200
Vasconcellos G.	130	Vnučec I.	184
Vasiljević M.	189	Von Heimendahl E.	150, 308
Vasilopoulos S.	189	Vozzo S.	182
Veiga C.	170	W	
Veldkamp T.	61	Wagner L.	364
Velkers F.F.C.	99	Wágner L.	328
Veluri S.	185	Walk C.	104, 132, 299, 320, 352
Venema K.	111	Walker H.	229
Venkatasubramanian K.	286, 342	Walker J.	252
Venne D.	208	Wall H.	422
Venter K.	15, 134, 163, 297	Wang J.	145, 396, 420
Verdú M.	230, 403	Wang L.	224
Vereecken M.	419	Wang Q.	252
Verge Mèrida G.	230	Wang S.	278
Vermaut S.	269	Wang Y.	224

Warren H.	378	Zhang J.	132
Watkins S.E.	23	Zhang Q.	132, 352
Wattrang E.	422	Zhou J.	145
Wealleans A.	254, 300, 311, 348	Zhou X.	181
Wealleans A.L.	335	Žikić D.	307
Westendarp H.	173, 295	Zokaityte E.	194
White E.	252	Zurak D.	92, 143, 188
Whiting I.	177	Zweifel R.	407
Willems E.	106		
Williams C.	375		
Wischer G.	268		
Wolfrum S.	183		
Wongphatcharachai M.	107		
Woyengo T.A.	40		
Wu S.	103, 145, 274		
Wu Y.	396		
X			
Xiccato G.	148, 332, 372		
Xiong Z.	158		
Y			
Yacoubi N.	100, 274, 282, 327, 423		
Yavuz B.	322, 323		
Yu I.	316		
Z			
Zaefarian F.	11		
Zambotto V.	244		
Zampiga M.	95, 110, 167, 366		
Zavistanaviciute P.	194		
Zawisza P.	365		
Zentek J.	149, 337, 370		
Zhang H.	93, 145, 224, 246, 396, 420, 421		

DIAMOND SPONSORS

dsm-firmenich

EVONIK
Leading Beyond Chemistry

KEMIN

NOVUS

Perstorp

Phileo
by Lesaffre

PLATINUM SPONSORS

AB·NEO

Elanco

NETAGRO
Like no one else

ZINPRO

GOLD SPONSORS

ADISSEO
A Bluestar Company

agrifirm

Barentz.
Always a better solution.

BASF
We create chemistry

CJ BIO

EASTMAN

innovad.
CREATE TRUST

Phibro
ANIMAL HEALTH CORPORATION

Selko

zoetis

SILVER SPONSORS

ABVista

ADDICAN
Animal Nutrition

Amlan
INTERNATIONAL

Biochem
Feed Safety for Food Safety®

BRENNTAG

Delacon.
performing nature

Denuco
Developing Nutritional Concepts

Herbonís

iff
DANISCO
ANIMAL NUTRITION
& HEALTH

JADIS ADDITIVA 25
FROM 2001, JADIS MAKES THE DIFFERENCE

JRS Fibers for Life.

Leiber
Excellence in Yeast

Lucta

METEX
ANIMAL NUTRITION

Natur Add
The Specialty Feed Ingredients Platform

PHYTOBIOTICS

saviolife

SILVATEAM

PARTNERS

Amadori

ASSALZOO
Associazione Nazionale tra i Produttori di Alimenti Zootecnici

ASSOAVI

HUVEPHARMA

una|italia
UNIVERSITÀ ITALIANA DI NUTRIZIONE ANIMALE

MEDIA PARTNERS

burleigh dodd's
SCIENCE PUBLISHING

POULTRY WORLD

WATT GLOBAL MEDIA