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Matrix

AFMA
SAFE FEED FOR SAFE FOOD
Animal Feed Manufacturers Association

Quarterly magazine of the Animal Feed Manufacturers Association

THE AFMA FORUM EDITION

Sustainable protein production • Fourth agricultural revolution • Heat stress • Gut health
Antimicrobial resistance • Twin screw extrusion • Feed additives • Vitamins

The eleventh AFMA Forum unlocks Agriculture 4.0

By Liesl Breytenbach, executive director, AFMA

This month marks the return of the triennial AFMA Forum at the Sun City Convention Centre in North West. Not only is it regarded as the flagship event of the Animal Feed Manufacturers' Association (AFMA), but it is the largest and most anticipated animal feed science event on the African continent. Every three years since 1992, the animal feed industry gathers at Sun City to share information, view the latest technologies and innovation, and network with like-minded professionals on all things animal feed.

It is expected that this year's event will attract more than 700 delegates from across the country and play host to a number of international guests who will share in AFMA's vision of being a thought leader in feed and food security. What better platform to share experiences, transfer knowledge, and build bridges among colleagues, stakeholders and value chain partners than at the AFMA Forum, all while enjoying the beautiful setting of Sun City sprawled along the border of the Pilanesberg National Park.

Opportunity through challenge

We remember all too well that the previous AFMA Forum in March 2019 marked the start of a rather uncertain time, with Covid-19 emerging soon after and re-defining the way we see the future. Not only did we have to navigate uncertainty; we also had to cope with the multitude of challenges that comes with sudden global change.

Liesl Breytenbach.

The animal feed industry remained strategically important and essential throughout the pandemic, and showed immense resilience and creativity in assisting to provide a continuous supply of animal feed products to the South African consumer.

Three years later, the pandemic is something of the past, but it has left us with many unanswered questions, lessons learnt and new challenges to face – challenges that have further escalated, manifesting in the disruption of global supply chains and local municipal service delivery, increased biosecurity threats and unemployment, as well as the severe deterioration of road and rail infrastructure across South Africa.

If one believes that in challenge lies opportunity, then the next era is filled with opportunity. Not only are we tasked with producing more food for more people; we are expected to do it in a more environmentally sustainable way.

All about knowledge and innovation

The AFMA Forum takes a closer look at the Fourth Agricultural Revolution, which holds the key to unlocking sustainable food supply for the future. The advancement of technology through artificial intelligence (AI), automation, data analytics, robotics and smart management systems, to name but a few, will be explored over the course of two and a half days and will likely initiate robust discussions on the optimisation of this technology in a struggling economy.

The conference programme will kick off using sustainable goals as a framework for innovation and will also look at emerging consumer trends that drive change. Subsequent sessions will deal with precision nutrition and health strategies, including a focus on antimicrobial resistance and its journey through science and policy.

Lastly, the advances in feed milling technology, with the integration of digital tools and automation, will help set the bar for real-time monitoring of feed safety and quality parameters, and be instrumental in controlling animal health and performance while reducing waste and the environmental footprint of future feed manufacturing.

Not only will delegates be inspired by world-class presentations at the AFMA Forum; we are also excited to welcome more than 30 exhibitors to the Superbowl Arena where they will be showcasing their most recent advances in animal feed technology and innovation. Allow me to extend a special thank you to all the exhibitors and sponsors of the 2023 AFMA Forum without whom this event will not be possible.

In keeping with tradition, the social events planned for the week include a welcome cocktail function, a speakers' bush braai, and a not-to-be-missed beach party at the Valley of the Waves to wrap up the networking opportunities.

Supporting animal science students

The forum organising committee has worked tirelessly to cater for all needs at this year's event and has included a special student programme, in collaboration with AgriCAREERConnect, which will give exposure to some of the top animal science students in the country. It remains critical that we facilitate training and skills development opportunities for the next generation, and support forward thinking youth in embracing the challenges of the future and finding solutions to revolutionise agriculture.

Thank you to the forum organising committee for their dedication and hard work. Welcome one and all to the eleventh AFMA Forum.

For more information, visit *www.afmaforum.co.za.*


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NEWS & views

Liesl Breytenbach to head AFMA

Liesl Breytenbach has been appointed to lead the Animal Feed Manufacturers' Association (AFMA) team as its new executive director. Breytenbach has been standing in as the interim executive director since the beginning of the year.

In 2011, she joined AFMA as a technical assistant and has since been applying her passion for the industry in the fields of nutrition and feed legislation. In 2015, she was promoted to the management team of AFMA as technical and regulatory manager and shifted her focus to creating an enabling environment for feed enterprises in South Africa. With almost 20 years' experience in the animal feed industry, Breytenbach brings vast experience and knowledge to the AFMA team. – *Press release, AFMA*

Liesl Breytenbach (right) has been appointed to lead the AFMA team as its new executive director. On the left is Anina Hunter, chairperson of AFMA.

New lead for swine innovation at Novus

Animal nutrition company, Novus International, recently brought on Dr Brandon Reinbold, DVM, to lead research and technology initiatives in the company's global swine team.

Reinbold joined Novus earlier this year as senior manager, global swine technology. In this position, he is tasked with creating the strategy and execution plan of the swine research programme, focussing on gut health and intelligent nutrition to optimise performance. He also helps develop the go-to-market strategy that takes solutions from ideation to the farm.

Supporting members of Novus' Swine Technical Services team around the world, Reinbold aids in their work with customers to ensure they get more from their animals. He says many NOVUS customers have dedicated R&D business units that are engaged in evaluating solutions. He supports those in-house efforts through his expertise and experience. – *Press release, Novus*

Dr Brandon Reinbold.

China's soya bean imports climb

China's July soya bean imports jumped by almost one quarter from a year ago, official data showed, boosted by improved demand in the world's biggest buyer, especially for use in animal feed and by higher arrivals from Brazil.

Arrivals for the first seven months of the year came to 62,3 million metric tons, up 15% from a year earlier. The increase was driven by higher demand for soya meal, a protein-rich animal feed ingredient made from soya beans, analysts said.

Chinese pig producers delayed the slaughter of pigs due to low pork prices, which in turn increased demand for animal feed, said Wang Mingwei, a Hangzhou-based analyst at Dayue Futures. Soya meal prices in China have risen 23% since the end of May, hovering at 4 500 Chinese Yuan per metric ton. – *The Pig Site*

Second-biggest US maize harvest expected

The United States' (US) maize harvest could be the second largest on record as rains during July shepherded the crop through its critical development phase, offsetting dry conditions early in the season and hot summer temperatures.

A strong harvest would add to domestic stockpiles that are expected to balloon as demand for US maize exports wilts due to a massive harvest in Brazil, which is expected to overtake the US as the world's top maize supplier. Maize prices fell 18% from their late-June peak during July, with improving conditions in the field weighing heavily on the market as the drought damage from the early season was not as bad as feared.

The new forecast if achieved would be the second-biggest harvest ever, behind the 2016 harvest of 15,148 billion bushels. Average yields were seen at 175,5 bushels per acre this year, which would be the fourth-biggest ever. – *Reuters*

NWK improves own profit record

Following its historic best financial results achieved last year, NWK Holdings Ltd has yet again improved its own record by delivering the highest profit in its 114-year existence for the year ended 30 April 2023. With an increase in turnover of 26,8%, NWK achieved a profit before tax of R360 million this year. The profit after tax amounts to R283 million (2022: R267 million) and represents a R16 million or 6% improvement. This resulted in equity increasing by 13% to just over R1,9 billion. The net asset value at year-end was 1 840c/share.

According to Heinrich Krüger, chairperson of NWK's board, favourable weather conditions played a prominent role in achieving the results. "Producers' higher income from last year had a positive effect on NWK's excellent earnings. The focus on core business – namely grain, general trade and financing – is definitely the route that produces the desired result," he said. – *NWK*

Floods in China damage crops

Floods have damaged maize and rice crops in China's key northern grain-producing belt, traders and analysts said. More rain was forecast due to another typhoon, threatening to add to global food inflation pressures.

Northern China, still grappling with swollen rivers and floodwaters recently caused by typhoon Doksuri, could see further crop damage with tropical storm Khanun. Initial estimates show that four to five million metric tons of maize, or around 2% of the country's output, have been affected by the floods, two trade sources said.
– *Reuters*

GMOs in feed despite harsh restrictions

Every tenth probe of Russian feed analysed by the Russian state centre for the quality of animal medicines and feed, VGNKI, has been found to contain undeclared genetically modified organisms (GMOs), which Russian scientists believe could be harmful.

Undeclared use of GMOs remains the most widely spread type of fraud in the Russian feed market. Currently, Russian veterinary regulations permit maximum GMO content in feed at 0,9% for registered lines and 0,5% for unregistered lines, and both must be labelled as containing GMOs.

Using GMOs allows farmers to make a substantial profit, the scientists claimed, warning that GMOs could be potentially harmful to farmed animals. At first glance, GMOs in feed induce no negative impact on animals and humans. But their use in undesirable quantities can lead to vitamin deficiency, impaired immunity and reduced productivity.

In addition, GMO-containing feed could make animals suffer diseases that are unexpected under a regular diet, the scientist added. Besides, in this case, glyphosate content in feed requires exceptional control. This herbicide is widely used in the cultivation of GM crops to control weeds. Cultivated plants do not suffer from glyphosate but accumulate it in significant quantities.

Scientific studies testify to the high carcinogenicity of glyphosate for both animals and humans. The Russian authorities take a strict stance on the use of GMOs in animal feed, punishing violations with fines. Claims about the threat of GMOs are also backed by the Russian Academy of Science. – *All About Feed*

Feed requirement a heritable trait

A team of scientists at the United States Meat Animal Research Center's Nutrition, Growth and Physiology unit recently conducted a study on the heritability of a cow's energy requirements. They measured the energy requirements of mature, pregnant cows for maintenance and determined that the amount of energy (feed) a cow needs is heritable. This means that a cow with high feed requirements is highly likely to have a calf that has the same high requirements.

Commonly, if a producer has a cow that requires a lot of feed to keep weight on and maintain her body condition, they may consider keeping her in their herd if she produces 'good calves'. However, the research suggests that they should cull the difficult-to-maintain cow and increase their number of 'easy keepers' to preserve the future efficiency of their herd, the study says. – *Midwest Messenger*

Peas to help UK feed industry be sustainable

A new £1 million research project into new pea varieties is underway to help the United Kingdom (UK) cut its reliance on imported soya.

Last year the UK imported three million tons of soya for use in human and animal feeds. As soya is also a crop associated with deforestation in South America, which contributes to the acceleration of climate change, the UK aims to make its feed industry more sustainable.

This latest pea protein project involves academics from Aberystwyth University, and is being spearheaded by grass and forage seed specialists and breeders, Germinal. Soya forms the basis of most plant-based protein options, which are now high in demand, but they are currently difficult to grow in a UK climate.

The aim of this project is to use peas as a home-grown protein source that can replace soya in human food. Peas are suited to the UK climate, are environmentally friendly, boost soil health by fixing free nitrogen from the air and even leave some in the ground for the next crop. – *All About Feed*

FEED AND FOOD: The Fourth Agricultural Revolution

By Bonita Cilliers, technical and regulatory advisor, AFMA

Since the humble beginnings of civilisation, agriculture has been an integral part of human existence. Our ancestors took their first steps in the realm of farming during the First Agricultural Revolution, a pivotal period in which they discovered the concept of cultivation and settled farming. Fast forward to the present day, and we find ourselves on the cusp of the Fourth Agricultural Revolution, also known as Agriculture 4.0.

This journey in agriculture has been nothing short of awe inspiring, with each revolution introducing groundbreaking advancements that have reshaped the way we produce food, raise livestock, and steward our land.

The evolution of agriculture

The First Agricultural Revolution, which began around 10 000 years ago, marked a turning point in the history of mankind. It was during this time that our ancestors transitioned from being hunter-gatherers to embracing the idea of cultivation. By domesticating plants and animals, they found a way to produce more food, leading to settled communities and a fundamental shift in human lifestyle. This revolution laid the foundation for agriculture as we know it today.

The Second Agricultural Revolution took place during the 17th to 19th centuries, coinciding with the Industrial Revolution. This era witnessed a surge in technological innovations that transformed farming practices. From the invention of the steam engine to the introduction of the tractor, mechanisation became the driving force behind increased agricultural productivity. With advancements in crop rotation, selective animal breeding, improved transportation, and land drainage, farmers were able to cultivate more land and produce greater yields.

The Third Agricultural Revolution, the so-called 'Green Revolution', emerged in the mid-20th century and focussed on boosting productivity and efficiency. With the advent of farm mechanisation, chemical fertilisers, and pesticides, average farm yields experienced geometric growth. Animal farming and industrialised storage methods further propelled the agricultural sector forward. However, this revolution also brought to light concerns regarding the environmental impact of industrialised farming practices.

While traditional agricultural practices have sustained humanity for generations, they are now confronted with unprecedented challenges. In response, the revolutionary concept of Agriculture 4.0 emerged, presenting a transformative change to address the pressing issues that plague the global food system.

A new paradigm in farming

The world is on the brink of the Fourth Agricultural Revolution, a digital transformation poised to revolutionise animal health and production. With an increasing global food demand, environmental concerns, and the quest for sustainability, this revolution holds the key to addressing these challenges.

Agriculture 4.0 significantly impacts sustainable animal health and production, gut health and immunity, precision livestock farming and nutrition, antimicrobial resistance, and feed safety and milling. We will explore how this evolution shapes these crucial aspects of modern agriculture.

1 Sustainable animal health and production

Opportunity: Traditional animal agriculture practices have come under scrutiny for their environmental and ethical issues. With a growing global population and increased demand for animal protein, a re-evaluation of our approaches is becoming imperative.

The Fourth Agricultural Revolution, driven by artificial intelligence (AI), robotics, and data analytics, offers a unique opportunity to bolster animal health and sustainable production. Digital agriculture enables innovative practices such as rotational grazing and regenerative farming, reducing ecological impact.

Precision technologies in animal agriculture, such as genetic engineering and data analytics, allow for real-time health monitoring, optimised breeding, and reduced resource usage. Smart management systems automate essential tasks such as feeding, minimising waste and environmental impact. Prioritising animal health through preventive measures and data-driven decisions can reduce the reliance on antibiotics, leading to healthier livestock.

As consumers demand transparency and ethical treatment of animals, the shift towards sustainability becomes both an environmental necessity and a market driven demand. This revolution also promotes the adoption of alternative protein sources, alleviating the environmental toll of traditional livestock farming. By emphasising animal welfare, reducing environmental impact, and maximising resource efficiency, this pillar assures a responsible supply of high-quality animal products.

Figure 1: The six crucial aspects of modern agriculture shaped by the Fourth Agricultural Revolution.

Challenges: Adopting sustainable practices necessitates substantial investments and producer education. Striking a balance between economic viability, ethical concerns, and environmental repercussions can present a multifaceted difficulty.

2 Enhancing gut health and immunity

Opportunity: The Fourth Agricultural Revolution places a strong emphasis on maintaining optimal gut health and immunity in animals. Innovations such as probiotics, prebiotics, and phytogenics are gaining popularity due to their ability to promote a balanced gut microbiome, strengthen immune reactions, and improve resistance against diseases. By understanding and harnessing these interrelationships, producers can rear livestock that are healthier and more robust, reducing the reliance on antibiotics and ultimately enhancing the overall wellbeing of animals.

Challenges: Developing a comprehensive understanding of the intricate interactions within an animal's gut microbiome requires ongoing research. In addition, obtaining regulatory approvals and garnering public acceptance for these novel practices present significant considerations.

3 Precision livestock farming and nutrition

Opportunity: The Fourth Agricultural Revolution embodies precision across every aspect, including livestock farming and nutrition. Driven by technology, precision livestock farming customises animal care and nutrition through precise and timely data, providing practical insights for informed decision-making.

Real-time data equips producers to optimise feeding, monitor growth, and manage health, ultimately enhancing efficiency and output. Internet of Things (IoT) devices and wearable sensors oversee livestock wellbeing, tracking vital signs such as heart rate and body temperature. Furthermore, Agriculture 4.0 technologies facilitate early disease detection by recognising subtle deviations from normal behaviour, thus reducing the need for antibiotics.

Genomic technologies, integrated into precision livestock farming, enable the selection of animals with desirable traits. Agriculture 4.0 accelerates this process by streamlining data collection, aiding breeders in pinpointing genetic markers associated with resilience and productivity.

Challenges: A strong technological foundation and efficient data management system are essential for successful precision farming. Equally important is safeguarding data privacy and security to prevent any potential misuse.

4 Combatting antimicrobial resistance

Opportunity: The overuse and misuse of antibiotics in agriculture have fuelled a concerning surge in antimicrobial resistance, jeopardising both animal and human wellbeing. The Fourth Agricultural Revolution is prepared to address this issue directly by implementing inventive strategies and responsible measures to reduce antibiotic dependence.

In line with the data-centric approach of the Fourth Agricultural Revolution, stakeholders can analyse extensive datasets encompassing animal health, genetics, and management practices. This empowers them to optimise disease prevention strategies, alleviate stressors contributing to diseases, and customise treatments for enhanced efficacy. Natural alternatives such as phytogenics, essential oils, and immune-boosting compounds provide options to reduce antibiotic reliance while preserving animal health.

Agriculture 4.0 advances the development and deployment of advanced vaccines, playing a critical role in disease prevention and reducing antibiotic usage. By leveraging improved genetic understanding and biotechnology, vaccines can be designed to offer robust immunity and minimise disease spread. Bacteriophages, specialised viruses targeting bacteria, hold promise as antibiotic alternatives. Agriculture 4.0 expedites research into phage therapies, enabling their application in animal health and production, thereby decreasing reliance on traditional antibiotics.

Rapid and accurate diagnostics are essential in curbing antibiotic misuse. Agriculture 4.0 drives the creation of new diagnostic tools that rapidly identify pathogens and assess their antibiotic sensitivity, guiding informed antibiotic use by veterinarians and producers.

Agriculture 4.0 advocates for responsible antibiotic practices through enhanced management. Automation, data analysis, and intelligent systems equip producers to administer antibiotics precisely when needed, ensuring appropriate drug usage in terms of timing and dosage.

Challenges: Transitioning away from antibiotic use necessitates a shift in mindset and practices within the agricultural sector. Ensuring the effectiveness and safety of alternative approaches is a critical consideration.

5 Advancements in feed safety and milling technology

Opportunity: Feed safety and milling technology is pivotal in shaping animal wellbeing and productivity. Advancements in feed processing, quality control, and traceability systems not only enhance the nutritional value of animal diets, but also mitigate contamination risks, contributing to overall sustainability.

With the integration of groundbreaking technologies such as the IoT, blockchain, and data analytics, the landscape of feed safety and milling has undergone a remarkable evolution. Real-time monitoring and data driven insights now enable stakeholders to oversee every phase of the production process. Progress in this critical aspect of animal agriculture not only enhances animal nutrition, but also aligns with broader goals of sustainability, animal health, and resource optimisation.

Agriculture 4.0 facilitates continuous monitoring and quality control throughout feed production, enhancing feed safety. This approach allows for precise feed formulation and production, leveraging data-driven insights to tailor feed for diverse animal species. The integration of digital tools and automation has introduced precision milling, finely grinding raw materials to optimal particle sizes for maximum nutrient absorption and feed efficiency. The outcome is improved animal health, less waste, and a smaller environmental footprint. Smart sensors and automation rapidly identify contaminants, ensure precise ingredient ratios, and maintain ideal processing conditions. This precision not only enhances traceability, but also decreases the likelihood of feedborne diseases.

Agriculture 4.0 technologies minimise the risk of cross-contamination during feed production by employing automated systems and robotics for ingredient handling. Digital systems streamline production scheduling, ensuring proper cleaning and sanitation between different feed batches. Incorporating IoT devices and sensors into feed storage facilities and mills allows for ongoing environmental monitoring. Immediate alerts for deviations trigger proactive measures, preventing harmful micro-organisms from proliferating and preserving feed quality and safety.

Additionally, the wealth of data generated from digital technologies empowers feed manufacturers to make well-informed decisions. Predictive analytics forecast challenges, optimise inventory management, and predict ingredient availability. This data-driven approach enhances efficiency, reduces costs, and fosters the overall sustainability of feed production.

Furthermore, Agriculture 4.0 fosters industry-wide collaboration and knowledge sharing. Digital platforms, forums, and networks facilitate the dissemination of best practices, technological insights, and emerging research in feed safety and milling technology. This collaborative effort expedites innovation and encourages the widespread embrace of cutting edge developments.

Challenges: Introducing sophisticated feed safety protocols demands technological and infrastructure investments. Ensuring the accessibility of these innovations to small-scale farmers is essential for widespread adoption.

6 Supply chain optimisation and traceability

Opportunity: In the realm of traditional agriculture, supply chains often operated in isolation, lacking visibility and transparency. This disjointed approach resulted in inefficiencies, delays, and challenges related to verifying product authenticity and safety. Nevertheless, the rise of Agriculture 4.0 has disrupted this established pattern, ushering in a transformative phase of improved supply chain optimisation and traceability. This evolution emphasises transparency from farm to table.

In today's landscape, consumers exhibit a heightened desire to understand the origins of their food, its journey, and the production practices involved. Technologies such as blockchain, radio frequency identification (RFID) tagging, and data driven logistics are instrumental in streamlining the movement of animal products. This technological integration ensures product quality and minimises waste, aligning with the changing expectations of conscious consumers.

Challenges: The integration of intricate supply chain technologies within varied agricultural systems necessitates co-operation and uniform protocols. Overcoming technological barriers and ensuring data accuracy will continue to present ongoing challenges.

Conclusion

The Fourth Agricultural Revolution offers unprecedented opportunities to transform sustainable animal health and production practices. Despite challenges such as technology and regulations, the potential benefits, including streamlined resource utilisation, improved animal wellbeing, and reduced environmental impact are immense.

By harnessing the capabilities of automation, data analytics, and innovative methodologies, the animal feed industry is poised to deliver animal nutrition that is not only safer and more efficient, but also ecologically responsible.

As this revolution continues to unfold, momentum grows toward a resilient and sustainable food system, benefiting animals, humans, and the planet. Embracing this shift through collaborative and forward-thinking sets the stage for a thriving animal agriculture in an evolving world, ensuring a brighter and more sustainable future for generations to come.

For more information, email technical@afma.co.za or visit *www.afma.co.za*.

AFMA Forum 2023
PROGRAMME

AFMA FORUM
5–7 September 2023 • Sun City, South Africa
Feed & Food – The 4th Agricultural Revolution

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MONDAY, 4 SEPTEMBER 2023

08:00 – 17:00	Exhibition build-up *(Superbowl)*
14:00	Delegates check in at leisure *(Various hotels)*
16:00 – 18:00	**AFMA Board of Directors' meeting**

TUESDAY, 5 SEPTEMBER 2023

09:00 – 17:00	Registration open
11:00 – 12:30	**AFMA Annual General Meeting** (all AFMA Members) *(Seers Court)*
12:30 – 14:00	Lunch for AGM attendees & welcome refreshments for Forum delegates *(King's Ballroom Foyer)*
14:00 – 16:35	**PLENARY 1 - AGRICULTURE 4.0: REVOLUTIONISING THE ANIMAL FEED INDUSTRY** **Moderator: Chantelle Fryer (Chairperson of the AFMA Forum Programme Committee)**
14:00 – 14:20	**Opening & welcome: Feed & Food – The 4th Agricultural Revolution** *Ms Anina Hunter, Chairperson, AFMA*
14:20 – 15:00	 **Revolution in balance: Using sustainable development goals as a framework for innovation** *Prof Emily Burton, School of Animal Rural & Environmental Sciences, Nottingham Trent University (UK)* Sponsored by: AFMA
15:00 – 15:40	 **Technology, a revolution, and (financial) success. Is this achievable?** *Mr Nico Groenewald, Head of Agribusiness, SA, Standard Bank Group (South Africa)* Sponsored by: AFMA
15:40 – 16:20	 **After The Fire: South African politics after the insurrection, the pandemic, and the 2024 elections** *Mr Justice Malala, Political Commentator and Author of 'The Plot To Save SA' and 'We Have Now Begun Our Descent' (USA)* Sponsored by: AFMA
16:20 – 16:35	Panel discussion (Q & A)
18:00 – 22:00	**Welcome function & exhibition opens** *(Superbowl)*

WEDNESDAY, 6 SEPTEMBER 2023

07:30 – 17:00	Registration & exhibition open *(Foyer & Superbowl)*
08:30 – 10:05	**PLENARY 2 - AGRICULTURE 4.0: UNVEILING EMERGING TRENDS** **Moderator: Janke Bestbier (Alltech)**
08:30 – 09:10	 **State we are in 2023** *Ms Bronwyn Williams, Futurist, Economist, Trend Analyst, Flux Trends (South Africa)* Sponsored by: AFMA
09:10 – 09:50	 **4th Revolution – Shaping FMCG retail** *Ms Kerry Elliot, Retail Industry Expert & Head of Sales, Trade Intelligence (South Africa)* Sponsored by: AFMA
09:50 – 10:05	Panel discussion (Q & A)
10:05 – 10:50	Tea / coffee break *(Superbowl)*

WEDNESDAY, 6 SEPTEMBER 2023 (continued)

10:50 – 12:35	**SESSION 1: SUSTAINABLE PRODUCTION & HEALTH (Monogastric)** **Moderator: Brett Roosendaal (Epol)**	**SESSION 2: SUSTAINABLE PRODUCTION (Ruminants)** **Moderator: Dr Ida Linde (Envarto)**
10:50 – 11:20	 **Integrated, step-by-step, holistic approach to make the "switch" to the responsible use of antibiotics easy and manageable for feeding the future** *Dr Barbara Brutsaert, Sustainability Manager Antibiotic Reduction, Trouw Nutrition (EU)* **Sponsored by: Trouw Nutrition**	 **Improving nitrogen efficiency in lactating dairy cows for sustainability and profit** *Mr Mike Shearing, Global Ruminant Amino Acid Formulation Manager, Adisseo (USA)* **Sponsored by: Adisseo**
11:20 – 11:50	 **New developments to mitigate effects of heat stress on broiler digestive function, nutrient intake, and performance** *Dr Peter Plumstead, Innovation Director, Chemuniqué (South Africa)* **Sponsored by: Chemuniqué**	 **Precise, validated and actionable data is key to the improved sustainability of animal protein production** *Mr Carlos Saviani, Global Sustainability Lead, dsm-firmenich (Brazil)* **Sponsored by: dsm-firmenich**
11:50 – 12:20	 **Benefits of a digital Life Cycle Analysis solution for dynamic environmental footprinting of feed and animal protein** *Mr Walter Van Hofstraeten, Senior Consultant Poultry Nutrition, Schothorst Feed Research (The Netherlands)* **Sponsored by: Epol**	 **Is carbon negative beef production on pasture possible: The Buck Island case study** *Ms Laurentia van Rensburg, Technical Mineral Manager, Alltech (USA)* **Sponsored by: Alltech**
12:20 – 12:35	Panel discussion (Q & A)	
12:35 – 14:00	Lunch *(Superbowl)*	
14:00 - 17:00	**SESSION 3: NEW DEVELOPMENTS IN GUT HEALTH & IMMUNITY** **Moderator: Jana Whitehead (Cargill Animal Nutrition)**	**SESSION 4: PRECISION NUTRITION & HEALTH (Ruminants)** **Moderator: Adéle Rothmann (Virbac)**
14:00 – 14:30	 **Matching field microbiota with feed and additives in poultry** *Dr Henk Enting, Sr. Poultry Technology Lead, Cargill Animal Nutrition (The Netherlands)* **Sponsored by: Cargill Animal Nutrition**	 **The influence of diet and feed additives on the rumen microbiome** *Dr Ida Linde, Research Scientist, Envarto (South Africa)* **Sponsored by: Envarto**
14:30 – 15:00	 **The role of new-era feed additives in modulating gut health in broilers** *Dr Rick Kleyn, Nutritionist, Spesfeed Consulting (South Africa)* **Sponsored by: Evonik**	 **Isoacids at the frontier of dairy nutrition** *Dr Dana Tomlinson, Global Technical Services, Zinpro Corporation (USA)* **Sponsored by: Chemuniqué**
15:00 – 15:45	Tea / coffee break & AFMA Awards announcement *(Superbowl)*	
15:45 – 16:15	 **Why gut health matters for sustainable young animal production** *Dr Jessika van Leeuwen, Global Category Manager Swine, Hamlet Protein (The Netherlands)* **Sponsored by: Nutribase**	 **The applications of rumen-protected nutrients in ruminant diets** *Dr Irene Brown-Crowder, Technical Service Manager, Kemin Animal Nutrition and Health – North America (USA)* **Sponsored by: Kemin**
16:15 – 16:45	 **Nutritional strategies: Meeting requirements of companion animals with trace mineral supplementation throughout all life phases** *Mr Steve Elliott, Global Director of the Mineral and Equine Divisions, Alltech (USA)* **Sponsored by: Alltech**	 **Post-rumen health and its implications on health and performance** *Mr Mark Hall, Ruminant Technical Manager, Trouw Nutrition (UK)* **Sponsored by: Trouw Nutrition**
16:45 – 17:00	Panel discussion (Q & A)	
18:00 – 22:00	**Speakers & Sponsor Bush Braai** (by invitation only) Delegates at leisure	

(Please turn over)

AFMA FORUM 2023 PROGRAMME (continued)

THURSDAY, 7 SEPTEMBER 2023

07:30 – 14:00 Registration & exhibition open *(Foyer & Superbowl)*

08:30 – 10:05 PLENARY 3 – AGRICULTURE 4.0: SCIENCE AND POLICY FOR AMR COMBAT
Moderator: Frans Hagg (Allied Nutrition)

08:30 – 09:10

AMR in livestock production from science to policy
Dr Shabbir Simjee, Chief Medical Officer & Global Regulatory & Technical Senior Advisor – Microbiology & Antimicrobials, Elanco (USA)
Sponsored by: Elanco

09:10– 09:50

Understanding the problem is half the solution
Dr Kirsty Gibbs, Poultry Innovation Lead, Danisco Animal Nutrition & Health (IFF) (UK)
Sponsored by: Chemuniqué

09:50 – 10:05 Panel discussion (Q & A)

10:05 – 10:50 Tea / coffee break *(Superbowl)*

10:50 – 12:35 SESSION 5: PRECISION NUTRITION & HEALTH (Monogastric)
Moderator: Marthie Nickols (Vitam International)

10:50 – 11:20

Recent developments in energy systems for poultry
Dr Yves Mercier, Scientific and Technical Support Manager, Adisseo France SAS (France)
Sponsored by: Adisseo

11:20 – 11:50

New perspectives and essential functions of key vitamins in animal nutrition
Dr Alvaro Gordillo, New Business Development & Technical Leader – EMEA & Americas – Vitamins & Carotenoids, BASF (Spain)
Sponsored by: BASF

11:50 – 12:20

Coccidiosis management in broiler chicken: A comparative in vivo study between 100% botanical-based active compounds and conventional coccidiostats
Dr Mohammed el Amine Benarbia, R&D Manager, Nor-Feed SAS (France)
Sponsored by: Vitam International

10:50 – 12:35 SESSION 6: PRECISION NUTRITION & HEALTH (Ruminants)
Moderator: Robyn Joubert (Chemuniqué)

10:50 – 11:35

Precision feed formulation: Strategies to utilise marginal raw materials to drive production efficiency
Dr Thomas Tylutki, CEO, AMTS LLC (USA)
Sponsored by: Phileo by Lesaffre

11:35 – 12:20

Maintenance of gut health in cattle
Prof Gregory B. Penner, Professor and Centennial Enhancement Chair in Ruminant Nutritional Physiology, Department of Animal and Poultry Science, University of Saskatchewan (Canada)
Sponsored by: Allied Nutrition

12:20 – 12:35 Panel discussion (Q & A)

12:35 – 14:00 Lunch *(Superbowl)*

14:00 Exhibition breakdown *(Superbowl)*

14:00 – 15:45 PLENARY 4 – AGRICULTURE 4.0: FEED SAFETY AND MILLING TECHNOLOGY ADVANCEMENTS
Moderator: Natasha Snyman (Chemuniqué)

14:00 – 14:30

The first extensive biomarker survey in South African farms
Dr Arnau Vidal, Global Technical Manager – Toxins & Stress, Innovad (Spain)
Sponsored by: Envarto

14:30 – 15:00

Saving energy in feed grinding and pelleting processes
Mr Arthur vom Hofe, Business Segment Manager, CPM Europe BV (The Netherlands)
Sponsored by: Graintech Milling Systems

15:00 – 15:30

Feed mills of the future
Dr Charles Stark, Jim and Carol Brown Professor in Feed Technology, Grain Science and Industry, Kansas State University (USA)
Sponsored by: AFMA

15:30 – 15:45 Panel discussion (Q & A)

15:45 – 16:05 **Closing of the Forum – Take home message**
Ms Chantelle Fryer, Chairperson of the AFMA Forum Programme Committee

18:00 – 22:00 **Closing function – Beach Party** *(Valley of Waves)*

AFMA
SAFE FEED FOR SAFE FOOD
Animal Feed Manufacturers Association

AFMA INTERVARSITY WRITER'S CUP 2023

Congratulations
to our 2023 winners!

Congratulations to Stellenbosch University for taking home the 2023 AFMA Intervarsity Writer's Cup championship title!

Overall winner, Category: Own research

Michelle Gouws
Stellenbosch University
Title: The effect of ionophore use and essential oil compounds in calf diets on animal growth and the prevalence of antibiotic resistant *Escherichia coli*

Supervisor: Dr Lobke Steyn, Stellenbosch University

Overall winner, Category: Literature review

Gerhard Claassen
University of Pretoria
Title: Vitamin D-elight

If you want to participate in the 2024 AFMA Writer's Cup, please email technical@afma.co.za for more information.

"Automill, both past and future versions, will always be client centric. Designed and implemented specifically to cater for our client's direct and indirect needs, helping them overcome the obstacles they face on a daily basis. Automill is the result of years of experience, with thousands of hours of research and development. We strive continuously to improve and expand our solution and thereby assist our clients to take their business to the next level."

With our vision and mission installed in us, we set out to develop Automill 4

VISION

To be the most sought after technology partner, improving efficiency, productivity and profitability of our clients by delivering exceptional quality solutions to a global market...because good enough, isn't.

MISSION

- "At the core of our business vision we strive to be sought after by clients, suppliers and employees.
- To be the preferred technology partner we at Automill commit ourselves to go the extra mile, to think beyond the current project and consider the client's needs and wants holistically.
- Through strict quality control mechanisms, consistency, reliability, combined with cutting edge hardware and innovative software we will achieve exceptional quality solutions on time, all the time."

We set out to reduce or totally eliminate problems in all areas Automill is present in.

Highlights of Automill 4

1. SECURITY GATE

Our system ensures seamless identification and verification, granting access only to authorized personnel and approved vehicles, enhancing security. It eliminates unauthorized vehicles entering your premises and saves time by automating data capture and report generation.

2. THE WEIGHBRIDGE

Ensuring weighbridge integrity is our top priority. Automill enforces quality standards, denying access to non-compliant materials. Authorized personnel maintain control, deterring criminal activities. Suspicious transactions are swiftly addressed, and vital data is proactively delivered via email for quick response.

3. INTAKES

Contamination causes substantial financial losses for feed mills annually. Automill prevents these losses when managing raw material intakes. With automated control, routes are automatically managed, avoiding intake operator errors.

4. RECLAIM

Automill eradicates raw material contamination when effectively employed for intake processes. Automated routing, preventing intake operator errors and automatic sequences reduce waiting times for raw material.

5. BATCHING

At Automill, our top priority is achieving fast and precise batching. We strive for the optimal batching rate, ensuring security with multi-level authorization. Timings for each batching section are meticulously recorded and reported, enabling collaboration with the maintenance team for cycle optimization. Automill tracks the entire process, identifying bottlenecks through comprehensive reports, saving time and increasing production.

6. PELLETER

Optimizing Pelleters yields substantial plant throughput benefits. Integrating them into the main control system enables automatic downtime tracking and tons per hour data for each recipe and version. Our fully automatic and seamless pelleter control positions us at the forefront of this technology. Real-time and historical insights into order and recipe quality, temperatures, and amps allow users to troubleshoot and optimize pelleters for full specification adherence.

7. OUTLOADING

Our control system ensures full traceability up to the farm and chicken coup level, managing the final product out loading seamlessly. Users can compartmentally load trucks with a predetermined load plan in Automill, reducing contamination risk. The control system captures out loading procedures, preventing bypasses for maximum product integrity.

8. QUALITY

Integrating the quality process from intake to final product out loading empowers users to assess material quality and control the final product. This comprehensive approach ensures visibility and enhances product integrity and customer satisfaction.

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Revolution in balance: Using sustainable development goals as a framework for innovation

By Prof Emily Burton, School of Animal, Rural and Environmental Sciences, Nottingham Trent University

Our work as feed manufacturers is pivotal to achieving food security; we continually advance the ability of humankind to create more from less. However, as we increase our detailed understanding, it is easy to lose track of the big picture: We have a wider role in ensuring we operate within the limits of the global environment. These limits, known as our 'planetary boundaries', are divided into nine domains. This concept indicates that there are boundaries for the global environment that must not be surpassed for humans to survive sustainably on the Earth.

Climate change is a key concern within South Africa as mean annual temperatures have increased by at least 1,5 times the observed global average and extreme rainfall events have increased in frequency, posing a significant threat to South Africa's water resources, food security, health, infrastructure, as well as its ecosystem services and biodiversity. Considering South Africa's high levels of poverty and inequality, these impacts pose critical challenges for national development.

Sustainable development

Surviving sustainably on Earth is one of a set of challenges that transcend national boundaries and are the primary focus of the United Nations (UN). The seemingly intractable conflict between globalised economic growth and accelerating ecological degradation has long been recognised. In 1983, the UN invited the 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).

Sustainable development was discussed in terms of climate change, economic development and equity until, in 2015, all UN member states pledged their support for 17 global goals. The UN Sustainable Development Goals (UN SDGs) provide a shared blueprint for peace and prosperity for people and the planet, now and in the future.

Revolution

In industry, the First Industrial Revolution started in 1780 and represented the mechanisation of manufacturing processes with the introduction of water and steam power. Thirty years later, the Second Industrial Revolution initiated the era of mass production, and in the late 1960s the Third Industrial Revolution introduced automation using electronics and information technology (IT).

Revolution in agriculture started much earlier and more slowly, switching around 12 000 years ago from a hunter-gatherer existence to selecting crops for agriculture. The Second Agricultural Revolution was both a contributing factor and consequence of the First Industrial Revolution: As societies grew larger and more complex, the farmers started looking for new ways to maximise productivity by replacing low-yield crops with higher-yielding ones and developing chemical fertilisers to increase output.

The Third Agricultural Revolution, known as the Green Revolution, spread globally until the late 1980s as a period of technology transfer initiatives that saw greatly increased crop yields and agricultural production. However, we are now experiencing some negative consequences: The energy for the Green Revolution was provided by fossil fuels, our use of inorganic fertilisers has created imbalances in geochemical flow of nitrogen and phosphorus, and pesticide usage has contributed to a reduction in biodiversity.

The Green Revolution irrefutably saved a number of nations from famine and economic disaster, but the luxury of hindsight allows us to reflect on whether any aspects of the Green Revolution could have been refined to avoid the associated negative environmental impacts.

Agriculture and industry are now intrinsically linked so, when revolution occurs, the effect is simultaneous. The Fourth Industrial Revolution is an advanced digital technology, combining artificial intelligence, robotics and big data to create Ag 4.0 or the Fourth Agricultural Revolution. This is creating opportunities to change the way we think and work, but with this opportunity comes both risk and reward. Our challenge, and indeed our responsibility, is to identify how to ensure that Ag 4.0 brings sustainable development for all, both locally in Africa and globally.

Three pillars of development

The UN *Brundtland Report* delineated how economic growth, social equity and environmental balance are essential to create a sustainable development solutions network – utilising local, national and global development strategies. From this report, sustainable development became based on three fundamental pillars: social, economic and environmental.

The 17 UN SDGs clearly exist 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 commonly visualised as a Venn diagram of overlapping circles (Royer, 2019). Without environmental sustainability, economic stability and social cohesion will not be achieved, so a flow of dependencies from environment through society to economy; is also a helpful conceptualisation of sustainability.

Feed production sometimes takes a narrow approach to environmental sustainability, with a strong focus on use finite resources and the environmental impact of resulting manure. However, environmental sustainability focusses holistically on the wellbeing of the environment and valuing it as 'natural capital'. The concept of natural capital extends to include the role of the environment and ecosystems in supporting human well-being through the supply of such important goods and services as clean water, fertile soils, and valuable genetic resources.

The UN considers natural capital in further detail as ecosystem services by dividing them into provisioning, regulating and cultural services, all of which may be influenced through our approach to Ag 4.0.

Responsible innovation

Ag 4.0 requires us to rapidly change the way we think and work in order to capitalise on the emerging opportunities in both production and processing of feed and animal proteins. Many of today's regulatory systems are based on those introduced in the 20th century for technologies that are very different from innovations associated with Ag 4.0. This means regulatory compliance may become a barrier to innovation unless a new approach is established between regulators and innovators.

The concept of responsible innovation, where companies give society opportunity to scrutinise the assumptions, values and visions that drive science, has been evolving in the EU from origins in responsible research frameworks developed for EU-funded research programmes through to consolidated responsible research and innovation frameworks (CRIFs) that support both academia and industry in a single resource (Tait, 2017).

Universal adoption of CRIFs is the foundation of a new ethos where regulators are increasingly willing to adapt their regulatory systems to ensure public safety is maintained while not delaying innovation that is beneficial to society. Standards such as the United Kingdom's *Publicly Available Specification on Responsible Innovation* (PAS 440) are expected to play a major role in the future regulatory reform by providing a standardised approach to identify, evaluate, record and communicate the benefits and possible risks of innovation (Tait *et al*., 2021).

One Health

Many of the global challenges that can be positively influenced through our choices in feed manufacture are encapsulated by the UN One Health approach. One Health is an integrated, unifying approach that aims to sustainably balance and optimise 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).

Feeding strategies designed to enhance poultry gut health in order to reduce reliance on antibiotics is a powerful example of One Health in practice (La Ragione and Burton, 2023).

African feed manufacturing

Previous agricultural revolutions have created a social consensus in some global regions that agriculture should not be industrialised. As our growing population requires more food from the same natural capital, this societal view is difficult to rationalise. However, exploring the basis for this stance gives insight into how to overcome resistance to adoption of Ag 4.0.

Practitioner barriers to adoption centre around IT. Where technologies require complex IT infrastructures and skill levels, the Africa feed sector risks a divide emerging between those with or without robust telecommunication infrastructures. Looking for opportunities to embed Ag 4.0 technologies via mobile phone apps and co-creating tools with diverse practitioners will reduce the risk of creating winners and losers from Ag 4.0.

> Feeding strategies designed to enhance poultry gut health in order to reduce reliance on antibiotics is a powerful example of One Health in practice.

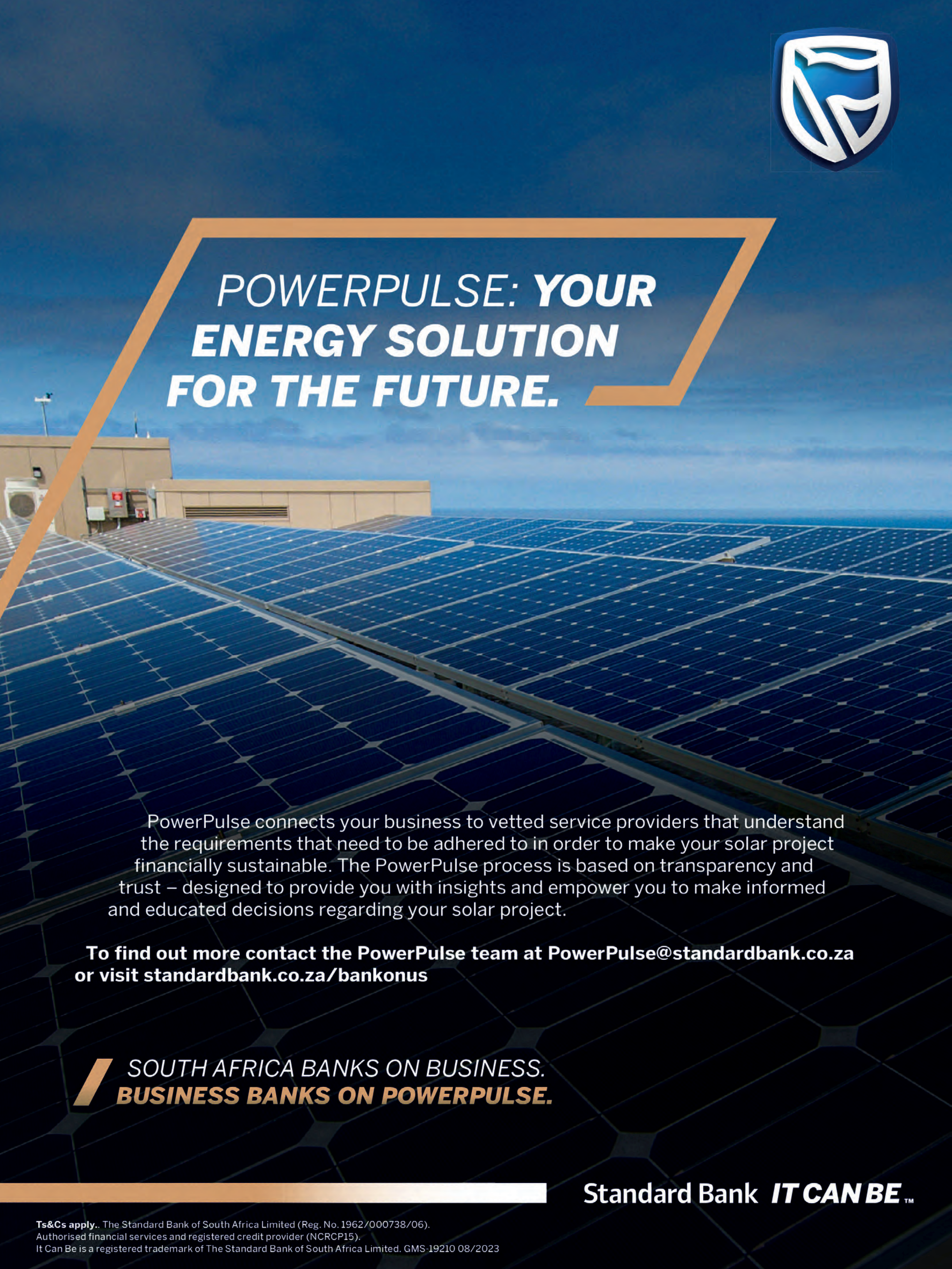
Consumer resistance to advances in agriculture commonly occur through lack of commonality between producers and consumers. Nutritionists and feed technologists have a critical role in ensuring Ag 4.0 develops in harmony with societal values. This will require us to observe society and listen to our producer and consumer stakeholders without defence or judgement.

We need to reflect societal mood and language in our narrative to ensure there is recognition and support for what we do well. This, combined with the transparencies encouraged by adopting responsible innovation frameworks, may be used to ease reluctant consumers towards acceptance and adoption of Ag 4.0 technologies.

Conclusion

Balancing sustainable development across the three pillars requires us to enhance our communication skills. The UN SDGs offer a framework for adopting a mindset of responsible innovation that will increase trust and confidence in our sector as we move through the Fourth Agricultural Revolution. Adopting the SDG language to contextualise the developments of Ag 4.0 will allow our stakeholders to better understand the co-benefits, risks, trade-offs and opportunities associated with emerging innovations.

For more information, send an email to Prof Emily Burton at emily.burton@ntu.ac.uk.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Fit-for-purpose technology: Key to maximising return on capital in a rapidly changing agricultural landscape

By Nico Groenewald, head of agribusiness, Standard Bank

In 2016, the founder of the World Economic Forum, Klaus Schwab, defined the fourth industrial revolution as "a world in which virtual and physical systems of manufacturing flexibly co-operate at the global level".

In agriculture, significant technological change has seen the fourth industrial revolution accelerate the performance of global agricultural value chains at a pace not deemed possible even a few years ago.

In medieval times, for example, livestock roamed free, breeding without selection practices. This resulted in stunted and underweight offspring. By the mid-1700s changed land ownership, technology and farming practices had improved the quality of grazing. Supported by regulatory amendments prioritising the cultivation of supplementary fodder, the average weight of animals sold at Smithfield (London's meat market) improved dramatically (*Table 1*).

Role of technology

In South Africa, the impact of technology, combined with improved farming practices, is evident in data from Grain SA. While the area under grain production decreased from 3,6 million ha in 1990 to 3,2 million ha in 2022, the average yield increased from 2,4 to 6,3 tons/ha over the same period (*Figure 1*). This increased yield performance was partly driven by the use of genetically modified maize seed.

While the world over, seed, irrigation and fertilisers have improved agricultural yields, a recent McKinsey article quantifies how advances in machinery have also expanded the scale, speed and productivity of farm equipment, leading to more land being cultivated more efficiently.

In future, agricultural production and output will be increasingly determined by how effectively the sector leverages artificial intelligence to use the many more data points made available by technology to optimise the efficiency and effectiveness of production, yield, distribution and marketing. McKinsey claims that if connectivity is successfully implemented in agriculture, the industry could increase the global gross domestic product (GDP) by US$500 by 2030.

Increased production

An article recently written for the World Government Summit identifies four broad factors currently challenging the ability of the world's agriculture sector to meet projected food and other key commodity demands. While different studies highlight slightly different factors, the general consensus acknowledges challenges in demographics, scarcity of natural resources, climate change and food waste.

While projections of future global demographics, especially population numbers, vary, there is broad agreement that an increasing – and increasingly urban – global population will demand significant increases in agricultural production. The United Nations' Food and Agricultural Organization (FAO), for example, regularly reports that global agricultural production will need to increase by as much as 70% by 2050. In addition, as the global human diet evolves to include much more animal protein, both the livestock and animal feed sectors are likely to come under increasing pressure to produce more.

Equally, arable land is a scarce natural resource central to any discussion of future agricultural productivity. Outside of Africa,

Table 1: The average weight of animals sold at Smithfield meat market.

Year	Beeves	Calves	Year	Sheep	Lambs
1710	370	50	1710	28	18
1785	800	148	1790	80	50

there is no new arable land. Moreover, the arable land currently under production is becoming increasingly degraded and unsuitable to produce food. Studies claim that as much as 25% of all farmland is already rated as highly degraded. In South Africa, the *South African Geomatics Journal* reported as early as 2013 that the already limited 11,9% of South African land suitable for agricultural production was being reduced by the expansion of urban footprints, lack of access to water (itself a scarce resource) and unsupported land reform initiatives.

While South African agriculture is also challenged with limited and erratic energy supply, technology, especially solar solutions, is fast becoming the leading capital expansion activity on farms as well as within broader agricultural value chains.

Technology for sustainability

In a presentation to the Agbiz conference in 2022, Prof Francois Engelbrecht of the University of the Witwatersrand reported that climate change is projected to see Southern Africa become systematically drier and drastically warmer. Specifically, South Africa's western interior is expected to become a driver, with an increase in multi-year droughts across the whole country. Higher temperatures and frequent droughts are likely to negatively impact crop yields.

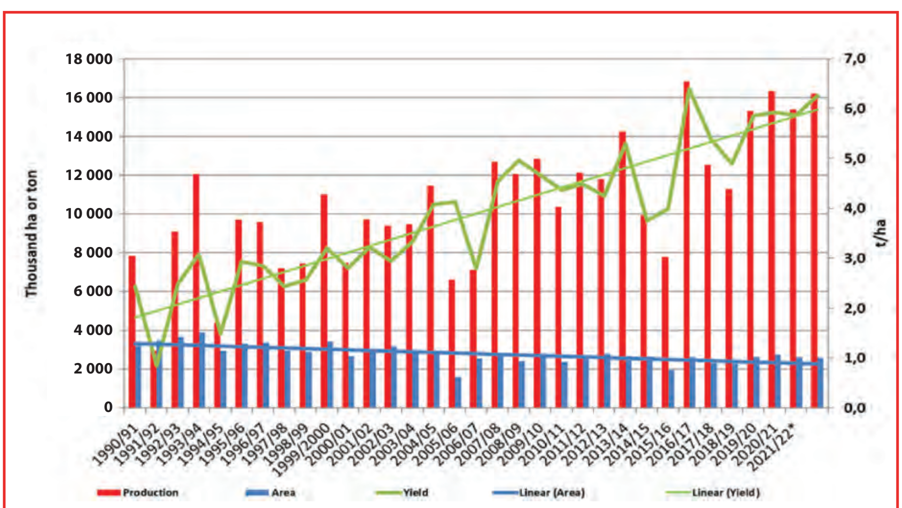
In this regard, recent advances in agricultural biotechnology provide a particularly promising set of tools to strengthen environmental sustainability in the face of climate change. Several new agricultural technologies also offer producers a host of responses to increase productivity or respond more flexibly to climate change.

Combatting food waste

The World Economic Forum recently quoted United Nations' estimates that food waste amounts to almost a fifth of global food production. Household food waste is the largest contributor. A further 14% of food is lost between harvest and retail – before it even reaches consumers. In short, around one-third of all food produced globally is wasted. This equals close to a trillion US$ in economic losses per year.

In response, several companies and institutions have turned to technology to combat the global food waste pandemic.

Figure 1: Total area planted, production and maize yield from 1990 to 2022. (Source: Grain SA)



In South Africa, for example, Standard Bank developed the OneFarm Share platform providing small-scale producers access to markets. OneFarm Share also provides a broking platform for the non-governmental organisation (NGO) sector to access local producers, or for large-scale producers or retailers with unsold produce to access communities in need. The platform has subsequently evolved a logistics solution matching goods requiring transport with empty trucks outward or return journeys.

Embracing technological advances

Despite the multiple global and numerous specific local challenges facing South African agriculture, the sector has not been left behind by the fourth industrial revolution. In fact, South Africa's agricultural sector today provides valuable case studies of how agriculture is leveraging technology to blend virtual and physical systems in the production of much more flexible, resilient and productive value chains.

The key challenge and opportunity for South African producers as agriculture pivots to leverage technology for growth is to understand the financial impact of these changes at the individual farm level. In this, Standard Bank has an important role to play in helping producers appreciate which technology funded through what structures can be justified through increased output and improved sales.

Getting the balance right requires applying a fit-for-purpose philosophy to agricultural investment. In short, Standard Bank is well placed to assist South African producers to embrace technology by ensuring that any investment can be supported by each operation's bottom line, ideally without encumbering the operation with more unproductive debt.

For more information, send an email to Nico Groenewald at nico.groenewald@standardbank.co.za.

The state we are in: Choose your reality

By Bronwyn Williams, futurist, economist and trend analyst, Flux Trends

The *State We're In* is the flagship, continually updated, executive summary from Flux Trends that monitors where the world is at and where it is going next. Using the acronym TRENDS – representing six trend pillars namely technology, retail, economy, natural world, diplomacy and society – the micro and macro trend shifts are captured. These elements are shaping how we will live, work and connect in the coming years and include brand new signals and deeper undercurrents of prevailing trends that are continuing to shift our global landscape.

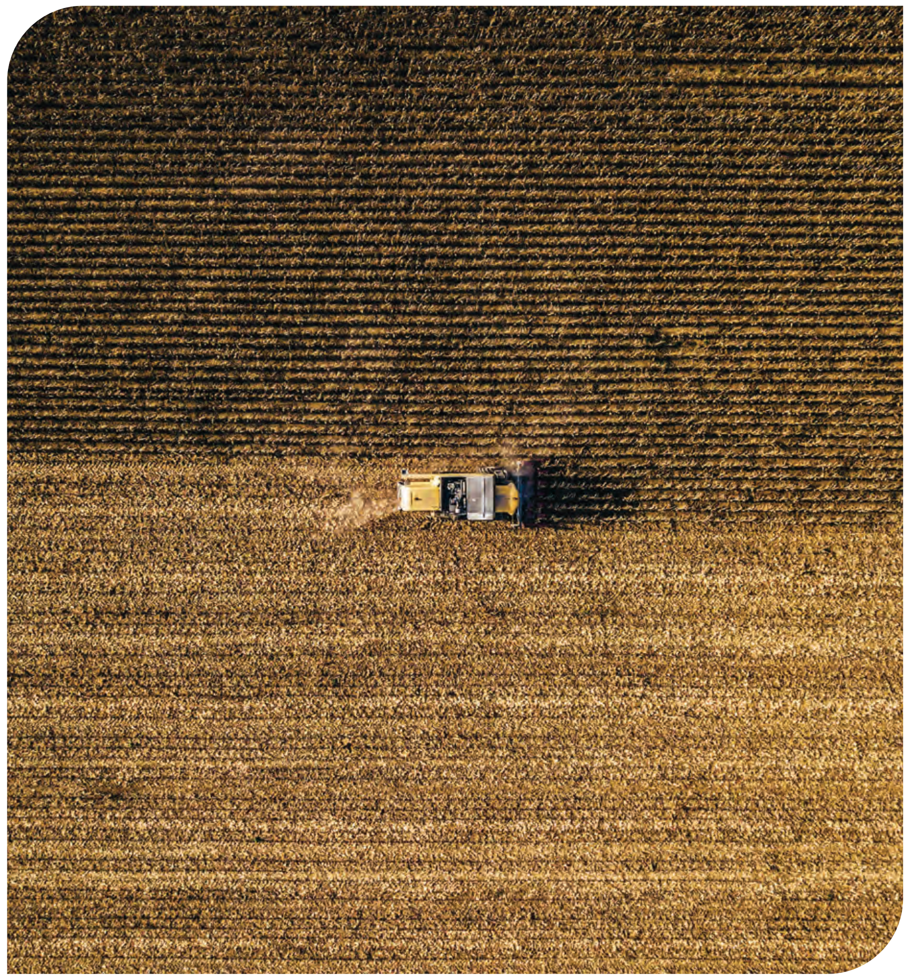
Polycrisis and permacrisis

This year started with the *Financial Times* coining the phrase 'polycrisis'. It is explained as "a problem that becomes a crisis when it challenges our ability to cope and thus threatens our identity. In the polycrisis the shocks are disparate, but they interact so that the whole is even more overwhelming than the sum of the parts. At times one feels as if one is losing one's sense of reality".

Since then, polycrisis discourse has made way for permacrisis discourse as wars and rumours of wars have been compounded without sight of an end. A global cost of living crisis adds to our existential angst around the rise of artificial intelligence (AI) and the looming threat of climate disruption.

Globally, in the wake of such precocity, the narratives that hold our economies and societies – the very ideas of democracy and capitalism – together are unravelling, leaving us dizzy and unbalanced. That sense of lost reality has only grown as we find ourselves stumbling into the uncanny valley of all things artificial at the same time as our real-world socio-economic stories are coming apart at the seams.

The future seems to be closing in on us as fast as it is opening up, causing some of us to retreat to a past we remember as simpler and more human, and others to escape into reliance on our machines for the answers we don't trust ourselves to come up with.



Agriculture fulfils human needs effectively and efficiently.

Here are some key trends emerging from our six pillars and how they can both complicate and mitigate the perma-polycrisis we find ourselves in.

Technology: Through the (uncanny) valley

Generative everything on demand sums up where we are with AI right now. From deep fake political ads proliferating on your social media pages to hyper-realistic multimedia art and even entire novels at the whim of any prompt you can imagine, there is AI for that. You can also create multiple identities for yourself, one for each job, social platform, relationship or project, each complete with a lifelike avatar and a complimentary personality.

This has of course caused a moral and existential panic to descend upon anyone who fears their humanity – or, maybe worse, their jobs – threatened by artificial obsolescence. It also means that our grip on reality, when we can orchestrate our

own at the click of a button, becomes that much more tenuous, causing some to escape into their rooms and virtual reality headsets and others to hallucinate that replacing their entire workforces with recursive chatbots will increase their stakeholder value in the long run.

Retail and marketing: Crisis of values (and value chains)

This year has been all about brands drinking their own Kool-Aid and attempting to fragment their own identities across target markets, even down to a target market of one. From big businesses proudly supporting lesbian, gay, bisexual, transgender, queer, questioning, intersex, asexual, etc. (LGBTQIA+) campaigns in Western markets while keeping silent about human rights violations of those same marginalised groups in more conservative Middle Eastern markets, to the Barbie movie being banned in Vietnam for subtly endorsing China's version of geopolitics in the South China Sea – commercial hypocrisy around social justice issues is hardly a new phenomenon.

However, combining brand schizophrenia with generative AI and effective advertising is fast leading to a world of hyper-personalised 'reality tunnels' where each intended recipient is served a personalised message to match their morals, values, desires – and even emotions. This sort of 'dark advertising' where we are served transient non-repeatable ads can be viewed as corporate gaslighting or as good business, depending on the price of your values.

Economy: Friend-shoring and making foes

Friend shoring is the business strategy of running supply chains only through countries that are close political partners. As the easy money 'everything bubble' deflates and the cost-of-living crisis continues, geopolitical tensions are also forcing producers to source local alternatives to the once easy and abundant just-in-time globalised economy.

Neighbouring and even neighbourhood supply chains that prefer security, solidarity and resilience in practice over efficiency in theory, begin to make more and more sense. As South Africa chooses its political friends, it also risks losing preferential trade deals with its new friends' enemies. All the more reason to invest in strengthening local market opportunities.

Furthermore, just as nations make new friends and new enemies in the process, the continued un-separation of church, brand and state means that brands not only need to choose who to offend at a target market level, but they also need to, increasingly, choose sides in geopolitical battlefields. Corporate political responsibility comes with a cost though, as the brands that have pulled out of Russia and Israel know all too well.

Natural world: Masters of the universe

The climate change crisis discourse has only intensified as the Covid discourse has died down. Climate regulations are ramping up, as are the lawyers and the assorted grifts and outright frauds to 'offset' inconvenient scores with increasingly unconvincing carbon credit schemes, some of which are being promoted by South Africa's own disgraced former president, Jacob Zuma.

However, the hubris that we can use red tape to protect us from floods and fires pales next to the more radical ideas being floated by scientists and politicians to recreate the world in our image. Geo-engineering schemes, from rain-stealing seeding schemes at the Indo-China border to James Bond villain-like proposals to deflect the sun's heating rays away from the earth's atmosphere, may be attempting to fly too close to the sun, so to speak, given humanity's history of underestimating our impacts on complex systems.

Diplomacy: Innovation vs regulation

The world of international relations and diplomacy is also virtualising. Nation states such as South Korea, as part of its pursuit of the perfect 'untact' society policy, where all messy (and unhygienic) interpersonal relations are replaced by mechanised or digitised alternatives, have created a metaverse for home affairs where your avatar can queue on your behalf.

At the same time, corporate titans and entire nation states are jostling for control of the two primary paths to power over the most dangerous and disruptive technology we have invented yet – AI. The two routes are, of course, innovation and regulation. If you can't own the accelerator, you can control the brakes. As such, ethics and regulation committees around biased AI inputs and control of AI output are dominating conversations in national and international political arenas. Control the machines that nudge the people, control the planet.

Socio-cultural: Gamification of everything

As behavioural economics and AI collide, we are living in the era of the gamification of everything – from dating apps and social media popularity contests to increasingly immersive corporate loyalty programmes – we are nudged towards choices and content with rewards and prizes. At the same time, AI avatars, or synthetic people, are becoming more human-like, and we, humans, thanks to digital filters and physical plastic surgery, are becoming more avatar-like.

Are you the person you see in the mirror, or the filtered and photoshopped image you see on your phone screen live stream? Digital technology is directly challenging our sense of self and our sense of belonging, as is evidenced by the loneliness epidemic. Adults under the age of 30 may have millions of likes and hundreds of thousands of followers online, but one in four of them has no friends at all in real life.

What does all this have to do with the future of agriculture, you may ask? Well, as the world virtualises, people will remember that you cannot fill your belly with non-fungible token (NFT) cake. While marketers and politicians are distracted by generative art, keep focussed on solving real problems for real people – and embracing whatever hardware, software and more human solutions that can help you fulfil those real human needs more efficiently and more effectively, even as tough physical conditions, due to geopolitical tensions and challenging climate conditions, persist.

For more information, email bronwyn@fluxtrends.co.za or visit *www.fluxtrends.com*.

Retailing during a polycrisis: The global megashifts shaping the retail trends outlook for 2023

By Andrea du Plessis, Andrea Ellens and Kerry Elliot, Trade Intelligence

How would one begin to describe the volatility, uncertainty, complexity and ambiguity of the past three years? Well, the *Collins English Dictionary* announced that its 2022 word of the year was 'permacrisis', describing an "extended period of instability and insecurity". It certainly felt that way, as many of us were expecting some level of reprieve in a post-pandemic year.

Historian Adam Tooze has a new term, describing the global economic situation as a 'polycrisis' "where a number of depressing factors have combined to create one big alarming super situation".

To illustrate the interconnectedness of the shocks we are experiencing and

Figure 1: State of the world at the beginning of 2022. (Source: Adam Tooze)

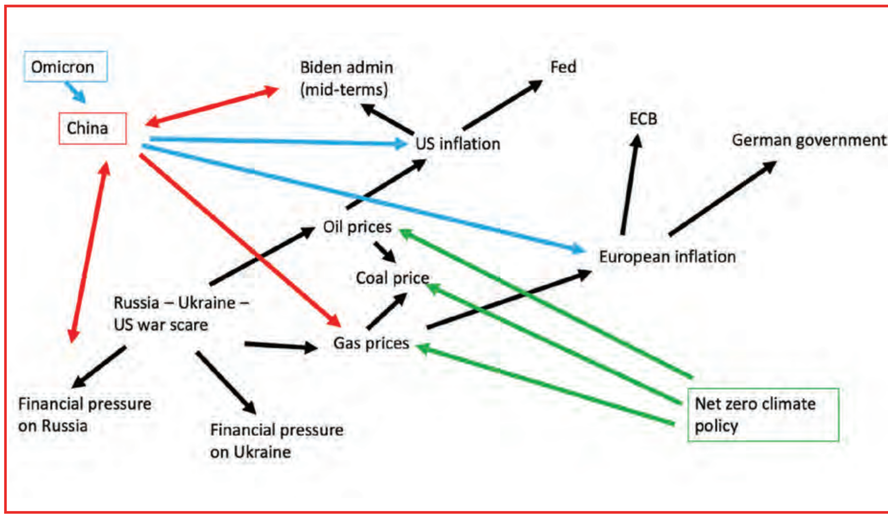
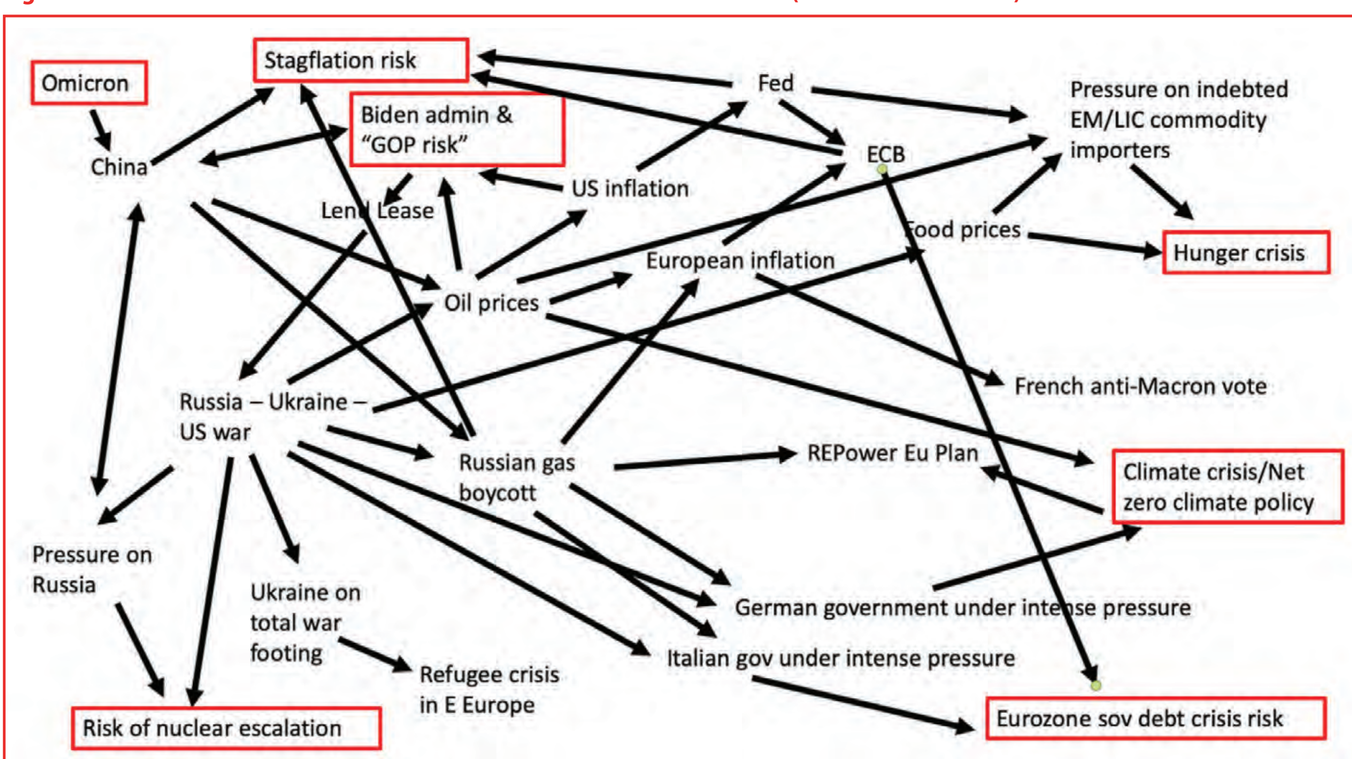


Figure 2: State of the world amid the Ukraine-Russia war six months later. (Source: Adam Tooze)



how they have exploded even during the current year, Tooze's graphic (*Figure 1*) depicts the state of the world at the beginning of 2022 when the war in Ukraine was a mere scare at the time. Then six months later, elements such as the risk of nuclear escalation and stagflation emerged (*Figure 2*).

Former United States Treasury secretary, Lawrence Summers, remarked: "This is the most complex, disparate and cross-cutting set of challenges that I can remember in the 40 years that I have been paying attention to such things." Many of us would agree.

So, in reflecting on the state of the global retail sector and the trends that will shape the industry, it is important to outline these global megashifts, as we refer to them at Trade Intelligence, as a backdrop to assessing the way in which they will influence retail and shoppers at large, in an interconnected fashion.

The Trade Intelligence *Retail Trends* report provides our clients and stakeholders with the latest insights into the outlook of the industry in preparation for the new year. The following is an outline of one of the main global megashifts, the global retail trend stemming from it and a related shopper trend that will drive behaviour in 2024 and beyond.

Global megashift: Race to net zero

The narrative around climate commitments is now firmly positioned as the 'race to net zero' and the recognition that the world needs to transition to a cleaner, more sustainable and secure future as quickly as possible. According to the United Nations' Intergovernmental Panel on Climate Change, CO_2 emissions need to be cut by 45% by 2030, versus 2010 levels, to meet the *Central Paris Agreement* goal of limiting temperature rise to 1,5°C by the end of this century. This is crucial to avoid the worst impacts of climate change, including more frequent and severe droughts, heatwaves and rainfall.

Global investments in energy transitions grew from US$32 billion in 2004 to US$755 billion in 2021, with Asia-Pacific being the leading region accounting for nearly half of the global energy transition investments, according to BloombergNEF.

Global retail trend: Brand refillutions

The concept of refillable products and in-store refill stations is not a new one and as retailers aim to reduce the use of plastic and single-use packaging, the refill trend has continued to grow. Some of the key questions, however, have been around what the role of the brand is within refill solutions, as stations have typically been unbranded and focussed on commodity categories. Other considerations have been around how refill solutions and products can integrate seamlessly into the store and enhance the overall shopping experience.

Retailers and brands in the food and beauty categories, in particular, are addressing these challenges by investing in creating refill solutions and stations that are impactfully branded and packaged, addressing zero-waste practices while providing the pleasurable shopping experience shoppers expect.

Impact and shopper activism

Shoppers have become increasingly in tune with broader society and the planet around them, with their expectations of governments, corporations and brands being as high as they have ever been. From expecting retailers to treat their staff and suppliers fairly, to supporting the local community and demanding sustainable practices and processes, shoppers will exercise their purchasing power as activists.

As we've established, the macro forces underway are mega-catalysts for how the retail industry is evolving and, ultimately, how shopper needs are developing and behaviours are changing. Although there is a lot of change underway, there is no doubt that the retail sector, both globally and locally, is adapting all the time, and ultimately serving society, shoppers and their staff better.

For more on these global megashifts, global retail trends, shopper trends and how they are poised to drive the response of South African retailers, look out for the latest Trade Intelligence *Retail Trends* report. ❖

For more information, send an email to Kerry Elliot at kerry@tradeintelligence.co.za or visit *www.tradeintelligence.co.za*.

Small switches
Big change
Antibiotic Reduction Program
We know you want to help reduce antimicrobial resistance, but it's hard to know where to begin.
Our integrated feed-farm-health approach can help you use antibiotics more responsibly - one step at a time
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Making the 'switch' to responsible use of antibiotics

By Dr Barbara Brutsaert, sustainability manager antibiotic reduction, Trouw Nutrition

Reducing the risk of antimicrobial resistance (AMR) is essential for animal producers to feed the growing population sustainably and safeguard our animal protein industry. A recent World Economic Forum report estimates that if current trends in antibiotic use continue, AMR could increase mortality rates by 1%, a loss equivalent to US$13 billion in livestock value, with the biggest impact in low- and low-middle income countries. The decrease in livestock production due to AMR is not only because of more untreatable diseases but also due to the 'fear factor' in case of disease outbreaks, with bans on imports.

Successful antibiotic reduction efforts from around the globe have demonstrated that it is possible to reduce antibiotics while maintaining or even improving health and performance. Our strategy in the Netherlands provides a good example of successful antibiotic reduction. After the antibiotic growth promotor (AGP) ban in 2006, a multi-stakeholder effort implemented between 2009 and 2021 that involved government, producers and retailers, helped bring about a 70,8% decline in antibiotic sales, while exports increased equally.

Ensuring flock health

From a flock health perspective, the multi-stakeholder strategy reduced resistance to antimicrobial classes among multiple strains of *E. coli* in broilers. This step-by-step approach applied worldwide is essential to keeping the process manageable and all the different stakeholders aligned and motivated to reach the objectives. It is clear that a single approach, such as replacing a certain antibiotic with a feed additive solution, is insufficient to keep animals healthy and guarantee flock performance.

It has been demonstrated that only a holistic feed-farm-health approach will lead to successful economic antibiotic reduction.

A five-step programme

An efficient antibiotic reduction programme relies on a five-step process to drive a continuous cycle of improvement and make the reduction effort easier to manage.

The first step would be to define realistic antibiotic reduction goals for the operations in question. How much and which types of antibiotics does the operation want to reduce? What is the timeframe for achieving the goal? What are the main drivers for antibiotic reduction? Clarify the purpose and desired outcome of an antibiotic reduction effort.

Some producers want to farm without AGPs, while some want to decrease their reliance on antibiotics, and others are seeking certification. Successful antibiotic reduction efforts require commitment across the organisation and a high-level meeting will set out expectations at the start. Clearly defined roles for all team members and trust between stakeholders are crucial for a successful project. Usually, antibiotic reductions are implemented incrementally, with successive reductions made only after positive evaluations (step 5 in *Figure 1* refers).

The second step is a comprehensive evaluation of feed management, farm management and health management conducted across the entire value chain.

Feed management

Consider the breed when evaluating feed intake and feeding schedule. A baseline scorecard should address questions such as: How long does it take day-old chicks to eat? What is the feed intake of weaned piglets during the first week after weaning? What is the nutritional analysis of the feed and is it consistent? Are levels of anti-nutritional factors, such as mycotoxins, moulds and Enterobacteria within acceptable feed safety ranges? If thresholds are exceeded, what levels should be reduced? Is feed structure

Figure 1: Antibiotic reduction programme that includes feed management, farm management and health management.

sufficient to support gastrointestinal function while respecting pellet quality?

Farm management

Young animals (day-old chicks or weaned piglets) are vulnerable, so evaluate visual inspection, weight uniformity and vitality. Is the temperature range in the house appropriate and the floor sufficiently warm? Does the ventilation need to be adjusted, especially during hot days and cold nights? Is fresh feed and water easily accessible? Do chicks and piglets feel comfortable enough to eat? What biosecurity measures are in place? Is the floor hygiene well managed?

Health management

It is important to know what antibiotics are being used on the farm and for what purpose. The following questions help to establish a baseline: Are the antibiotics consistently effective and if not, why not? Are antibiograms performed? Is there a properly administered customised vaccination schedule? What feed and drinking water additives are used? In addition to inputs, evaluate animal droppings/manure for consistency and quality. Blood samples, necropsies and other analyses can provide valuable additional info.

Design of value added programme

Based on the previous information, a value-added programme is being designed. Science-based nutritional strategies covered in the 2021 Food and Agriculture Organisation (FAO) paper are being combined with farm (e.g., biosecurity) and health (e.g., vaccination schedules) management advice, and tailored to the assessment findings and agreed targets.

The value of the programme is designed and calculated together with the producer, so as to maximise the success of implementation and economic performance. Examples include:

Feed management (Figure 2)

- High-quality young-animal feed, including precision nutrition and optimal physical properties.
- Structure to improve gizzard function in poultry. Making use of degradation kinetics (speed of digestion) to analyse insoluble and soluble dietary protein, starch and fibre in the feedstuffs to formulate for optimal nutrient absorption.
- A mycotoxin risk management programme that mitigates mycotoxin risks directly or via mould control.

Farm management

- Advice on house climate, positioning of feeders and drinkers according to broilers' age and other environmental considerations.

Health management (Figure 3)

- Strategic use of a synergistic combination of feed additives based on five pillars delivering targeted modes of action.
- Advice on how to reduce the need for antibiotics and use it in a responsible way when needed. Review of vaccination schedules.

A solid AMR strategy must make sense in terms of efficacy and producer economics. If not, a new review of needs and solutions is needed. A return-on-investment calculation is done based on the resources (feed adaptations, feed additives, etc.) required to implement suggested solutions with the potential return based on local actual prices (e.g., feed and meat prices) and past experience.

For successful implementation, a good cross-divisional collaboration between the different scientific and practical experts is essential, where all stakeholders understand the programme and trust each other.

Finally, it is important to assess whether the implemented intervention meets the customer's needs as outlined in step one. Once this has been achieved, the cycle is repeated until the next level of antibiotic reduction is reached. The process is repeated until the final goal is achieved. In a dynamic marketplace, the initial goal will inevitably be fine-tuned over time. Our antibiotic reduction programme approach is designed on the latest insights, and validated and perfected in practice.

Through this process, a leading broiler integrator in Spain was able to achieve a 95% decrease in antibiotics in six years along with a 36% lower mortality. An important swine producer in the same market reduced his treatment costs by 75% while reducing mortality by 3% and feed conversion ratio by 15 points, resulting in more than €1 extra value per piglet.

You choose how you can make a difference: One switch at a time!

Figure 2: Feed management strategies.

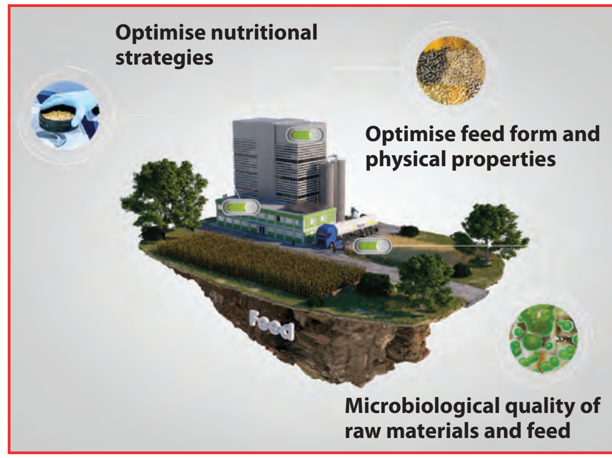
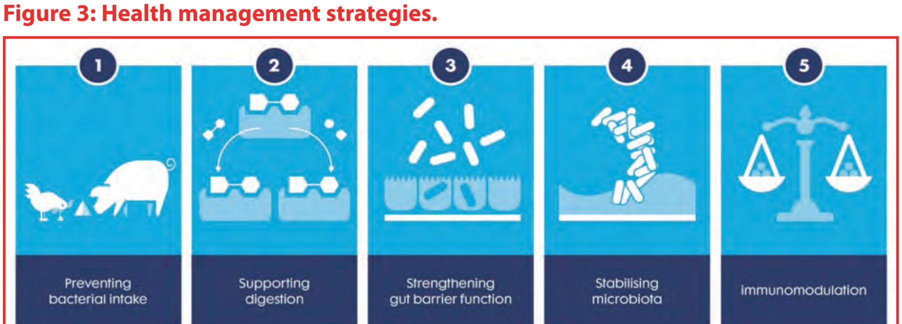


Figure 3: Health management strategies.



References available on request. Email Barbara.Brutsaert@trouwnutrition.com for more information, scan the QR code or visit *www.trouwnutrition.com.*

New developments to mitigate the effects of heat stress on broiler physiology, digestive function, nutrient intake and performance

By Dr Peter Plumstead and Kyle Venter, Chemuniqué

Many broiler growers across South Africa encounter a seasonal reduction in live performance which, during the summer months, reduces profitability and threatens the sustainability of our poultry industry. The drivers of reduced performance are multifaceted and attributed to physiological stress responses associated with high heat production in fast-growing broilers that exceed the thermoregulatory capacity of the bird. This stress is often compounded in modern broiler production when combined with high stocking densities and poor air or litter quality.

The production and economic losses arising from this are commensurate with the degree of heat stress (HS) that leads to changes in behaviour, reduced feed intake, shifts in blood supply to visceral tissues, panting and shifts in acid-base balance, inflammation, oxidative stress, compromised gastrointestinal function and impaired immune defences. Due to the diverse impact of stress on the bird, a multifaceted management and nutritional approach to mitigate its impact is warranted.

New research has elucidated several solutions that can effectively be applied to support bird performance under stress. These, together with a better understanding of the physiological effects of stress in poultry, will enable farm managers and nutritionists to mitigate the inevitable challenges that growing commercial broilers in summer brings with it.

Cause of performance losses

When birds are hot, they will inevitably spend less time eating and walking, and more time drinking and resting. The reduction in feed intake that contributes to performance losses in summer is simply due to birds being more lethargic and attempting to reduce metabolic heat production in the body. However, the reduced feed intake of stressed birds explains only part of the reduction in performance.

The associated changes in physiological balance, loss of intestinal integrity and digestive function, bacterial and endotoxin translocation, coupled with a compromised immune system are equally, if not more important in explaining reduced performance under HS. This was elucidated in a recent study at the University of Arkansas where broilers were raised under thermoneutral or cyclical HS together with a pair-fed control group.

Stressed birds performed significantly worse than their pair-fed counterparts that were feed restricted, but not stressed. Stress was also associated with a significant reduction in gut integrity, along with increases in inflammatory cytokines, heat shock proteins and glutathione peroxidase. These effects can be attributed to elevated corticosterone production as well as shifts in blood supply away from visceral tissues towards the skin. This, in turn, reduces oxygen supply to the intestine, resulting in increased reactive oxygen species (ROS) and oxidative stress to these tissues.

Several other studies support this and indicate that stress also results in significant shifts in microbial populations, intestinal morphology, and modifies gut permeability by disruption of tight junction proteins, causing leaky gut syndrome and allowing entry of pathogens and harmful metabolites.

Commensurate with this understanding, a key focus area of new research to mitigate the commercial impact of HS has been to nutritionally support the key areas that drive the reduced performance in HS. These are primarily intestinal health and function, antioxidative defence systems, immune system, and acid-base balance.

Support gut health functionality

The loss of intestinal integrity and capacity, oxidative stress, coupled with unfavourable shifts in microbial populations are some of the main drivers of reduced broiler performance in HS. According to Kogut's research, supporting gut health nutritionally should be done in a holistic manner by considering the major elements that synergistically affect it, namely the gastrointestinal (GI) epithelium, GI immune and antioxidative system, and GI microbiota.

Benefits of probiotic or direct-fed microbial (DFM) supplementation on reducing Gram-positive and -negative pathogens, improving intestinal morphology, and supporting improved live performance are not new and has driven the widespread implementation in commercial broiler diets. However, their benefits specific to heat stress are less known.

Two recent HS challenge studies conducted at Iowa State University investigated the effects of a three-strain DFM on intestinal permeability, ileal energy digestibility and live performance of heat-stressed broilers reared in challenging conditions on used litter. Results from this study showed DFM supplementation to improve bodyweight (BW) gain to 28 days and feed conversion ratio (FCR) to both 28 and 32 days of age.

These improvements in live performance of DFM-supplemented birds were supported by significant improvements in ileal energy digestibility, as well as improvements in intestinal permeability. The improvement in intestinal permeability is indicative of tight-junction integrity between enterocytes which, when compromised, allows a portal for bacterial and endotoxin translocation into the body and is a major cause of increased infections observed during HS.

One of the mechanisms whereby intestinal integrity is lost during HS lies in the reduced blood flow to the viscera, reduced supply of oxygen, subsequent oxidative stress, and loss of tight-junction integrity. Nutritionally, antioxidants, such as vitamin E, or minerals, such as selenium (Se), manganese (Mn), copper (Cu) and zinc (Zn), which are important parts of antioxidant systems, are included in commercial premixes for poultry.

In most cases, their levels in premixes are sufficient to meet the physiological requirements in these elements. However, in commercial intensive broiler production where stress is part of daily life, and particularly when additional stressors such as high ambient temperatures compound this, there is a need for additional support for the antioxidant systems.

Zn plays an important role in the integrity of tight junctions, antioxidant defence system, immune system and bone, all of which are compromised in HS conditions. Specific to antioxidant systems, Zn is part of superoxide dismutase, glutathione, glutathione S-transferase and hemeoxygenase-1, and thereby helps suppress elevated levels of free radicals incurred during stress. HS has also been shown to alter Zn homeostasis and lead to a redistribution of Zn in broilers, which was reflected in increased Zn concentrations in the jejunum, liver, and tibia.

In this context, recent HS challenge studies at the University of Ghent support the use of more bioavailable forms of Zn in the form of Zn-amino acid (Zn-AA) chelates. Due to its greater bioavailability, Zn-AA was shown to increase plasma malondialdehyde (a marker for oxidative stress) and glutathione peroxidase activity, supporting an improved oxidative status compared to birds supplemented with inorganic Zn sulphate. This translated to improved villus length and villus:crypt depth ratio, supporting increased digestive capacity.

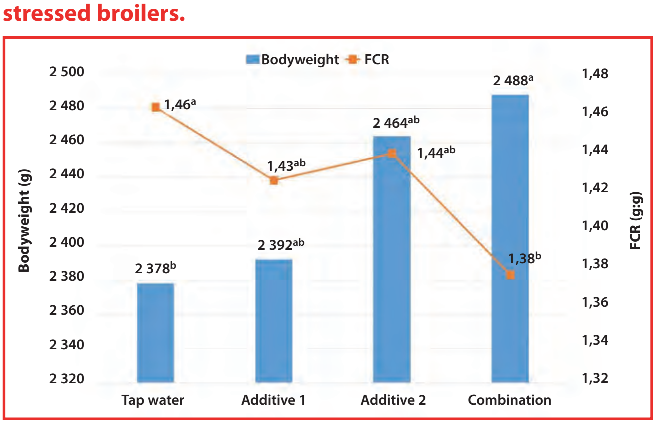
A second study by the same group again showed significant benefits of Zn-AA on intestinal morphology with improved BW gain to 35 days of age and improved FCR from 28 to 35 days of age when Zn-AA was combined with 50 IU/kg vitamin E, with no effect when vitamin E levels were increased to 100 IU/kg. This supports that the new direction of nutritionally considering antioxidant strategies needs to understand combined effects of active compounds holistically under stressed conditions rather than individually.

Maintain electrolyte balance

Since birds do not have sweat glands, they are dependent on panting for evaporative cooling. However, panting also causes negative effects. The first is that continuous panting will result in dehydration, increasing water requirements and consumption. Furthermore, panting is an energy expensive process that utilises calories that would otherwise be used for productive purposes and contributes to poorer FCR.

Excessive panting will also lead to respiratory alkalosis, which is associated with elevated blood pH and decreased blood carbon dioxide (PCO_2) and bicarbonate (HCO_3^-). Efforts by the bird to restore acid:base balance leads to increased urinary excretion of sodium (Na^+) and potassium (K^+) and thus reduced levels of these cations in the blood. These changes in the birds' blood physiology during HS are well understood and can be actively supported via dietary and/or water-based supplementary strategies.

Figure 1: Performance effects of water supplements for heat stressed broilers.



a,b Columns or points with different superscripts differ significantly (P<0,05).

Nutritionists routinely control minimum and maximum dietary levels Na^+, K^+ and chloride (Cl^-) in commercial diets. These are known as 'strong ions' because they exert characteristic effects on the chicken's acid:base homeostasis and play major roles in the tissue protein synthesis, cellular homeostasis, osmotic pressure, and acid:base homeostasis. By maintaining a base excess of the diet close to zero, as well as strategically supplementing Na K, performance of broilers can be supported during HS.

New water-based solutions

One of the limitations of feed-based strategies to mitigate the negative impacts of HS is that feed intake is reduced both under commercial conditions at high stocking density and is exacerbated during HS. In contrast, high ambient temperatures increase water intake. This makes water an ideal delivery system for specific active compounds that have been shown to support broilers' physiologically when they are stressed.

The potential benefits of water-based additives in broilers subjected to cyclical HS was investigated recently by Venter and co-workers (*Figure 1*). In that study, a combination of multiple compounds that had previously individually been shown to be beneficial in supporting the physiological impact of HS was evaluated. Broiler performance at 35 days of age showed additive effects of individual compounds with an improvement of 110g BW and eight points FCR versus the control that received tap water.

In summary

HS in broilers has a significant impact on broiler performance that is exerted through multiple behavioural and physiological mechanisms, and is often compounded by the stress of high-density commercial broiler production systems. Due to the diverse impact of HS on the bird, a multifaceted nutritional approach to mitigate its impact is warranted that should include support of the gut microbiota, intestinal functionality, antioxidant systems, and the immune system. ❖

References available on request. For more information, email peter@chemunique.co.za or visit *www.chemunique.co.za*.

Benefits of a digital life-cycle analysis solution for dynamic environmental footprinting of feed and animal protein

By Walter Van Hofstraeten, senior consultant poultry nutrition, Schothorst Feed Research

The scientific community worldwide knows and recognises that animal protein production is posing challenges regarding sustainability. Livestock production today impacts 14,5% of all human-induced greenhouse gasses, as well as consumes significant amounts of freshwater (8%), requires substantial land for crop production (33%) and leads to nitrogen (N) and phosphorus (P) runoffs (33%).

If we couple these issues with the fact that the population is forecast to increase to ten billion people by 2050, our industry has a major challenge to satisfy this demand (+70%) while remaining respectful to the environment.

Across species and especially in pork and poultry, feed shows the greatest contribution to climate change and environmental impact. It is estimated that in pork production 49% comes from feed production and 33% from manure and excretions, which are heavily influenced by the animals' diets.

Across other species, we see similar patterns focussing on climate change, with a significant contribution of enteric fermentation in ruminants. The impact of land use change (LUC) from pasture expansion or soya bean expansion on climate change is the highest in poultry. In conclusion, how you design your feed makes a difference for the environment.

Digital life cycle analysis

Opteinics™, a digital life-cycle analysis solution for dynamic environmental footprinting of feed and animal protein, can be connected via a simple user interface with the least-cost formulation software.

With minimum data input required, it is the nutritionist or formulator who is able to understand the environmental impact of the feed (s)he formulates and adapts formulations to minimise impact.

Both feed and animal protein footprints can be calculated. In addition to nutritional requirements and costs, environmental impact becomes the third dimension in feed formulation, balancing the least cost and least impact in ration design.

Combining nutritional and environmental evaluation enables competence to produce more sustainable products. It makes it possible to share sustainability insights with stakeholders since brands, retailers and regulators have ambitious sustainability goals. A reduced environmental impact of feed or animal protein enables sustainability claims and most probably a price premium as well.

Soya bean meal-free diets

A feeding trial was conducted at Schothorst Feed Research to demonstrate the feasibility of replacing soya bean meal (SBM) as a protein source in broiler diets.

A total of 360 Ross 308 male broiler chickens were allotted to 18 floor pens ($2m^2$) and three dietary treatments with 20 birds/pen and six replicate pens/dietary treatment. Experimental diets were provided in starter (D0-10), grower (D10-24) and finisher (D28-37) phases.

As a reference, maize-wheat-SBM-based diets were formulated according to Schothorst Feed Research's nutritional recommendations. The SBM-free diets contained wheat, peas, dehulled or non-dehulled faba beans, sunflower seed meal, rapeseed meal, maize gluten meal and potato protein as protein sources.

Various sustainability indicators were evaluated. The global warming potential (GWP) per ton of feed was calculated by multiplying ingredient inclusion levels with GWP figures provided by the Global Feed Lifecycle Assessment Institute – GWP per ton of carcass weight was calculated as well.

Details on diet formulations (ingredient composition, calculated crude protein [CP] level of diets) as well as on broiler performance (feed intake [FI], bodyweight gain [BWG], feed conversion ratio [FCR], mortality) were entered into Opteinics™. A Dutch scenario was defined as feed manufacturing, the origin of cereals and protein sources (except SBM) originated from Europe whereas SBM originated from Brazil (deforested land). Sustainability impact factor values were available for all synthetic amino acids used. For all other input options, e.g., energy mix for feed manufacturing or animal housing, default values by Opteinics™ were used.

Opteinics™, a digital life-cycle analysis solution for dynamic environmental footprinting of feed and animal protein, can be connected via a simple user interface with the least-cost formulation software.

In addition to sustainability indicators, nitrogen (N) utilisation (%) and N-excretion were calculated based on N-intake (calculated from FI and CP level of diet) and N-retention, assuming 30g N-retention per kilogram BWG.

Results and discussion

Dietary CP, performance parameters and N-related indicators for the starter phase (D0-10), grower phase (D10-24), finisher phase (D24-35) and overall period (D0-35) are given in *Table 1*.

Despite a higher addition of synthetic amino acids, CP levels in both SBM-free diets were higher than in the reference diet, especially in the starter and grower phases. This can be explained because protein and amino acid digestibility is lower

Table 1: Dietary CP, performance parameters and N-related indicators for the starter phase (D0-10), grower phase (D10-24), finisher phase (D24-35) and overall period (D0-35).

Dietary treatment	Reference	SBM free	
	Non-certified SBM deforestation	Non-dehulled faba beans	Dehulled faba beans
Starter (D0-10)			
CP in diet (g/kg)	211	220	224
FI (g/bird)	280	300	282
BWG (g/bird)	252	265	266
FCR (g/g)	1,111	1,132	1,060
N-intake (g/bird)	9,45	10,56	10,10
N-retention (g/bird)	7,56	7,95	7,98
N-utilisation (%)	80%	75%	79%
N-excretion (g/bird)	1,89	2,61	2,13
N-excretion (g/kg BWG)	7,51	9,85	8
Mortality (%)	0	0	0,8
Grower (D10-24)			
CP in diet (g/kg)	197	207	211
FI (g/bird)	1460	1536	1500
BWG (g/bird)	1130	1163	1213
FCR (g/g)	1,292	1,321	1,237
N-intake (g/bird)	46,02	50,87	50,64
N-retention (g/bird)	33,9	34,89	36,39
N-utilisation (%)	74%	69%	72%
N-excretion (g/bird)	12,12	15,98	14,25
N-excretion (g/kg BWG)	10,72	13,74	11,75
Mortality (%)	2,5	0	1,7
Finisher (D24-35)			
CP in diet (g/kg)	172	175	173
FI (g/bird)	1955	2029	1979
BWG (g/bird)	1261	1274	1280
FCR (g/g)	1,550	1,593	1,546
N-intake (g/bird)	53,80	56,81	54,78
N-retention (g/bird)	37,83	38,22	38,40
N-utilisation (%)	70%	67%	70%
N-excretion (g/bird)	15,97	18,59	16,38
N-excretion (g/kg BWG)	12,67	14,59	12,80
Mortality (%)	0	1,7	0,8
Overall (D0-35)			
CP in diet (g/kg)	185	191	192
FI (g/bird)	3695	3865	3761
BWG (g/bird)	2643	2702	2759
FCR (g/g)	1,398	1,430	1,363
N-intake (g/bird)	109,27	118,24	115,53
N-retention (g/bird)	79,29	81,06	82,77
N-utilisation (%)	73%	69%	72%
N-excretion (g/bird)	29,98	37,18	32,76
N-excretion (g/kg BWG)	11,34	13,76	11,87
Mortality (%)	2,5	1,7	3,3

in most of the alternative protein sources used. The weighted averaged dietary CP levels (WACP) across all phases were 185, 191 and 192g/kg for the reference diet, SBM-free diet with non-dehulled faba beans and SBM-free diet with dehulled faba beans, respectively.

Overall, FI was the highest on the SBM-free diet with non-dehulled faba beans (3 865g/bird), followed by the SBM-free diet with dehulled faba beans (3 761 g/bird) and the reference diet (3 695g/bird).

Overall, BWG was the highest on the SBM-free diet with dehulled faba beans (2 759g/bird), followed by SBM free diet with non-dehulled faba beans (2 702 g/bird) and reference diet (2 643g/bird).

Overall, FCR was the lowest on the SBM-free diet with dehulled faba beans (1,363) followed by the reference diet (1,398) and SBM-free diet with non-dehulled faba beans (1,430). The same ranking in FCR was observed in every feeding phase. The higher FCR for the SBM-free diet with non-dehulled faba beans can be explained by the higher tannin level in this diet, which causes lower digestibility.

Since WACP and FI were the lowest for the reference diet, N-intake was also the lowest (109,3g/bird), followed by the SBM-free diet with dehulled faba beans (115,5g/bird) and SBM-free diet with non-dehulled faba beans (118,2 g/bird).

N-retention was calculated from BWG assuming 30g N per kilogram BWG and was the highest for the SBM-free diet with dehulled faba beans (82,8g/bird), followed by SBM-free diet with non-dehulled faba beans (81,1g/bird) and reference diet (79,3g/bird).

N-utilisation was calculated as N-retention as % of N-intake and was the highest for the reference diet (73%), followed by SBM-free diet with dehulled faba beans (72%) and SBM-free diet with non-dehulled faba beans (69%).

N-excretion per kilogram BWG was reduced at the same time and was the lowest for the reference diet (11,3g/kg BWG), followed by SBM-free diet with dehulled faba beans (11,9g/kg BWG) and SBM-free diet with non-dehulled faba beans (13,8g/kg BWG). The same ranking in N-excretion was observed in every feeding phase.

Further results for sustainability indicators will be shown at the AFMA Forum.

Conclusions and applications

Schothorst Feed Research uses Opteinics™ as a tool to calculate the consequences of feed formulation strategies on N-utilisation and other sustainability indicators. Studies are conducted to compare the effect of the country of origin of SBM, replacing SBM with alternative protein sources, or improvement of animal performance or carcass yield. These calculations reveal that the impact of feed composition is significantly larger than the impact of performance efficiency on the farm or in the slaughterhouse.

The calculations show that replacing SBM with alternative protein sources does not always result in lower emissions. The alternative protein sources require more arable land and fossil fuels, and usually have a lower protein and amino acid digestibility. Therefore, life cycle assessment tools will help food retailers and food services companies to better understand and explain the ecofootprint effects of the choices they make to meet consumers' preferences.

For more information, send an email to wvhofstraeten@schothorst.nl or visit *www.schothorst.nl.*

Improving nitrogen efficiency in lactating dairy cows for sustainability and profit

By Mike Shearing, global ruminant amino acid formulation manager, Adisseo

Dairy producers around the world face many challenges, including adverse weather, labour shortages, competition for limited water and land resources, and government regulations. Dairy farms also face economic pressure as profits are often limited by rising input costs and low market prices. Often, short periods of high profitability are followed by prolonged periods of low or negative profitability, causing producers to exit the industry and resulting in greater consolidation among the remaining producers.

This consolidation results in fewer, larger and more efficient dairy operations which can produce more milk at a lower cost; however, it can result in excess supply. Due to inelastic demand for dairy products, excess supply often results in lower-pay prices and reduced profitability, which causes further attrition and consolidation. This is a seemingly never-ending cycle.

Sustainability and climate change

Dairy producers now face mounting pressure to improve sustainability to help mitigate climate change. Although estimates vary, there is no doubt that animal agriculture (and particularly dairy) contributes to increased levels of greenhouse gas (GHG) emissions which accelerate global warming. Additionally, animal agriculture and the production of the necessary feed crops can contribute to soil acidification and water eutrophication – both of which are harmful to the environment.

Consumers, food producers, industry groups and governments all are asking for or mandating that dairy producers reduce their environmental impact significantly, with the ultimate target of 'net zero' GHG emissions in the future.

Dairy production impacts the environment in many ways. Crop production, harvesting, processing and transportation all utilise energy, typically fossil fuels that elevate GHG levels. Feed and additives often require extensive processing and/or transportation as well. Ruminant animals produce enteric methane, and the manure from ruminants can release methane as it degrades. Nitrogen lost from dairy production in the form of nitrous oxide (N_2O) is a potent GHG. The global warming potential (GWP_{100}) of N_2O is 273 times that of carbon dioxide and ten times that of methane.

Exploring sustainability options

Significant improvement in dairy sustainability requires addressing all areas of opportunity. Many of the options today require added investment and/or may potentially reduce productivity or profitability. For example, the utilisation of locally produced feed and forages and careful selection of grains, byproducts and additives can minimise the carbon footprint of dairy rations; however, animal performance may be compromised.

Additives to reduce enteric methane emissions are available now, and more are being developed and tested. The cost of this type of treatment may be modest, but there may be no improvement in performance to offset this cost, so there is a net negative economic impact. Although they require a large capital investment, methane digesters can convert manure into a saleable resource.

Finally, sophisticated ration formulation allows increased animal productivity with lower nitrogen inputs, which increases nitrogen efficiency and reduces nitrogen losses to the environment. Formulation of dairy rations to improve nitrogen efficiency can improve profitability with higher income over feed cost (IOFC) with minimal investment and a short turnaround time. Greater animal productivity also dilutes other costs and improves other measures of sustainability when evaluated per kilogram of milk produced.

This paper summarises three published studies which support this position, and then details a simulation of South African dairy ration reformulation which demonstrates a method to improve nitrogen efficiency and dairy profitability by increasing nutrient density while reducing feed costs.

Study 1

The 2006 Colmenero and Broderick study demonstrates that reducing crude protein (CP) in the diets of lactating dairy cows can improve nitrogen efficiency and reduce nitrogen excretion through urine.

In the introduction, the authors state: "It is well established that, as the CP content of the diet increases, the amount of protein degraded in the rumen also increases. If rumen degradable protein (RDP) exceeds microbial needs, then large amounts of ammonia (NH_3) are produced, absorbed into the blood, converted to urea in the liver and excreted in the urine. In the manure, urinary urea can be rapidly hydrolysed to NH_3 and lost by volatilisation to the environment (Muck, 1982). Overfeeding CP also reduced profit margins because of the relatively high cost of protein supplements and the poor efficiency of N use by dairy cows fed high protein diets (Broderick, 2003)."

In this study, the five treatment diets all contained 50% forage with equal parts maize silage and lucerne silage. The CP levels ranged from 13,5 to 19,4% of the ration dry matter (DM). The amounts of rolled high-moisture maize and soya bean meal (SBM) were varied to achieve the desired CP levels while all other ration ingredients were constant.

Milk yield showed a trend for a quadratic response to dietary CP, with the highest yield at the intermediate CP level and the lowest milk yields at the extremely high and low CP levels. This suggests that maintaining productivity will require some minimum amount of dietary CP and that simply lowering CP will compromise productivity and is not a viable alternative.

This data shows that reducing nitrogen intake by reducing dietary CP

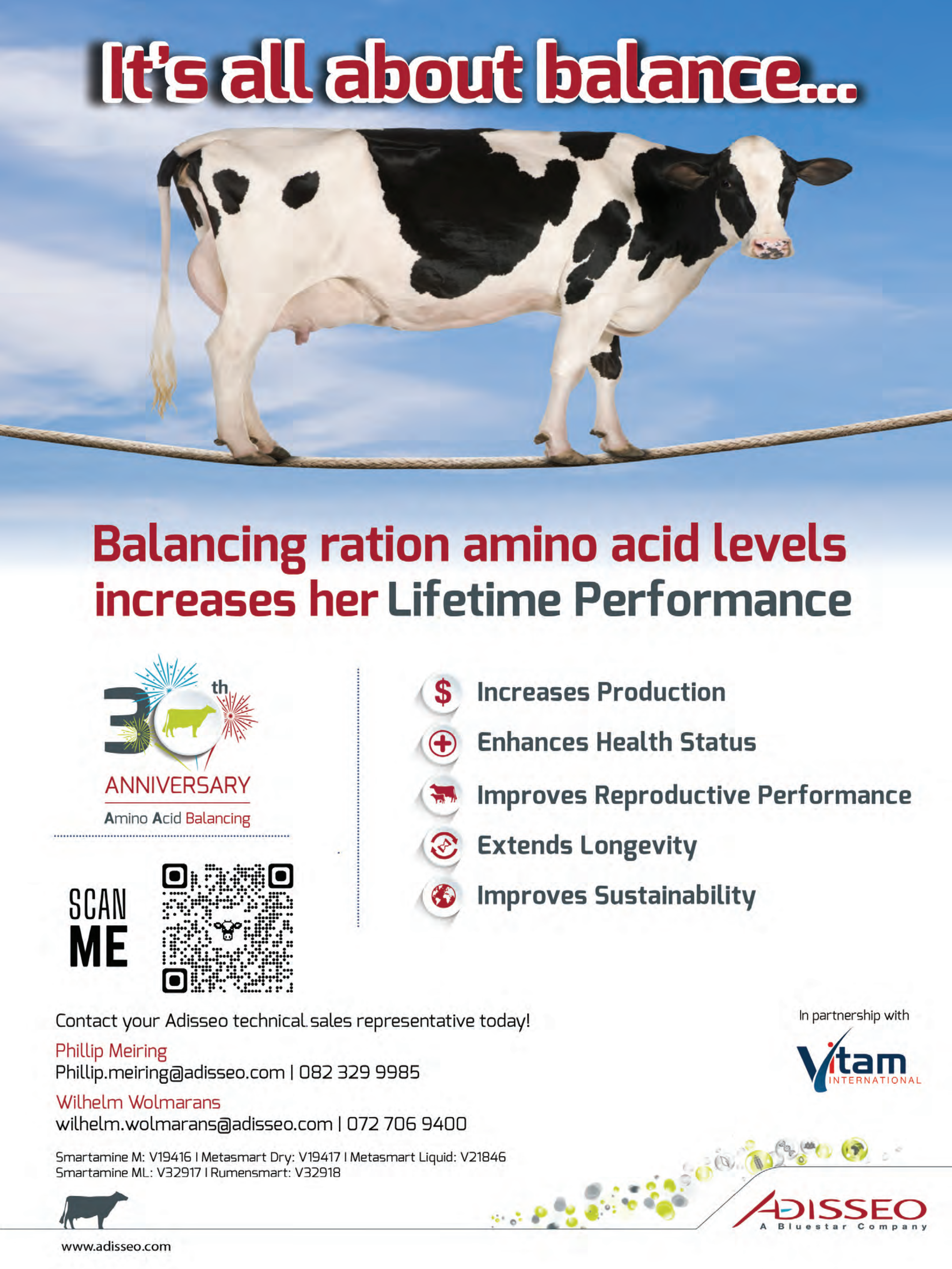

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Table 1: The key data from the 2006 Colmenero and Broderick study.

		Treatment				
Measurement	**Unit**	**13,5% CP**	**15% CP**	**16,5% CP**	**17,9% CP**	**19,4% CP**
DMI	kg	22,3	22,2	23	22,3	22,9
Actual milk	kg	36,3	37,2	38,3	36,6	37
Fat	%	3,14	3,27	3,27	3,47	3,44
True protein	%	3,09	3,15	3,09	3,18	3,16
CP	% DM	13,5	15	16,5	17,9	19,4
NDF	% DM	22,4	22,4	22,4	22,4	22,4
NFC	% DM	55	53,5	51,9	50,4	48,8
N intake	g/d	483	531	605	641	711
Milk N	g/d	173	180	185	177	180
Milk N efficiency	%	36,5	34,0	30,8	27,5	25,4
Total N excretion	g/d	309	316	376	410	467

from 19,4 to 13,5% of ration DM will in turn result in less urinary nitrogen excretion and greater nitrogen efficiency as measured by milk protein nitrogen as % of nitrogen intake.

Reference: JJ Olmos Colmenero and GA Broderick (2006). "Effect of dietary crude protein concentration on milk production and nitrogen utilization in lactating dairy cows." *Journal of Dairy Science* 89: 1704-1712.

Study 2

The 2003 Noftsger and St-Pierre study demonstrated that reducing ration CP while improving the amino acid balance by supplementing both butanoate (HMTBa) and rumen-protected methionine (Met) in a diet with adequate lysine, resulted in numerically or statistically significant improvements in milk yield, milk protein content and milk protein yield with higher gross nitrogen efficiency calculated as milk N/N intake and a lower environmental efficiency calculated as kg N excreted/kg N in milk.

In the abstract, the authors state: "Supplementing the highly digestible rumen undegradable protein (RUP) source with rumen available and rumen escape sources of Met resulted in maximal milk and protein production and maximum nitrogen efficiency by cows during the production trial, indicating that post-ruminal digestibility of RUP and amino acid balance can be more important than total RUP supplementation."

The production trial included four treatments: two with high CP levels and either low or high digestible RUP sources; and two with a low CP level and high digestible RUP sources and without or with a rumen-protected Met source.

Table 2: Data collected from two treatments.

		Treatment	
Measurement	**Unit**	**HiCP/LoDRUP**	**LoCP/HiDRUP+Met**
DMI (dry matter intake)	kg	21,7	23,6
Actual milk	kg	40,8	46,6
Milk protein	%	2,95	3,09
Butterfat	%	3,42	3,73
CP	% DM	18,3	17
NDF	% DM	32,8	32,3
Fat	% DM	5,7	5,4
NSC	% DM	38,3	40
Rumen-protected Met	g/d	0	6
N intake	g/d	641	651
Milk N	g/d	188	228
Milk N efficiency	%	29,5	35
Total N excretion	g/d	547	487

Two treatments in the 2003 Noftsger and St-Pierre study are of interest: the high CP ration with a low digestibility RUP profile; and the low CP ration with a high digestibility RUP profile with added Met supplementation.

LoDRUP ration, the cows fed the LoCP/HiDRUP+Met ration produced more milk with higher milk components and with better nitrogen efficiency.

Reference: S Noftsger and NR St-Pierre (2003). "Supplementation of methionine and selection of highly digestible rumen undegradable protein to improve nitrogen efficiency." *Journal of Dairy Science* 86:958-969.

Study 3

The 2011 Chen *et al*. study evaluated performance responses and nitrogen utilisation when different combinations of absorbable Met were fed to lactating dairy cows in low CP diets. In the introduction, the authors state: "Met and Lys are considered the most limiting essential amino acid (AA) for the synthesis of milk and milk protein in the high-producing dairy cow (Schwab *et al*.; 1992, Rulquin *et al*., 1993).

Met often limits milk secretion in high-producing dairy cows when diets are formulated from typical North American ingredients, particularly when supplemental protein comes primarily from SBM. Hence, lactating cows often respond to post-ruminal Met supplementation with increased milk protein (MP) synthesis and secretion. Balancing rations with Met supplementation to improve the profile of essential AA in MP is fundamental to allowing the feeding of lower levels of dietary CP and RUP, maximising lactation performance and minimising N excretion."

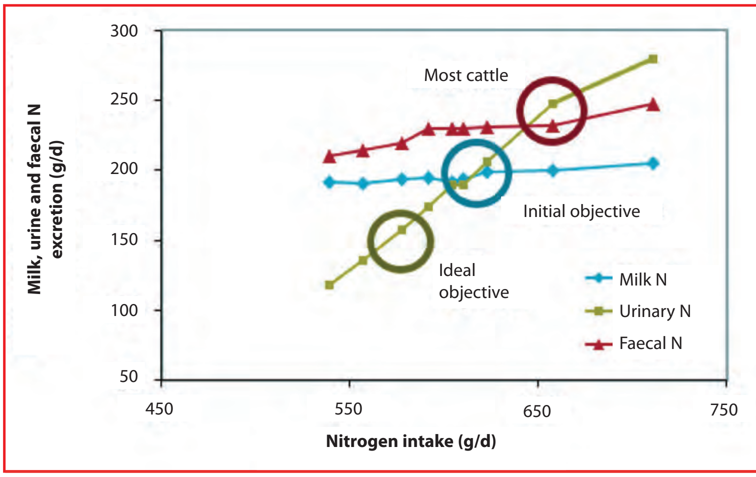
Three treatments in the 2011 Chen *et al*. study are of particular interest: the negative control (NC), rumen-protected methionine treatment (RPM) and positive control (PC).

In the conclusions, the authors state: "Over a 12-week feeding study, supplementation of lactating cows with HMBi or RPM (with or without HMB) increased yield of ECM, ECM/DMI and milk content of true protein and SNF, and resulted in trends for increased protein yield and milk fat content and yield.

Table 3: The effect of different treatments.

		Treatment		
Measurement	**Unit**	**NC**	**RPM**	**PC**
DMI	kg	24,9	24,6	24,7
Actual milk	kg	41,8	41,7	41,2
Milk protein	%	3,03	3,15	3,05
Butterfat	%	3,52	3,77	3,85
CP	% DM	15,6	15,6	16,8
NDF	% DM	26,7	26,7	28,7
NFC	% DM	46,8	46,8	43,6
Rumen-protected Met	zg/d	0	9	0
N intake	g/d	623	619	670
Milk N	g/d	199	213	201
Milk N efficiency	%	32	34,5	30,2
Total N excretion	g/d	347	337	365

Figure 1: Quality of nitrogen excreted in the faeces and urine (Source: Van Amburgh *et al.*, 2015, *Journal of Dairy Science*)



"Overall results from this experiment suggested that HMBi was comparable in effectiveness to the RPM source, in which Met was protected with a physical coating when fed to lactating dairy cows. These responses indicated that when either source of absorbed Met was added to a 15,6% CP diet, performance was equal to or better than that of cows fed a 16,8% CP diet, but with reduced N excretion and improved N utilisation."

Reference: ZH Chen, GA Broderick, ND Luchini, BK Sloan and E Devillard (2011). "Effect of feeding different sources of rumen-protected methionine on milk production and N-utilization in lactating dairy cows." *Journal of Dairy Science* 94:1978-1988.

Nitrogen excretion

These and other trials and field experience confirm that nitrogen excretion to the environment by lactating dairy cows can be reduced by lowering dietary CP levels and that it is possible to maintain or even improve animal performance when rumen-protected Met is added to moderate or low CP diets.

Lower CP rations not only reduce the amount of nitrogen excretion to the environment, but also impact how the cow excretes the nitrogen. Nitrogen consumed but not utilised for productive purposes (such as maintenance, production of milk, growth, reproduction, etc.) will be excreted into both the urine and faeces. As the intake of nitrogen is reduced, the quantity of nitrogen excreted in the faeces remains fairly constant while the quantity of nitrogen excreted in the urine tends to decrease (*Figure 1*).

Urinary urea is more volatile than the nitrogen contained in the faeces and can be rapidly converted to ammonia (NH_3), which is often lost to the atmosphere, soil or groundwater. Nitrogen excreted by dairy cows into the environment, especially through urine, contributes to increased levels of nitrous oxide (N_20) – a potent GHG.

Reducing nitrogen excretion by lactating dairy cows will improve the sustainability of our dairy farms. Supplementing Met and possibly other essential, limiting amino acids in conjunction with feeding lower CP diets can help maintain or even improve animal productivity. Finally, applying forward-thinking approaches to ration formulation can improve profitability such that the income over feed cost (IOFC) of a well-balanced low CP ration with rumen-protected Met can be greater than that of a conventionally balanced ration.

Ration simulation

To demonstrate this concept, a simulation was developed to show how a high-production ration from South Africa could be reformulated to reduce nitrogen excretion and improve IOFC by incorporating supplementation of rumen-protected amino acids (Met and Lys) to maintain or improve milk and component production.

Starting from a set of real rations fed to high-production groups of dairy cows on well-managed South African dairy farms, a representative diet that approximates the feeding rates and nutrient levels that are being provided to a typical herd was developed. This conventional ration was then reformulated to improve nitrogen efficiency and animal productivity in a profitable manner.

This simulation is meant to demonstrate these concepts and is not meant to represent any specific dairy farm or situation. The ration evaluation and reformulation were developed with the AMTS software program with the CNCPS v6.55 biology using library values for all feed ingredients and with estimated prices. A similar simulation could also be done with other effective models including the Dairy NRC (2001), INRA and others.

Results

The reformulated ration provides more energy than the conventional ration, with slightly more carbohydrates and lower levels of total ether extract and total unsaturated fatty acids. The predicted rumen pH of the reformulated ration is slightly higher than the conventional ration, suggesting that the reformulated ration would maintain rumen health.

Supplemental rumen-protected Met and Lys are included to both improve the Lys:Met ratio (to the ideal 2,69:1 for CNCPS version 6,55) and to increase the total supply of these limiting amino acids. The concentration of metabolisable Met in the reformulated ration is improved to 1,08g/Mcal of ME but is still below the current optimal target level of 1,19g/Mcal of ME. Because the energy supply and the amino acid balance are both improved, milk yield and milk components would be expected to increase above the basal level.

Table 4: Amount of ingredients used.

Ingredient (kg/head/day)	Conventional	Reformulated
Maize silage	9	9
Lucerne hay	3	3,65
Wet brewer's grain	2	2,30
Cottonseed	1,60	1,82
Ground maize	4,65	4,84
Soya bean hulls	0,25	–
Wheat bran	1,50	0,89
Molasses	0,80	1,20
Canola meal	0,80	–
Soya bean meal 48%	1,40	1,62
Bloodmeal	0,20	0,10
Urea	0,07	–
Calcium salt	0,20	–
Mineral and additive	0,53	0,53
Rumen-protected Met	–	0,012
Rumen-protected Lys	–	0,034
Total	26	26

Table 6: Nitrogen excretion and nitrogen efficiency predictions.

Factor	Unit	Conventional	Reformulated*
DMI	kg	26	26
CP	%	17,18	16
Nitrogen intake	g	715	666
Total N excretion	g	495	434
Faecal N	g	260	251
Urine N	g	235	183
Productive N: Total N		0,33:1	0,37:1
Productive N: Urinary N		0,99:1	1,34:1

**Values for the reformulated ration are based on the expected animal performance for milk yield and milk components.*

Table 7: Estimated economic results.

Factor	Unit	Conventional	Reformulated
DMI	kg	26	26
Ration cost	ZAR/hd	125,36	126,43
Expected milk	kg	43	44
Expected butterfat	%	3,8	3,9
Expected milk protein	%	3,15	3,25
Milk income	ZAR/hd	333,25	345,4
IOFC	ZAR/hd	207,89	218,97

Metabolisable Met and Lys are nonlinear nutrients; the supply available to the cow depends not only upon the concentration within the feedstuffs consumed, but also on the fermentation in the rumen which produces microbial protein. Factors that impact passage rate (such as feed intake or forage digestibility) or rumen pH (such as starch degradability) will change the microbial crude protein flow and thus the net supply of essential amino acids such as Met and Lys that are available to the cow at the small intestine.

Nonlinear optimisation is a mathematical process that allows finding an optimal solution to a problem that includes nonlinear constraints. In the context of ration formulation, this involves using a sophisticated software tool to rapidly evaluate options and identify better alternatives than might be possible by manual ration balancing.

Commercially available rumen-protected amino acids are expensive ingredients and adding them to dairy rations normally will increase ration cost. By utilising nonlinear optimisation, it is possible to minimise this cost impact. Nonlinear optimisation can help to maximise the supply of essential amino acids that are provided by the least expensive sources such as microbial crude protein and basal feeds such as canola and SBM. Nonlinear optimisation may also reduce bias for or against specific feed ingredients.

Finally, we must remember that nonlinear optimisation is simply a tool to help us perform a lot of math very quickly. At least for now, the computer cannot think and so the experience and judgement of the nutritionist who formulates the ration is still the key to success.

Table 5: Nutrient levels.

Nutrient	Unit	Conventional	Reformulated
DMI	kg	26	26
ME	Mcal	67,9	68,2
ME allowable milk	kg	44,5	45
MP allowable milk	kg	41,6	41,5
Forage	%	46,2	48,7
NDF	%	31,4	30.9
Forage NDF	%	18,5	19,4
Rumen pH (AMTS)		6,12	6,13
NFC	%	39,8	41,4
Starch	%	27,6	27,6
Fermentable starch	%	20,9	20,8
Sugar	%	5,3	6,4
EE	%	5,2	4,7
Total unsaturated	%	3,2	3
CP	%	17,2	16
MP	g	2,864	2,846
RDP	%	10,6	9,9
Rumen NH_3	% of req	154	136
Met	g	6,.5	73,6
Met:ME		0,92	1,08
Lys	g	188,6	198
Lys:Met		3,02:1	2,69:1

Conclusion

In this simulation, it was possible to develop a ration with a significantly improved amino acid balance that we would expect to support more milk with higher milk components with only a very minor cost increase. Even using very conservative estimates for the performance responses, the economics of this approach are very favourable.

The reformulated ratio will also improve sustainability due to reduced nitrogen excretion – especially urinary nitrogen. Higher milk volume, higher milk protein content, and a greater total milk protein yield coupled with a reduced nitrogen intake result in significantly better nitrogen efficiency. In this simulation, the ratio of productive N to urinary N increases from 0,99:1 to 1,34:1. It would not be unreasonable to expect comparable results in a real-world situation.

With our current knowledge, ration formulation tools and available commercial products, it is now possible to formulate dairy rations to reduce nitrogen excretion while simultaneously improving profitability for the dairy producer.

For enquiries, send an email to mike.shearing@adisseo.com or visit *www.adisseo.com*.

Precise, validated and actionable data is key to the improved sustainability of animal protein production

By Carlos M Saviani, global sustainability lead, dsm-firmenich

As the world's population grows, the demand for animal protein will continue to rise. To meet this demand sustainably, within planetary limits, will be a big challenge.

At dsm-firmenich we have been working for decades on food sustainability, especially with respect to animal proteins – it is the basis of our purpose. We strongly believe in balanced, healthy nutrition with animal proteins being a highly nutritious and key part of a balanced, healthy diet. However, like other forms of food production, livestock farming comes at a cost. This cost is increasingly evident and is highly nuanced depending on farming methods, geography and animal species.

Nevertheless, the sustainability of mainstream animal production is under increasing scrutiny from the value chain, policymakers and associated stakeholders. This means that continuing to operate as we have done in the past is not an option. All players involved in the production of animal protein need to be aware of the challenges we are facing.

We must work together to solve them – applying new thinking, new technologies and new business models in order to create a more sustainable industry – protecting the planet and being socially responsible and economically viable.

Global changemakers

We have seen several examples around the world showing that it is possible, that it can be done. From carbon-neutral beef produced in Brazil without any deforestation, to salmon produced in Norway with zero use of finite marine ingredients and helping to reduce pressure on our over-fished oceans.

From huge and very traditional poultry and pork operators embracing sustainability, measuring their impacts and setting up aggressive, publicly stated targets and actions, to the largest fast-food chain in the world making a public commitment to zero deforestation and revolutionising the relationship with their supply chain and civil society stakeholders to make it happen.

From a small farm in Swaziland producing eggs to improve the nutrition and health of thousands of orphan children in the country, to the largest grain traders and meatpackers in the world getting together to adopt a satellite monitoring system to monitor and reduce deforestation from happening in their supply chains in Brazil. Many initiatives and actions are unfolding as we speak, based on new approaches to business, greater collaboration through the value chain and the greater use of technologies.

Technology for sustainability

If the Third Agricultural Revolution, known as the Green Revolution, brought significant productivity improvements in agriculture, the Fourth Agricultural

Revolution must, through precision technology and digitalisation, bring equitable advances in the sustainability of agricultural production.

And the case for engaging all available technologies to improve the sustainability of animal protein production is an urgent priority given the estimates that animal farming accounts for 11 to 19% of all human-derived greenhouse gas (GHG) emissions – this is set to rise without systemic change to our food systems and farming practices. Feed alone is responsible for between 50 and 90% of the environmental footprints of animal proteins, similar to the weight it has on the cost of production.

Life cycle assessment

Making this change responsibly and with transparency requires accurate, credible environmental footprint measurement of animal production and it goes beyond GHG emissions to include nitrogen and phosphorus pollution, soil quality, the use of water resources, land use and impacts on biodiversity. It also requires the use of accurate and credible data that is based on validated life cycle assessment (LCA) processes, scrutinised by global regulators, retailers, consumers and financial institutions.

A well-run LCA qualifies, quantifies and pinpoints the environmental impacts along the animal protein value chain and allows for the evaluation of precise interventions to improve the farming process, reduce its environmental footprint, and make efficiency gains impacting the bottom line. Ultimately, it should enable operators, producers and integrators to look at multiple farm comparisons, with benchmarks, or targets, identifying best practices, areas for improvement and investment in a targeted way.

The good news is that there are publicly available LCA methodologies allowing for that to happen that are science-based and defined by well-respected multistakeholder initiatives such as the Food and Agriculture Organization of the United Nations Livestock Environmental Assessment and Performance (FAO LEAP), Intergovernmental Panel on Climate Change (IPCC), European Product Environmental Footprint (EUPEF), International Organization for Standardization (ISO) standards for LCA, ISO14040/44, the Agri-footprint database and the Global Feed LCA Institute (GFLI) database. There are even specific guidelines for carbon footprinting for dairy provided by the International Dairy Federation (IDF) and for beef provided by the Global Roundtable for Sustainable Beef (GRSB).

User-friendly LCA

However, these are very complex and sophisticated methodologies. Previously an LCA required external experts and was slow and expensive to produce results. The technology now exists in the form of a user-friendly, intelligent platform that has the functionality, speed and user independence to enable animal protein producers to improve their environmental impact.

In one platform, multiple 'what if' scenarios can be run instantly by operators to qualify and quantify the best technologies such as energy resources, manure and farm/emission management, as well as feed formulations and additives across multiple species, from dairy to aquaculture, to poultry, pork and beef. All industry stakeholders, be it ingredient suppliers, feed millers, producers, integrators, processors and retailers, can today view, understand and run footprint improvements before implementing and investing in changes at farm level.

But for primary, granular and actionable environmental footprints to be calculated, there is a key element needed: data. And in the case of animal proteins, mainly feed and farm data. Collaborative efforts to collect, anonymise, protect and share farm data will provide valuable insights and enable more informed decision-making.

Data is just one element

However, it is crucial to remember that data alone is not the solution; it is simply a necessary means to an end to generate insights, which can drive positive sustainability impacts across supply chains.

Accurately measuring and identifying the best methods for reducing the environmental footprints of feed and farm operations enables industry players to know and improve the sustainability of animal protein production, allowing them to:

- Take ownership of their footprint and not be judged on industry averages.
  - A paper published by the FAO Global Livestock Environmental Assessment Model (GLEAM), *GLEAM 2.0 – Assessment of GHG emissions and mitigation potential,* concluded that the estimation for mitigation is around 33%, or approximately 2,5 gigatonnes CO_2-eq, with respect to the baseline scenario.
- Reduce the environmental footprint and business risk while enhancing the resilience and profitability of animal production.
  - For example, the Gigaton initiative from Walmart and the World Wildlife Fund (WWF) is the first of its kind initiative that has the potential to mobilise its suppliers – the largest supply chain in the world – to avoid emitting one gigaton of carbon into the atmosphere by 2030.
- Engage their employees, creating a culture of purpose and sustainability in their business.
  - For example, in a recent Hewlett Packard workforce survey, 56% of respondents felt that ignoring sustainability in the workplace is as bad as ignoring diversity and inclusion. Forty percent said they would look for new jobs if their current employers did not engage in sustainable business practices and 39% said they would warn others of their company's poor sustainability practices.
- Elevate their company and product brand and demonstrate leadership in sustainability.
  - Leading salmon producer and co-operation partner Bakkafrost, based in the Faroe Islands, was the development partner for the Sustell™ salmon module and is one of the first to utilise Sustell™ to model and reduce the environmental footprint of their salmon farming operations.
- Improving product value via sustainably branded products, and meeting the needs of discerning consumers (higher price points and brand loyalty).
  - In a US Consumer Packaged Goods (CPG) study by the New York University Stern Center for Sustainable Business, Sustainable Market Share Index, July 2020, sustainability-marketed products delivered 54,7% of CPG value

growth (2015-19) despite being 16,1% of the category value, and they grew 7,1 times faster than conventionally marketed products.

- Access sustainability-linked finance with improved terms, increase the loyalty of their customers and improve the value of their products by improving the environmental, social and governance (ESG) ratings and benefitting from various financial instruments (low cost of debt, etc.), resulting in improved share and market value.
    - The Farm Animal Investment Risk and Return (FAIRR) initiative is a collaborative investor network that raises awareness of the ESG risks and opportunities brought on by intensive livestock production. Each year it releases a global assessment of the 60 largest meat, dairy and farmed fish producers on material ESG risks.
    - Globally, the average cost of capital for high ESG companies (6,16%) is -0,4%p lower than for low ESG companies (6,55%), reflecting lower risk (source: *www.msci.com/www/blog-posts/esg-and-the-cost-of-capital/01726513589*).
    - Over the last decade high ESG ratings led to higher valuations ('price to book value'): +0,4 price multiple to book value (source: *www.msci.com/www/blog-posts/esg-and-the-cost-of-capital/01726513589*).
    - Sustainable debt financing quintupled in the last three years to a volume of US$1 500 billion, 44% in manufacturing (source: *Bloomberg*).
- Access regulatory benefits and avoid penalties, continuing freedom to operate and compliance in an ever more stringent regulatory environment.
    - According to the World Bank there are 68 direct carbon pricing instruments operating as of June 2022 in 46 national jurisdictions around the world. These comprise 36 carbon tax regimes and 32 emissions trading systems.
- Allows investors and the broader financial community to make comparisons and modelling scenarios to evaluate opportunities for the environmental and economic sustainability of potential investments.
    - For example, Rabobank offers a price difference of up to 20 base points in some countries for sustainability-linked loans. Some banks consider providing higher interest rates for deposits depending on sustainability criteria.

While there is still a long way to go, there is a shared consensus that a sense of absolute urgency is necessary. The time has come to move beyond discussions and rhetoric and embark on taking meaningful action to scale. The time for action is now, and the industry – across the full value chain – must rise to the occasion to shape a sustainable future for food and agriculture. Sustainability is a journey, not a destination.

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The Buck Island case study: Is carbon-negative beef production on pasture possible?

By Laurentia van Rensburg, technical mineral manager, Alltech

The United States (US) beef industry is a major contributor to the global food system, with approximately 20% of global beef supplies produced within the US. Although the industry has made significant advances in reducing its environmental footprint, it still faces increasing pressure to reduce greenhouse gas (GHG) emissions.

According to the US Environmental Protection Agency's (EPA) GHG emissions inventory, only 2% of US emissions come directly from cattle and these include methane from cattle belches as well as methane and nitrous oxide from manure.

For the 2% of emissions attributed to beef cattle production, the cow-calf phase is considered responsible for approximately 70% of the GHG emissions within the beef value chain. As a result of improvements in genetics, nutrition and management practices, the US beef industry is considered a leader in production efficiency and has the lowest emission intensity per kilogram of beef produced.

However, in order to reach global sustainability goals and further offset emissions, cattle producers will need to become even more efficient and also consider grazing's impact on carbon sequestration as part of the complete environmental footprint.

Research from a multi-year collaboration between Alltech and the Archbold Biological Station, conducted at a Florida cow-calf operation and research facility called Buck Island Ranch, has shown that by focussing on production efficiencies, we can essentially produce more beef with the same resources. With proper land and pasture management, it is indeed possible for grazing cattle to sequester more nutrients back into the soil, reducing the operation's carbon footprint and enhancing pasture growth.

Improving production efficiency

Sustainability can be defined as meeting the growing global beef demand by balancing environmental responsibility, economic opportunity and social diligence throughout the supply chain. It comprises three very different yet intersecting pillars: social responsibility, economic viability and environmental stewardship.

Improving production efficiency and producing the same amount of beef with the same or fewer resources, boosts producer profitability and supports economic viability, and it can protect the environment in significant ways.

Reproductive efficiency can be defined as the proportion of cows eligible to be bred that become pregnant during an oestrous cycle. It determines the calving-to-conception interval and has the potential not only to improve farm profitability but to also lessen the environmental impact, since fewer cows need less land, feed and water and since fewer animals yield lower emissions. Weaning, or producing more kilograms per exposed female, can thus be considered one of the greatest opportunities not only to increase producer profitability, but to potentially reduce GHG emissions and the environmental footprint of the cow-calf operation as well.

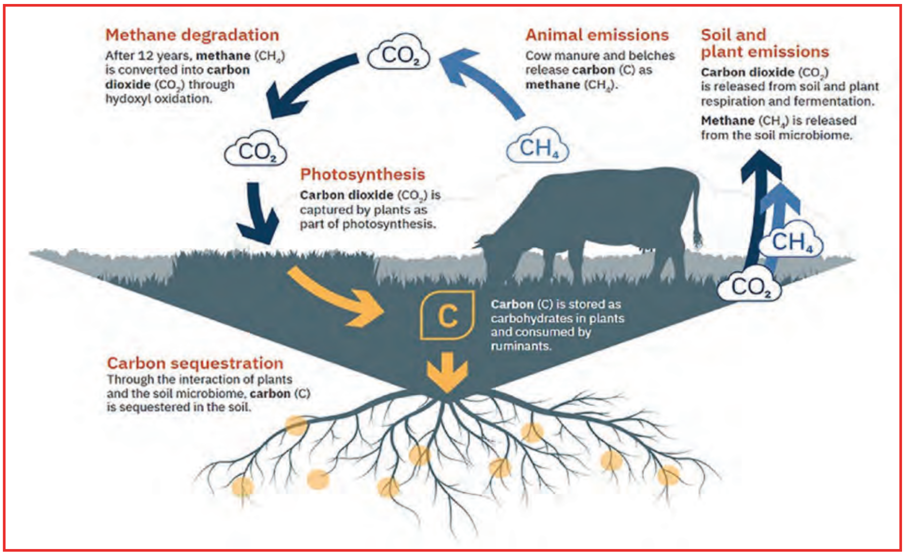
Nutritional issues, especially the trace mineral status of the cow, can directly affect her performance. Cows and heifers in suboptimal trace mineral status, for example, are less likely to cycle, become pregnant, maintain the pregnancy or successfully wean a healthy calf. Making incremental changes in pregnancy percentage and getting more cows bred earlier in the breeding cycle can thus yield more kilograms of beef produced.

Supplementation with organic trace minerals has been shown to reduce days to first service and lead to fewer days open, improved ovarian activity, decreased embryonic mortality and increased

Table 1: US greenhouse gas emissions sources and sinks (2017).

Item	Million metric tons of CO_2e	% of US total GHG emissions
Beef cattle	138,3	2%
Other animal ag	117,5	2%
Crop agriculture	286,3	4%
Agriculture total	542,1	8%
Transportation	1 800,6	28%
Electricity	1 732	27%
All other human-caused GHG emissions	2 382	37%
US total GHG emissions	6 456,7	100%
Land use, land use change, forestry	-714,1	
Agriculture, land use, land use change, forestry	**-172**	

Figure 1: The carbon cycle.



pregnancy rates. To assess the impact of nutritional strategies on performance and carbon intensity, cattle at Buck Island Ranch were supplemented with organic trace minerals (Blueprint® programme with Bioplex® and Sel-Plex® from Alltech) and the results were compared to a historical baseline of four years (2015 to 2018) when cattle were supplemented with a typical commercially available inorganic trace mineral programme.

Cattle supplemented with the Blueprint mineral programme showed an average improvement of 13% in pregnancy percentage and a 14% improvement in weaning rate. This improvement in production efficiency had a positive impact on carbon intensity as expressed by units of carbon dioxide equivalent per unit of live weight produced.

Carbon sequestration

Carbon sequestration refers to the long-term capture and storage of carbon from the atmosphere, typically in the form of carbon dioxide (CO_2). Enhancing biological carbon sequestration in soil and plants is a promising method of reducing GHG emissions and combatting climate change.

Rangelands account for a large portion of global carbon stocks and have a high potential for carbon sequestration if managed properly. Since domestic livestock grazes about 50% of the world's land surface area and given that these rangelands can account for up to one-third of global carbon stocks (above and below ground), it is imperative to understand how grazing impacts soil carbon stocks, which are considered indicators of climate regulation.

Subtropical, humid grasslands (as found in Florida, US, where Buck Island Ranch is located) are an important land use, supporting approximately 30% of the US beef herd. The Archbold and Alltech research collaboration at Buck Island Ranch strived to develop and understand various tools and models for measuring carbon pools associated with sequestration and carbon emissions.

Even though there was considerable variation over the years, driven by rainfall as well as pasture and cattle management practices, the data indicated that Buck Island Ranch is a net sink of GHGs (taking up more carbon than it emits) and that calves leaving Buck Island Ranch have a negative emission intensity. In this case, considering soil, plant and animal emissions, carbon was sequestered back into the soil through photosynthesis and the interactions of plants with the soil microbiome.

Carbon can be stored as carbohydrates in plants, which in turn are consumed by ruminants and turned into protein. It is generally accepted that the beef production system can be considered a net protein contributor – meaning that it produces more protein than it consumes – to the human-edible protein supply. In addition, beef is rich in many essential micronutrients, including zinc, iron, selenium and vitamins.

Balancing emissions

Emissions are the downside to cattle production, but this can be balanced against the positive impact grazing cattle can have:

- Utilisation of pasture or rangeland that might be unfit for crop production.
- Utilisation of byproducts from biofuel and other industries (distillers' grains, beet pulp) reducing the volume of waste going to landfills.
- Preservation of rangelands and wildlife habitats.
- Carbon sequestration.
- Economic benefits.
- Protein contribution.

It is evident that the beef cattle industry's carbon footprint is not solely determined by emissions and that more accurate measures and models for sequestration throughout all sectors of the beef supply chain are needed. Environmental life-cycle assessments can help provide key benchmarks on environmental contributions and the impact of the cattle industry, as well as help to identify potential areas for improvement.

Productivity is a powerful tool for improving the sustainability of food production, including beef, in the face of a growing population and increasing food demands. Nutritional strategies, including the utilisation of organic trace minerals and enzymes, can help to optimise health and performance, getting animals to perform as close to their genetic potential as possible.

Economic, social and environmental sustainability do not have to be mutually exclusive from one another. The industry can support all three by continuing to evaluate and implement practical solutions to improve on-farm efficiency, productivity and profitability for beef producers and the integrated beef supply chain.

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Matching field microbiota with feed and additives in poultry

By Dr Henk Enting, Dr Jean de Oliveira, Anne Goderis and Malhar Khambete, Cargill Animal Nutrition

The main effect of anti-microbial growth promoters (AGP) is through the modulation of microbiota composition and immune responses. With the reduction of the use of AGP, most of the research is focussed on how to shift the microbiota composition in the desired direction and, to a lesser extent, on how to influence immune function.

Due to the complex and diverse nature of microbiota composition, and potentially non-linear relationships between bacteria and factors influencing bacteria growth, it has been challenging to unravel microbiota function and composition, as well as understand how this affects bird performance and health. For that reason, most experimental trials focus on the effects of specific (potentially) pathogenic bacteria.

To get more insights into how microbiota composition may affect bird performance, a microbiota analysis platform based on a fluorescence microarray was developed, including pre-selected microbiota biomarkers that had been associated with birds with differences in performance and food safety. The bacteria biomarker probes cover different bacteria at the family, genus or individual species level found along the gastrointestinal tract of broiler chickens.

The biomarkers were validated in research trials with different feed compositions and samples from farms with different performance levels, and other differences in selected parameters such as footpad dermatitis, heat stress and pathogen challenge. Advanced statistics and non-linear artificial intelligence-based models helped to find relationships between microbiota composition and performance or other parameters such as *Salmonella* incidence. The biomarker list is updated over time to ensure it covers the most relevant microbiota composition and performance differences that were observed in the field, as well as other selected parameters.

Broiler trials and field studies

The described platform was used in a large number of broiler trials under research conditions and field studies on farms in different parts of the world. Trials included the effects of raw materials, nutrients such as dietary protein or fermentable crude protein, and feed additives on microbiota composition and performance.

In the broiler chicken trials, differences in feed composition were reflected in differences in microbiota composition and development.

Field studies also showed clear differences in microbiota composition between farms with differences in performance level or incidence of footpad dermatitis, for example. Data from commercial operations showed that deviations in microbiota maturation with age were associated with low performance. Good performing flocks have

Figure 1: Heat map of microbiota differences between good and less good (bad) performing farms at 14, 21 and 35 days of age.

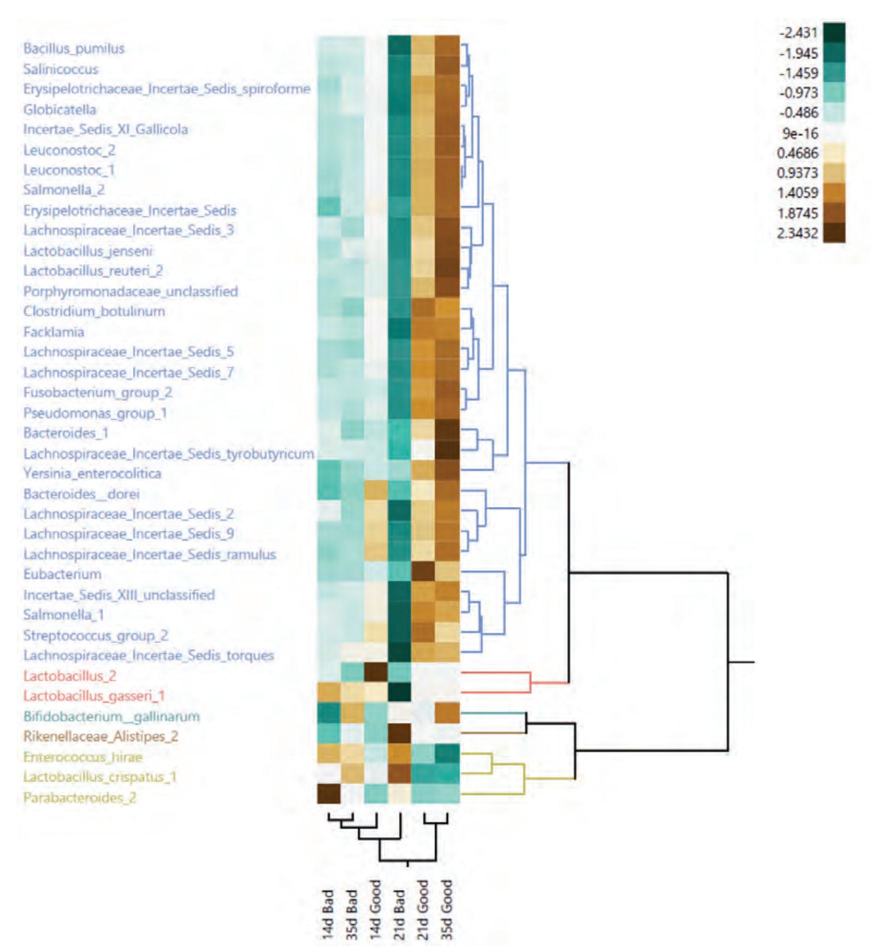
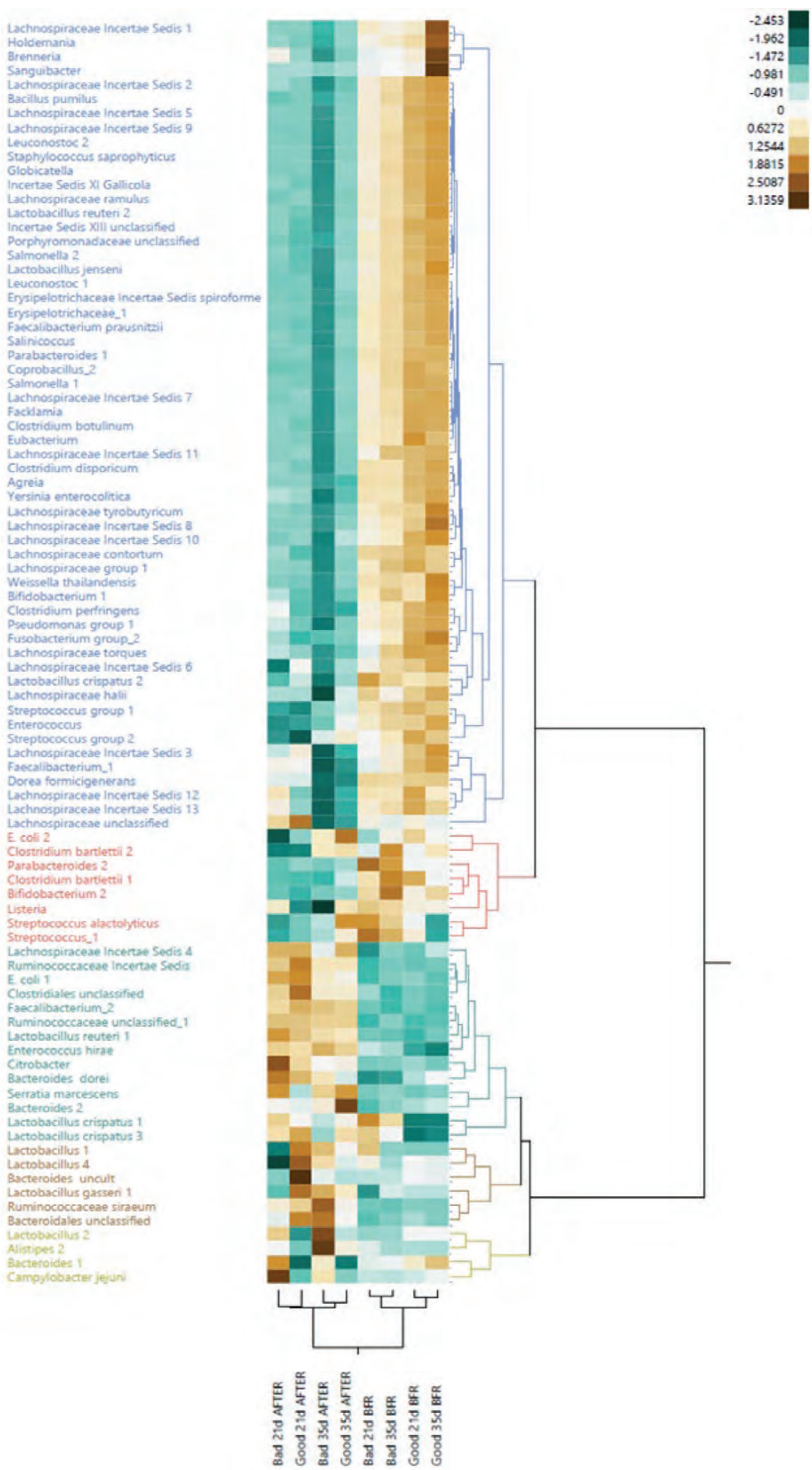


Figure 2: Heat map of microbiota differences between good and less good (bad) performing farms at 21 and 35 days of age, before (BFR) and after (AFTER) the introduction of new feed with the aim to change the microbiota composition.



a more stable microbiota at a younger age compared to low-performing flocks.

Over time, a database was constructed that included microbiota data and associated metadata from all research trials and field samples from different farms in different geographies. This database currently includes over 36 000 samples from 140 events, either research trials or field cases. The database can be used to estimate, for example, the effect of changes in feed composition, housing or disinfection procedures on microbiota composition and development, as well as bird performance.

Information regarding the microbiota composition of chickens that is obtained with specific feed or farm management conditions can be compared with results from samples in the database, after which recommendations can be derived on how to change the microbiota in the field – for example in modulating microbiota towards that found on farms with a good performance or a better microbiota maturation.

Results and discussion

In order to confirm to what extent information in the microbiota database could help design changes in feed composition or farm management procedures in order to change microbiota composition, several field studies have been performed. Comparisons usually include contrasts between top- and bottom-performing flocks, or other contrasts such as a high and low incidence of footpad dermatitis or high versus low prevalence of pathogenic bacteria.

As an example, a feed intervention study was designed for farms that had a relatively high feed conversion ratio and a high incidence of necrotic enteritis. The study included four farms: two performed relatively well, while the performance of the other two was lacking. Per farm, 24 cloaca swabs of individual chickens were taken at 14, 21 and 35 days and deposited in a solution that kills all organisms but preserves nucleic acids. The samples were analysed by Eurofins BioDiagnostics Inc (River Falls, Wisconsin, United States).

The relative intensity for each bacteria marker was submitted to ANOVA in a factorial arrangement with farm performance level, age and their interaction as fixed effects. Fluorescence readings were also used for hierarchical clustering analysis to group samples according to similarity in significantly different bacteria across performance levels and ages. Pairwise comparisons were made for each biomarker and differences were considered as significant by passing a false discovery rate test with P = 0,05.

Figure 1 presents a heat map of farm performance classes and ages grouped based on the similarity of the vertical clusters of bacteria of the first collection before any changes were made in the feed composition. Bacteria are horizontally grouped based on similarity. The different farms were grouped mainly together by performance class and to a lesser extent by age, which indicates that the maturation of the microbiota was not optimal; with good maturation, we observe that the results are grouped by age and then by other classes.

> The relatively large performance improvement might have been due to the high incidence of necrotic enteritis on both good and less good-performing farms.

The samples of different ages of the farms with lower performance clustered together, with the cluster of the good-performing farms at 14 days of age. These samples were showing a low abundance of the bacteria shown in the cluster in blue, which includes bacteria that are found in well-developed caeca such as *Lachnospiraceae*, *Bacteroides* and *Streptococcus*. However, this cluster was also high in pathogens such as *Salmonella*, *Clostridium botulinum* and *Yersinia enterocolitica*.

To improve the maturation of the microbiota and increase the bacteria present in well-developed caeca, a change in feed compositions was proposed by comparing the results of the analyses of the cloaca swab samples with the profile of feed ingredients, nutrients and feed additives in the microbiota database. The proposed changes included a reduction of dietary protein levels in the pre-starter and starter phases (1 and 0,5% respectively), the inclusion of a pre-biotic in the pre-starter feed and a change in feed additives in the grower and finisher phase.

The recommended feed additives based on the microbiota profile involved a mix of medium-chain fatty acids, butyrate and essential oils. After the new feed was applied, a new round of swabs was taken on days 21 and 35 at the same farms, and the samples were analysed for microbiota composition as done in the first collection.

Figure 2 provides the change in microbiota on the farms on which cloaca swab samples were taken for the assessment of the microbiota. The samples were clustered clearly by round (before and after the changes in feed composition), which indicates there was a clear change in microbiota composition. In addition, the samples were now clustered by age rather than by farm performance, indicating that the maturation of the microbiota had improved.

Main differences in the microbiota composition before and after the diet changes were observed in cluster one (blue), which decreased after the diet change. This cluster included most pathogenic bacteria, such as *Salmonella*, *Clostridium perfringens*, *C. botulinum*, *Enterococcus*, *Staphylococcus* and *Y. enterocolitica*. Clusters three (dark green) and four (brown) increased after the diet change and these clusters included *Faecalibacterium*, *Ruminococcus* and *Lactobacillus crispatus*.

The change in microbiota composition after the introduction of the new feed was in line with the projected changes based on the microbiota that was found in earlier studies on which the diet changes were applied. These results indicate that it is possible to modulate the microbiota in field conditions by making changes in diet composition.

The improved maturation profile of the microbiota, as well as the overall changes in microbiota composition that moved towards the microbiota that is associated with good performance according to the microbiota database also resulted in improved performance of the farms; average final bodyweight across all farms increased from 2,884 to 3,140g and feed conversion ratio improved from 2,039 to 1,976.

The relatively large performance improvement might have been due to the high incidence of necrotic enteritis on both good and less good-performing farms. The expectation is that the difference in performance between top and bottom-performing farms would get smaller after the diet change was not met; further work is ongoing to reduce this gap.

For more information and references, email henk_enting@cargill.com or visit *www.cargill.com*.

Why gut health matters for sustainable young animal production

By Dr Jessika van Leeuwen, global category manager swine, Hamlet Protein

Gut health is key for optimal profitability in animal production. However, under modern production conditions, farm animals are continuously exposed to various stressors, including high stocking densities, feed changes, temperature extremes and pathogenic pressure.

A properly functioning immune response is necessary to cope with such stressors and/or to eliminate it from the body. These defence mechanisms can be costly to performance resulting in the partitioning of nutrients away from performance to support the immune system. This is due to the inflammatory response that is activated when the immune system is triggered.

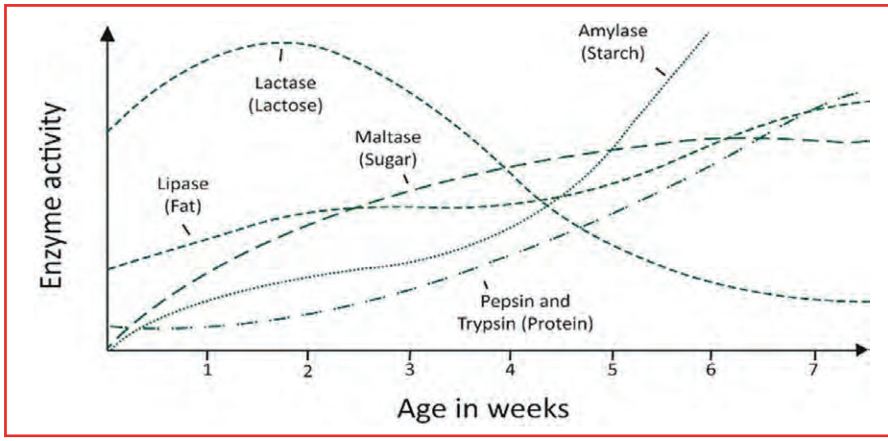
Nutritional requirements

Young and growing animals differ largely from mature animals when it comes to their nutritional requirements. Young animals mature and develop at a fast pace, gaining muscle and growing bones while their brains and nervous systems also develop. This requires a high concentration of nutrients, specifically protein and calcium.

In addition, the nutrition of young animals requires special attention when it comes to gut health as the digestive tract of young animals cannot digest protein as well as that of developed animals due to limited enzyme production (for piglets, see *Figure 1*). Furthermore, the amino acid requirement of young animals is higher per energy unit than during later growth stages, resulting in a higher concentration of protein in young animal diets.

One factor behind this relatively high protein requirement in young animals is hypertrophy, the fact that organs and muscle growth in young animals is high relative to e.g., fat growth, which requires more protein. For example, the intestinal tract of a weaned piglet grows from 4m around weaning to 15m at 11 weeks of age; this equals roughly 14cm per day.

Figure 1: Enzyme activity increases with age in piglets.



In order to meet these extraordinary growth demands, high levels of protein sources are included in pig diets resulting in expensive (high-quality) diets. The most cost-beneficial protein source for pig diets is beyond a doubt soya, because of its balanced amino acid profile.

However, raw unprocessed soya naturally contains so-called anti-nutritional factors (ANFs) that serve the crop as protection against mould, bacteria and consumption by wild animals. The ANFs can be grouped according to their effect on the nutritive values of feed ingredients and biological responses in animals. The three most important soya ANFs for piglets are trypsin inhibitors (TIA), alpha-galactose-oligosaccharides (αGOS) stachyose and raffinose and beta-conglycinin.

Influences of ANFs

The presence of certain TIA reduces the digestibility of protein. Consequently, undigested protein ends up in the hindgut to be fermented by potentially pathogenic bacteria. As a result of this process, toxins are produced that impair the integrity and functioning of the intestinal membrane and activate the immune system.

The galacto-oligosaccharides stachyose and raffinose alter gut morphology and trigger gas formation and osmotic diarrhoea.

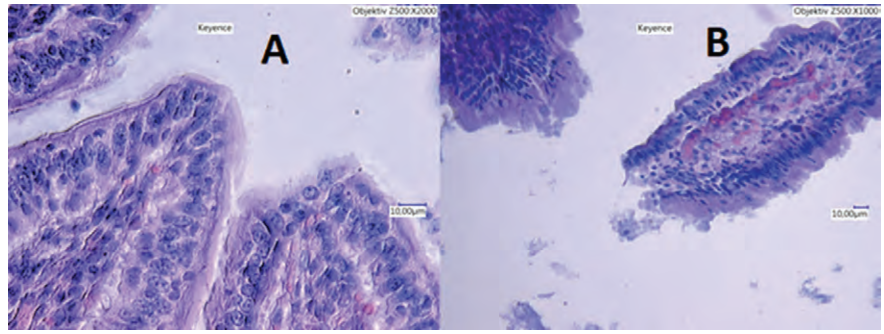
Beta-conglycinin is an antigen and triggers a direct inflammatory response in the gut leading to chronic inflammation. This reduces the absorption capacity and increases nutritional requirements for maintenance to sustain the inflammatory response. So, fewer nutrients are available for the growth and performance of the animals. Feeding diets high in soya ANF's therefore have a detrimental effect on the growth performance of young animals. Reducing inflammation in the gut through the reduction of ANFs in the diet is a good strategy to maximise performance in a sustainable way.

To understand to what extent ANFs affect the performance of piglets, we conducted a meta-analysis (n=17) investigating the effect of partial replacement of soya that has high ANF levels with an enzyme-treated soya bean meal low in ANFs (ESBM; HP 300 from Hamlet protein) in nursery diets the first two weeks postweaning.

Because all trials used similar response measurements, the comparisons were done based on the difference in the mean response (mean difference, MD) for the control and HP 300 groups. An overall effect was calculated by weighing the individual MD by the inverse variance of the trial from which it was determined. In other words, results from trials with less variation are given greater importance in the overall comparison. Forest plots were used to visualise the results of the meta-analysis.

The random effects model was often the best fit for the data due to the high variation observed between trials. Results show that replacing all or part of ANFs from SBM improves piglet growth by 6% (P<0,01) and feed efficiency by up to three points, likely to be caused by a higher digestibility and efficiency of the protein as our previous research has shown an increase in nitrogen retention of 4% for broilers and 5% for piglets when ANFs were partially or completely removed, respectively.

Figure 2: Electron microscopy of the gut mucus layer of piglets fed A: with a diet with reduced ANF content (enzymatically processed soya bean meal, ESBM – HP 300) and B: with conventional soya bean meal. Clear damage is visible in picture B. (Pictures: Hamlet Protein A/S)



Conclusion

In the current situation of extremely high feed costs, it is recommended to have a careful look at the complexity of nursery diets, starting with highly digestible good quality protein ingredients low in ANFs. The results of this study show that nutrition plays a key role in driving sustainability in animal production.

Optimising diets for low ANF reduces the pressure on the immune system and therefore impacts FCR and protein efficiency. This results in a reduction of the total amount of feed fed, which reduces the land needed to grow ingredients on. An improved protein efficiency shows we can produce more with the same amount of protein and reduce nitrogen excretion into the environment.

For more information, send an email to jle@hamletprotein.com or visit *www.hamletprotein.com*.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Nutritional strategies: Meeting requirements of companion animals with trace mineral supplementation throughout all life phases

By Steve Elliott, global director, mineral and equine divisions, Alltech

Along with growing awareness regarding our health and wellness, there also seems to be a deepened interest in improving the overall health and longevity of our pets. With pets living longer and a large percentage of pets classified as geriatric, it comes as no surprise to see a rise in associated health issues, including osteoarthritis, diabetes, heart disease, hypertension, certain types of cancers and cognitive decline.

While the immune system undergoes many changes from developing and maturing in young animals to gradually declining in old age, a requirement for an adequate supply of micronutrients to support and optimise immune function remains consistent throughout.

Micronutrients, such as vitamins and trace minerals, are essential for healthy growth and development but are required only in very small amounts. Vitamins (including A, D and E) are required to sustain a wide range of metabolic functions, whereas trace minerals (including copper, zinc, manganese, iron and selenium) serve many physiological functions (*Table 1*).

Micronutrient requirements

Micronutrients are integral to a pet's immune function, and this highly complex and integrated immune system requires an ongoing supply of these key dietary components. These essential nutrients often work in synergy, and it is important to have a balance throughout all life stages. An oversupply of a single micronutrient cannot compensate for a deficiency in another.

Often, micronutrient requirements, especially when it comes to trace minerals, are based on maintenance or growth studies. However, we know that requirements for optimal immune response when challenged may be higher, emphasising the need to supply these essential nutrients in the most bioavailable form. Bioavailability is an inherent property of a molecule resulting from its chemical composition, which influences how it is processed in the body.

Efficacy *in vivo* can be affected by many factors, including trace mineral form. Trace minerals can be supplemented in either an inorganic form (oxides, sulphates, chlorides) or organic form. Inorganic trace minerals (IOTMs) are unstable across the gastrointestinal tract and often dissociate before reaching the small intestine. This renders them susceptible to interaction with other minerals and compounds, which reduces the chance of absorption.

Organic trace minerals

Organic trace minerals (OTMs) are far superior. The process of creating them by complexing or chelating elements such as copper or zinc typically involves reacting inorganic mineral salts with a suitable bonding group, such as a peptide or amino acid, after which the mineral becomes part of a biologically stable structure.

Today, several production processes are in use to manufacture OTMs that can be made available to the market. Although OTMs are widely recognised as being more stable and bioavailable than IOTMs, they fall under several different categories of classification based on the production process and bonding group used.

Table 1: Metabolic role of key trace minerals.

Mineral	Role of trace mineral
Iron	• Constituent of haemoglobin and myoglobin for oxygen transport and cellular use. • Component of enzyme systems involved in oxidation reduction (redox). • Enzyme function for immunity and metabolism. • Mother-offspring transfer.
Copper	• Component of enzyme systems involved in redox reactions and energy metabolism. • Key factor in the development of collagen, bone and connective tissue, skeletal development and hair pigment.
Zinc	• Essential component of 200+ enzyme systems. • Major role in the immune system, wound/tissue repair, growth and reproduction. • Critical in skin, bone and hair development.
Manganese	• Activator of enzyme system in the metabolism of carbohydrates, fats, proteins and nucleic acid. • Plays a role in the brain, collagen, nervous system and bone development.
Selenium	• Critical in enzyme function for immunity, antioxidants and reproduction. • Maintains normal functioning of the thyroid gland.


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Table 2: Official terminology for organic trace minerals by the Association of American Feed Control Officials (AAFCO) and the European Food Safety Authority (EFSA).

AAFCO		EFSA	
Metal proteinate (57.23)	The product resulting from the chelation of a soluble salt with amino acids and/or partially hydrolysed protein.	**Metal chelate of protein hydrolysates**	A powder with a minimum content of x% metal where x = 10% copper, iron, manganese and zinc. Minimum of 50% copper, iron, manganese and 85% zinc chelated.
Metal amino acid chelate (57.142)	The product resulting from the reaction of a metal ion from a soluble metal salt with amino acids.	**Metal chelate of amino acids hydrate**	Metal amino acid complex where the metal and the amino acids derived from soya protein are chelated via co-ordinated covalent bonds.
Metal amino acid complex (57.150)	The product resulting from complexing a soluble metal salt with an amino acid(s).	**Metal chelate of glycine hydrate (liquid)**	A liquid with a minimum content of 6% copper or 7% zinc.
Metal (specific amino acid) complex (57.151)	The product resulting from complexing a soluble metal salt with a specific amino acid.	**Metal chelate of glycine hydrate (solid)**	A powder with a minimum content of 15% copper, iron, zinc and manganese.

These differences will impact not only overall stability but *in vivo* efficacy.

OTMs can support stability in feed as well. According to a 2006 report by the National Research Council (NRC), the inactivation of almost all vitamins, which occurs in the preparation of extruded and canned food, is directly related to the temperature and duration of the processes and the presence of free metals. Having minerals in less reactive forms (organic chelates and proteinates) can thus decrease the loss of many vitamins compared to when minerals are present as sulphates or free metals.

Table 2 outlines the most common OTMs fed to animals, as defined by the Association of American Feed Control Officials (AAFCO, 1998). In comparison, *Table 2* gives an overview of the European Union classification definitions, which demonstrate the difficulties of assessing nutritional products using regulatory terminology.

The stability of trace minerals in companion animal premix or complete feed is critical in maintaining vitamin potency. Several studies have shown that trace mineral form and inclusion rate can impact not only the degradation of several essential vitamins but in-feed antioxidants and enzymes as well, which can have a direct impact on overall feed quality and ongoing animal health and performance.

A recent study (Byrne *et al*., 2021) analysed a range of commercially available organic copper sources to determine the *in vivo* stability over a range of pH conditions. In this work, samples were assessed for the percentage of bound copper after exposure over a pH range of three to eight. This confirmed that commercial OTMs vary considerably in their pH-dependent stability.

Another important aspect of OTMs is that – because they better represent the form of minerals in the animal's natural diet – they are assimilated and retained by target tissues much more readily than IOTMs. As a result of this increased bioavailability compared with IOTMs, organic sources may be supplemented at lower levels. This lower-level supplementation programme can be carried out without harming immunity, health and performance.

In recent companion animal studies, the use of proteinated OTMs and organic selenium yeast has supported and promoted better trace mineral status, bone mineral density, and growth and immune measures in both cats and dogs. Certain trace minerals, including selenium, are considered important antioxidants.

Oxidative stress and antioxidants

Many of the most common diseases associated with ageing (cognitive decline, atherosclerosis, osteoporosis and diabetes) are related to low-grade inflammation, and oxidative stress has a role in inflammaging, emphasising the role of oxidative stress in the complex mechanism of ageing. Immune cells, which contain high levels of polyunsaturated fatty acids (PUFAS) in their plasma membranes, are thus highly sensitive to changes in the oxidant-antioxidant balance and an imbalance can result in cell and tissue damage.

Since antioxidants can help minimise free radical formation and oxidative stress, they are often considered an important part of an 'immuno-nutrition' strategy to help prevent and manage age-related health issues. Nutritional strategies to slow the pro-inflammatory state, including supplementation with OTMs (as proteinates and selenium yeast), can thus be considered an important and viable strategy to aid in immune function and promote longevity in companion animals of all ages and life stages.

Conclusion

Immuno-nutrients will continue to be part of a targeted nutritional approach as our understanding of both the function and overall dietary effects of trace mineral supplementation evolves. When considering the overall health and longevity of our pets and selecting micronutrients, it is important to look for product-specific research and validation.

Consideration must be given to the bioavailability and stability of such nutrients, and efforts must be made to choose forms that reduce potential losses to other dietary components. Doing so will ensure optimal nutrition and health, which will have positive effects on our pets as they grow and enter old age.

For more information, email Steve Elliott at selliott@Alltech.com or visit *www.alltech.com*.

The influence of diet and feed additives on the rumen microbiome

By Dr Ida Linde, research scientist, Envarto

A few decades ago, micro-organisms were viewed negatively, and all micro-organisms were seen as potentially pathogenic. However, as research started to delve into the functions of the micro-organisms found in living organisms such as humans and livestock, it was observed how essential their functions are to ensuring a healthy organism. This is especially true for ruminants.

Ruminants do not have the ability to degrade complex carbohydrates; this ability is the responsibility of the micro-organisms found within the rumen. Through fermentation, these micro-organisms produce approximately 70% of available energy in the form of volatile fatty acids (VFA), which the ruminant uses for maintenance and production (Bergman *et al*., 1990). Fermentation products in the rumen include VFAs, predominantly propionate, butyrate and acetate, as well as microbial proteins while methane is produced as a by-product.

Furthermore, microbial protein supplies 60 to 85% of the amino acids available in the small intestine of ruminants for digestion and absorption (Hackmann and Firkins, 2015). The composition, diversity and richness of the rumen microbiome determine the proportion and amount of fermentation products produced.

The rumen microbiota consists of bacteria, protozoa, fungi, archaea and viruses. These micro-organisms can produce amylolytic, cellulolytic, hemicellulolytic, lipolytic and proteolytic enzymes that degrade starch, fibre, fat and protein. Bacteria are the most abundant (50 to 70%) micro-organisms in the rumen microbiome with 10^{10} to 10^{11} CFU/g of rumen content (Newbold and Ramos-Morales, 2020).

Bacteroidetes and Firmicutes followed by Proteobacteria are the most abundant phyla (Henderson *et al*., 2015). A higher abundance of Bacteroidetes with a lower abundance of Firmicutes in the rumen has been reported to be correlated with improved feed efficiency (Delgado *et al*., 2019).

Archaea (methanogens) use the excess H_2 produced from the fermentation process to produce methane as a by-product. Certain pathways, such as the production of acetate, result in the release of H_2 that can become toxic to the animal if not utilised, while other pathways, such as propionate production does not produce H_2. The production of methane uses energy, approximately 2 to 12%, that could theoretically have been used for maintenance or production (Matthews *et al*., 2019). Fungi, protozoa and archaea degrade plant cell walls and lignin into smaller fragments with larger surface areas which bacteria degrade further (Edwards *et al*., 2008).

Viruses are probably the least studied of the rumen microbiota due to various challenges involved in their sequencing. Their presence within the rumen microbiome has an impact on substrate availability, nutrient cycling, and genetic exchanges through horizontal gene transfer with the other micro-organisms (Flint *et al*., 2000).

Effect of diet on the microbiome

The rumen microbiome can be affected by various factors: birth process, genetic makeup as well as the environment. However, for the rumen microbiome, the biggest influence is the diet the animal receives. This includes the composition of the diet, raw materials as well as any additional feed additives included in the diet. The forage-to-concentrate ratio is one of the aspects that influences the rumen microbiome the most, causing a shift in the rumen composition.

Cattle fed a predominantly forage diet have a higher diversity of bacteria and fungi within the rumen microbiome compared to those fed a predominantly starch diet (Belanche *et al*., 2012). This is because roughage-based diets are less acidic compared to predominantly starch diets, which results in micro-organisms growing faster and generating more cellulosic and heteropolysaccharide substrates.

> A balance between a more efficient microbiome and a healthy microbiome needs to be established for optimal functionality.

In concentrate-based diets, such as feedlot diets, the pH within the rumen decreases due to the excessive amount of fermentable carbohydrates that are converted to VFAs (Neubauer *et al*., 2020). Most starch-degrading microbes produce propionate, leading to more energy being available to the animal for improved production (Chen *et al*., 2021). However, when the pH decreases too far this can result in acidosis leading to dysbiosis, decreasing the bacterial diversity, and ultimately affecting the animal negatively (Belanche *et al*., 2012; Zhang *et al*., 2017).

The risk of dysbiosis is much higher in predominantly concentrate-based diets since there are fewer microbes and subsequently more substrates available to pathogenic micro-organisms for growth. A balance between a more efficient microbiome and a healthy microbiome needs to be established for optimal functionality.

Effect of feed additives

Feed additives are commonly used in ruminant diets to promote the health of the animal, increase its production, or decrease the production of methane. Ionophores are used as antibiotic growth promoters that are included in the feed of animals. The mode of action of ionophores is still being researched as the earlier thought that they only target gram-positive bacteria is lacking as more recent studies have reported that they also inhibit gram-negative bacteria.

In-feed antibiotics can decrease the diversity of pathogenic as well as commensal micro-organisms in the rumen and lower gastrointestinal tract. Although ionophores have been reported to increase the growth and feed efficiency of animals, studies have reported a decrease in the effect of ionophores on the performance of the animals from previous years; this can partially be due to the higher concentrate inclusion in the diets (Duffield *et al*., 2012).

However, the possibility exists that the rumen micro-organisms became adapted to the use of ionophores. The use of antibiotics and in-feed antibiotics has resulted in the abundance of antimicrobial-resistant microbes in the livestock production environment (Matthews *et al*., 2019), which is a threat to both animals and humans.

Inclusion of probiotics

Probiotics have been reported to improve the health of the animal when administered at adequate levels (Hill *et al*., 2014). The increase in the diversity and richness of the microbiome due to probiotic supplementation can lead to a stable resilient microbial population. One of the modes of action of probiotics is to compete against pathogenic bacteria for substrates and binding sites, while another is to aid in nutrient digestion due to the production of enzymes (Michalak *et al*., 2021).

Probiotics containing lactic acid bacteria, such as *Lactobacillus*, *Streptococci* and *Bifidobacterium*, as well as *Propionibacterium*, *Enterococcus*, spore-forming *Bacillus*, the yeast *Saccharomyces* and the fungi *Aspergillus*, are the most commonly used (Kulkarni *et al*., 2022). Yeast-based probiotics can promote the growth of bacteria within the rumen through the creation of an anaerobic environment which is favoured by lactate-utilising and fibrolytic bacteria (Newbold *et al*., 1996).

Different species of microbes have different effects on the microbiome, however different strains of the same species will also have different effects. One strain of a species will aid in the digestibility of feedstuff, while another of the same species can have an improved effect on the immunity of the animal.

A study by Wu *et al*. (2021) investigating the effect of a multi-species probiotic in newborn calves reported that the average daily gain of the calves that received the probiotic was higher with fewer incidences of diarrhoea. This might be due to the higher abundance of *Ruminococcaceae* and *Bifidobacterium*, which are fibre-degrading and play a role in the immunity of the animal.

In a study investigating the effect of a *Bacillus* probiotic on the rumen microbiome of feedlot cattle, it was reported that the animals receiving the probiotic had a lower abundance of Proteobacteria compared to those receiving no additive within the finisher period (Linde *et al*., 2022). A high abundance of Proteobacteria has been linked to dysbiosis as some bacteria belonging to the Proteobacteria phyla have pathogenic characteristics (Auffret *et al*., 2017).

Secondary metabolites

Plant secondary metabolites, such as essential oils, tannins, flavonoids and saponins, are feed additives that have been reported to affect the production performance and rumen microbiome. Due to the fact that plant secondary metabolites are derived from plants and different parts of plants, a wide variety of active compounds exist, each with different characteristics and effects on the rumen microbiome.

Essential oils have anti-inflammatory, antimicrobial and antioxidant characteristics (Ku-Vera *et al*., 2020). Some essential oils have been reported to have the same mode of action such as ionophores in that they are more effective against gram-positive bacteria than gram-negative bacteria. This results in an increase in propionate-producing micro-organisms and a decrease in acetate-producing micro-organisms. The supplementation of carnosic acid and carvacrol essential oils has been reported to decrease the acetate concentration while increasing the propionate concentration (Torres *et al*., 2020).

Ku-Vera *et al*. (2020) reported that the supplementation of essential oils can have a decreasing effect on methane emissions by impairing the energy metabolism of methanogens. Supplementation of rosemary extract to high-producing dairy cows resulted in an increase in milk yield, protein and lactose percentage (Kong *et al*., 2022). The study also reported a lower diversity that has been linked to higher production parameters and increased VFA production (Li *et al*., 2017). The use of essential oils is dose-dependent; only certain doses can elicit the response needed and some studies have reported the adaptation of the rumen microbiome to essential oils in the long term (Torres *et al*., 2020).

Conclusion

The goal of feeding livestock should be to ensure that the animal produces as efficiently as possible while maintaining its health. It is therefore imperative that the effect of nutrition and feed additives be explored on the rumen microbiome as the rumen and small intestine microbiome play important roles in the production and health of the animal. Knowledge of this interaction can result in precision nutrition strategies that ensure that the microbiome remains in balance and the efficiency of production and the health of the animal increases.

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Branched-chain volatile fatty acids: The new frontier in dairy nutrition

By Dr Dana Tomlinson, global technical services, Zinpro Corporation

Across the globe, dairy producers face volatile market pressures and rising feed costs, with pressure to address nutrient waste and emissions. The goal is to improve dairy cow performance, efficiency, and profitability. Feed costs comprise approximately 60% or more of dairy operating costs, so it is no surprise that dairy producers and nutritionists focus on ways to control input costs while striving to maintain production efficiency.

Protein supplementation tends to be the most expensive component in a typical dairy ration. Unfortunately, dairy cattle are not efficient at converting feed nitrogen to milk and metabolisable protein, averaging only approximately 24% (range: 14 to 41%) across 1 737 North American and European research diets. The aim is therefore to optimise digestion and utilisation of feedstuffs in the rumen to maximise yield of microbial protein and capture energy for production of milk and/or partition to growth.

The role of BCVFA

Rumen fibre-digesting bacteria require branched-chain volatile fatty acids (BCVFA, also known as isoacids) to digest fibrous feedstuffs. These BCVFA, which are essential nutrients, act as carbon sources to be utilised with highly digestible protein to produce much-needed microbial protein and energy. This is a primary source of key amino acids and BCVFA needed for production of milk by the mammary gland.

Normally, fibre-digesting bacteria in the rumen receive BCVFA through digestion (proteolysis) of rumen-degradable protein (RDP). Typically, fibre-digesting bacteria must rely upon amylolytic, or starch- and sugar-digesting, bacteria to complete proteolysis – the protein breakdown process to release branched-chain amino acids (BCAA) and, ultimately, BCVFA.

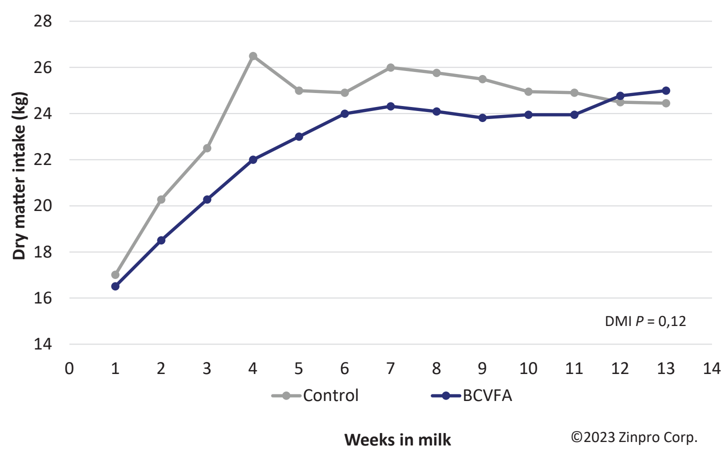
BCVFA are formed when the BCAA, leucine, isoleucine, and valine, contained in feedstuffs high in RDP, such as soya bean, rapeseed, cottonseed, or sunflower meals, are degraded in the rumen. Unfortunately, amylolytic bacteria can out-compete fibre digesters for the BCVFA being released, and, under certain dietary conditions, there may simply not be enough BCVFA produced to meet the requirements of the fibre-digesting bacteria.

An insufficient supply of BCVFA is problematic, as fibre-digesting bacteria not only use BCVFA to synthesise microbial protein, but they are also key to the formation of branched-chain long-chain fatty acids utilised in their cellular membranes. These fatty acids help give the bacteria cellular fluidity and are essential to their survival within the harsh rumen environment.

Production of BCVFA is an inefficient process as it requires a significant supply of expensive RDP and, when feed passage rates are high – as often observed in high-producing cows (with higher intake) – much of the RDP is not available to the rumen bacteria due to shorter rumen residence time. Failure to provide an adequate supply of BCVFA may reduce microbial protein yield and fibre digestion, since limiting the availability of BCVFA will also limit the growth of the fibre digesters. This ultimately results in poor nitrogen efficiency, inadequate microbial protein production, and poorer utilisation of forage.

Direct supplementation with BCVFA, versus relying solely on RDP, is beneficial. Fibre-digesting bacteria utilise BCVFA more efficiently than RDP or BCAA. BCVFA improve microbial yield and fibre digestion (measured by neutral detergent fibre, or NDF, digestibility), resulting in improved performance, especially when ruminal starch degradability is high. Improvements in microbial protein yield may also provide an opportunity to reduce dietary crude protein (CP) while

Figure 1: Dry matter intake (DMI) of multiparous cows over the first 13 weeks of lactation.



maintaining performance. Responses to BCVFA appear best when RDP is limiting (<10,2% 'true' RDP, i.e. RDP minus urea or readily soluble protein fractions).

The research background

Multiple studies have shown the positive benefits of supplementing lactating dairy cattle diets with BCVFA. A summary of ten controlled studies showed that BCVFA supplementation increased the yield of energy-corrected milk (ECM) and feed efficiency by 3,9 and 4,6%, respectively.

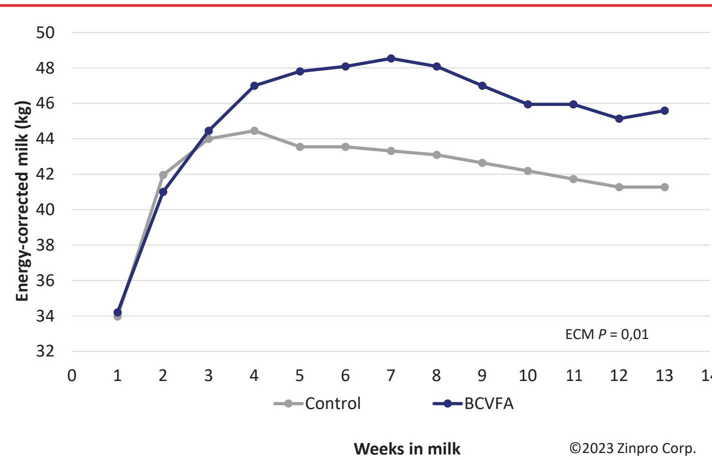
Research conducted at a private research institute in Europe showed decreased dry matter intake (DMI), increased ECM, and improved feed efficiency. Beginning 27 days pre-calving through 90 days in milk, treated cows (BCVFA group) were supplemented with a proprietary mix of BCVFA, while cows in the control group received the same diet without the addition of BCVFA. Dry cows received a diet containing 12,3% CP, while lactating cows received a diet containing 15,4% CP.

Multiparous cows fed the BCVFA mix had numerically lower DMI (*Figure 1*), and higher milk yield, fat percentage, protein yield, and ECM (*Figure 2*) than cows in the control group. This study also showed improved energetic status among multiparous cows receiving BCVFA. While eating less and milking more, cows receiving BCVFA were better able to maintain bodyweight (BW) in early lactation versus unsupplemented control cows (1,2% BW loss versus 3,4% BW loss, respectively).

These findings are supported by observational results from commercial herds in the United States and Europe that were supplemented with BCVFA. Field observations were conducted in approximately 50 herds representing over 70 000 cows. Cows receiving BCVFA for 60 days or more had, on average, a 2% reduction in DMI (whole-herd basis) with 4,3% greater ECM resulting in a 5,5% improvement in feed efficiency (ECM/kg DMI). Optimal responses were seen when cows received BCVFA beginning in the dry period and continuing throughout lactation.

Cows can also maintain BW and may regulate body temperature more easily, improving herd resilience. Research has shown that cows receiving BCVFA during periods of heat stress have been better able to maintain milk yield and BW due to the benefits in microbial performance and NDF digestibility. The BCVFA are benefitting heat-stressed cows by improving energy status and potentially reducing the heat of fermentation and the heat created by and energy lost by the movement of undigested feed through the gastrointestinal tract.

Figure 2: Energy-corrected milk (ECM) production of multiparous cows over the first 13 weeks of lactation.



Conclusion

Dairy producers have both an economic and environmental incentive to improve nitrogen efficiency. Much of the dairy industry's focus on improving nitrogen efficiency has been on utilising higher-quality rumen undegradable protein and rumen-protected amino acids, and this strategy has been effective. Today, it is common to have diets with <16,5% CP, while 18% CP diets were common not so long ago. The next stage in improving nitrogen efficiency is to maximise rumen microbial protein production and efficiency.

When the rumen is performing optimally, cows have the potential to meet their full energy and protein requirements without needing to eat more, thus potentially reducing DMI while supporting greater milk production with less waste.

Supplementation of dairy diets with BCVFA, which are essential nutrients required by the rumen, is the new frontier in dairy nutrition and diet formulation, and will lead to significant advances in feed efficiency and sustainability.

For enquiries, send an email to Dr Dana Tomlinson at dtomlinson@zinpro.com or visit *www.zinpro.com*.

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The applications of rumen-protected nutrients in ruminant diets

By Dr Irene Brown-Crowder, technical service manager, Kemin Animal Nutrition and Health

The field of animal nutrition has evolved in the form of nutrients supplied through the diet. Performance in high-producing animals has surpassed typical fed rations and the need for more concentrated precise nutrients has grown. For ruminants, understanding those targeted needs for animal performance can enhance production, animal health and gene expression in young animals.

The balancing of ruminant diets with methionine (Met), lysine (Lys) and choline using a rumen-protected form may help to enhance production, allow for better flexibility during diet formulation and increase the sustainability of the operation.

Rumen-protected amino acids (AAs) and choline can result in a cost-effective solution when formulating ruminant diets. Supplementation of rumen-protected AAs and choline can aid in maintaining a healthy status with high bioavailable sources and improve the efficiency of protein metabolism. Most research will focus on late gestation into early lactation but a consistent supply of rumen-protected AAs in the diet can offer a consistent and reliable source.

Effective RPs

Technologies have been developed to protect Lys, Met and choline from microbial degradation, allowing the RP product to pass to the abomasum and small intestine where they are absorbed. An effective RP product must be stable during grain mix preparation, feed mixing and in the total mixed ration. It must survive the passage through the mouth (mastication, salivation), releasing little in the rumen and passing quickly into the omasum and then into the intestine for absorption.

The industry has accepted that we cannot cover limiting AA (Lys, Met) requirements for maximum genetic expression for milk production without external supplementation. Lys and Met are limiting AAs in all different types of diets in most parts of the world (due to the low concentrations of these AAs in most feed proteins relative to concentrations in rumen bacteria, milk and tissue protein). Therefore, if we want to work in precise nutrition in modern dairies, it is imperative to use RP-Met and RP-Lys in lactating diets and RP-choline in transition diets.

The benefits of Lys and Met balancing with RP-Met and RP-Lys in production and milk protein production are well understood. Recent research indicates the benefits of RP-choline in the transition period (liver function, inflammation, oxidative stress, improved immuno-metabolic status). Most recent studies focus on the role of gene expression, reproduction role and pathways in the liver of newborn calves.

In other ruminants such as sheep and beef cattle, research indicates a benefit with the combination of RP Lys, Met and choline. In addition, optimisation of protected AAs and choline in ruminant diets allows for better nutrient management plans, improves the feed efficiency, health costs and losses of nitrogen in the manure while reducing inputs.

Conclusion

The nutrition of ruminants has simply evolved based on available diets, maximum performance and environmental concerns. Common practices to provide precision rumen-protected products will allow greater animal performance through production, feed efficiency and sustainability.

For more information, send an email to Dr Irene Brown-Crowder at irene.brown-crowder@kemin.com or visit *www.kemin.com*.

Post-rumen health and its implications on health and performance

By Mark Hall, ruminant technical manager, Trouw Nutrition

The gastrointestinal tract is one of the most metabolically active tissues in ruminants, accounting for approximately 20% of their oxygen consumption and 30% of metabolic processes and protein.

Traditionally, digestion and absorption of nutrients have been considered its primary functions. However, its constant exposure to microbes (both commensal and potentially pathogenic) and its role maintaining an impermeable barrier to immunogenic luminal content reveal a central role within the immune system. This is supported by the fact that 75% of all lymphocytes of a healthy organism reside in the gastrointestinal tract.

Further, being the main interface with the external environment, it has been proposed that the evolutionary origin of the immune system is in the gut. An adequate gastrointestinal barrier function is currently considered essential to preserve animal health and well-being.

The term 'gut health' is being increasingly used, although a precise definition is currently lacking. From a human perspective, Bischoff described five criteria to characterise a healthy gastrointestinal tract:

- Effective digestion and absorption of food.
- Absence of gastrointestinal illness.
- Normal and stable intestinal microbiota.
- Effective immune status (based on an adequate barrier function and appropriate immune tolerance).
- Status of wellbeing (referring to a normal quality of life).

The challenge facing the gut

The gastrointestinal tract is sensitive to multiple stimuli and several factors are known to have an impact on it. Feed deprivation, dietary changes, heat stress, social and psychological stress, and systemic inflammation and disease have all proven to be detrimental for intestinal barrier function.

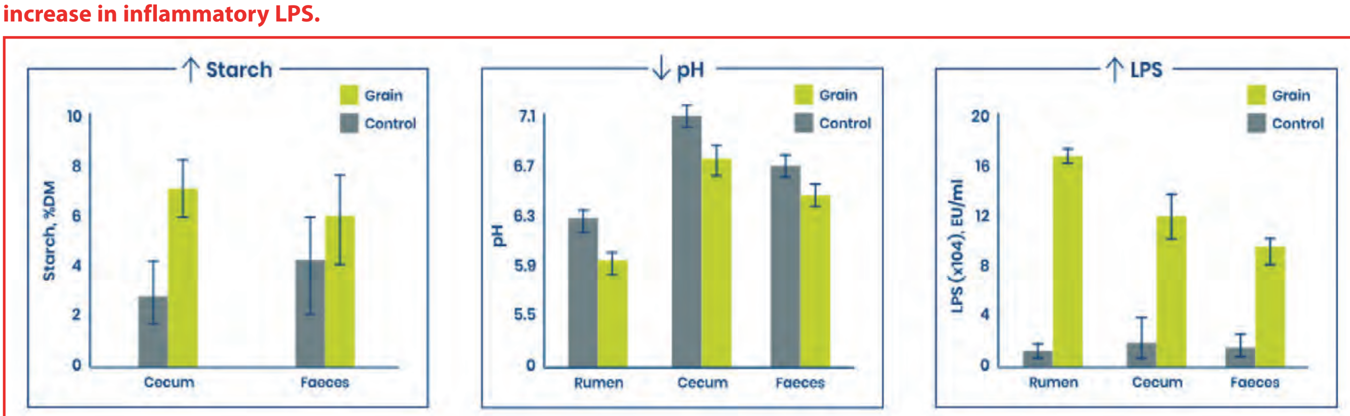
Furthermore, combinations of these factors can occur simultaneously, particularly in the critical transitions of the productive cycles of dairy and beef cattle. For instance, during the transition from pregnancy to lactation, dairy cows experience a decrease in voluntary feed intake, systemic inflammation due to the calving process, and an abrupt dietary change, characterised by an increase in the proportion of rapidly fermentable carbohydrates at the expense of effective fibre. Concomitantly, the massive increase in the energy required for lactation, typically resulting in body reserves mobilisation, provides additional stress.

Similarly, in beef cattle, animals arriving to feedlots endure feed and water deprivation, social mixing, and potentially heat or cold stress during transportation, to be then subjected to an abrupt change in diet composition, also towards greater fermentability and lower effective fibre.

In both cases, the summation of these factors may have cumulative or synergistic detrimental consequences on gut health. A defective intestinal barrier function results in both local and systemic inflammation due to infiltration of luminal content across the epithelium. Upon activation, immune cells drastically increase their energy and nutrient requirements, which directly competes with agriculturally relevant processes such as milk synthesis and growth.

Moreover, inflammation has been associated with the incidence of a variety of diseases. Therefore, supporting gut

Figure 1: A visual representation of the impact of hindgut acidosis on inflammatory markers in cattle, clearly showing a marked increase in inflammatory LPS.



health and reducing inflammation represents an attractive strategy to improve overall health and performance.

Gut health is an everyday problem

The effects of introducing high grain diets in both transition cows and feedlot cattle on gastrointestinal health are likely the best characterised in the literature. Increasing the proportion of grain in the diet is an extensive practice intended to support the high energetic demands of lactation and maximise somatic growth. However, a rapid shift in dietary fermentation rate can ultimately lead to different degrees of rumen acidosis (acute versus subacute) and its associated clinical signs.

While ruminal health has received much attention, it is increasingly evident that the impact of such diets on other sections of the gastrointestinal tract might substantially contribute to the overall pathophysiology of the disease. Increasing the dietary inclusion of grains leads to an increase in rumen bypass starch reaching distal sections of the intestine. Specifically, the effects of high grain diets on the hindgut are likely comparable to those in the rumen, as a result of carbohydrate fermentation by the large intestine microflora.

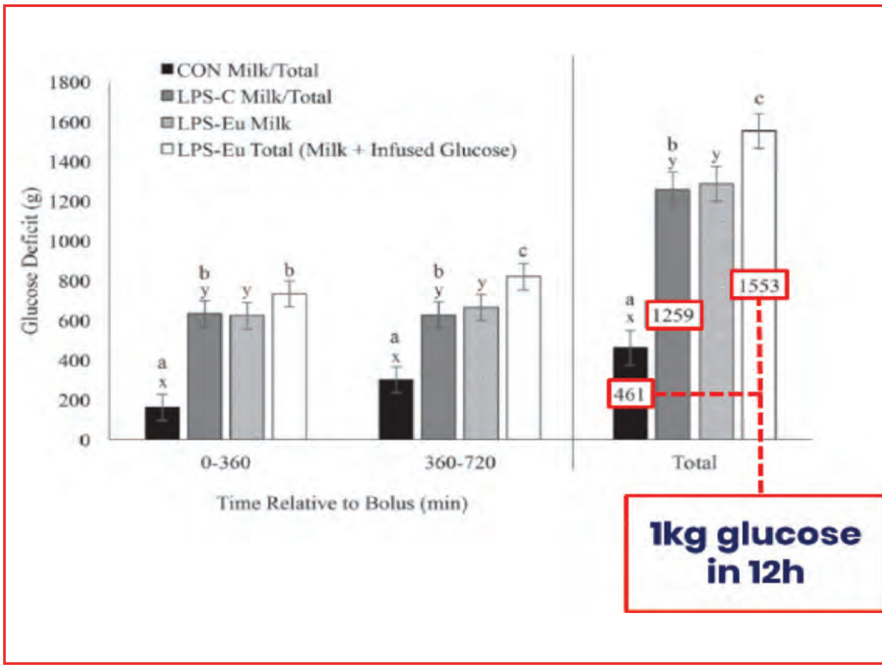
The cost of poor gut health

Excessive inflammation is an animal welfare concern that can ultimately affect health, growth, and reproduction by diverting energy away from these productive processes and towards the immune response. The energetic response to inflammation has been studied for well over a century.

As early as the 1830s, medical doctors such as Robert J Graves (for whom Graves' disease is named) began teaching about the importance of maintaining energy intake during illness. Recent findings have demonstrated that both innate and adaptive activated immune cells undergo a metabolic shift from oxidative phosphorylation to aerobic glycolysis, known as the Warburg effect, which substantially increases their glucose consumption.

Accurately determining the nutrient requirements of the immune system is difficult due to its ubiquitous and fluctuating distribution throughout

Figure 2: Glucose utilised by the immune system in a 12h period.



tissues. During infection, both whole-body energy expenditure and glucose utilisation markedly increase, but tissues with a large immune compartment (e.g., spleen, liver, lung, and ileum) show the largest increases in glucose utilisation.

Furthermore, Mészáros *et al*. examined different cell fractions within the liver after an i.v. LPS challenge and demonstrated glucose uptake did not change in Animals 2020, 10, 1817 7 of 18 parenchymal cells, but markedly increased in Kupffer cells (~7-fold) and neutrophils (~5-fold).

Better understanding the impact of immune-activation on whole-animal glucose consumption has practical implications to animal agriculture, as glucose availability is a critical signal for anabolic processes required for animal performance. Using the LPS-euglycemic clamp technique, Kvidera *et al*. determined glucose requirements of an acutely activated immune system were 0,66, 1, and 1,1g/kg BW 0,75/h in cows, steers, and pigs, respectively.

The consistency in the glucose requirements on a metabolic bodyweight basis suggests a relatively conserved immune system response across different ages, physiological states, and species. In the lactating dairy cow model, this equated to ~1kg of glucose utilised by the immune system in a 12-hour period. Thus, infection and inflammation noticeably redirect resources toward the immune system and away from synthesis of economically relevant products.

Maximising hindgut health

Considering modern farming systems, where multifactorial issues can cause a plethora of production challenges, maximising hindgut health should be a focus for all cattle system types. Targeting the hindgut with precise nutritional strategies requires additional considerations in cattle and circumventing the rumen through bypass technologies is essential.

Stimulating the hindgut's ecological balance and barrier function through nutritional interventions might represent a window of opportunity to further improve health and productivity in cattle; the use of protected calcium gluconate shows considerable promise in improving this area. Furthermore, consideration should be given to management practices that work to reduce the incidence of dry matter intake reduction, be this through reduction in heat stress, ration changes, lameness and so forth.

For more information, send an email to mark.hall@trouwnutrition.com or visit *www.trouwnutrition.com*.

Antibiotic resistance: From science to policy

By Dr Shabbir Simjee, chief medical officer, global regulatory and technical senior advisor: microbiology and antimicrobials, Elanco (US)

Antimicrobials remain a key tool for the treatment of infectious diseases in animals. There are three different circumstances for the therapeutic use of antibiotics in food-producing animals: treatment, metaphylaxis/control and prophylaxis/prevention.

In all cases where administration of an antibiotic is required, this should be prescribed following appropriate diagnosis by a veterinarian preferably with a good knowledge of the disease epidemiology on the farm. Animals with clinical signs of a bacterial infection that is impacting their health and welfare in many cases need treatment with antibiotics.

Metaphylaxis/control means the administration of a medicinal product to a group of animals after a diagnosis of clinical disease in part of the group has been established, to treat the clinically sick animals and control the spread of the disease to animals in close contact and at risk and which may already be subclinically infected.

Prophylaxis/prevention means the administration of a medicinal product to an animal or group of animals before clinical signs of a disease, in order to prevent the occurrence of disease or infection i.e., in the absence of sub-clinical infection or detectable pathogens, there is a risk of disease outbreak.

Regulations in place

Over the past several years significant progress on achieving better antibiotic stewardship in the veterinary sector has been achieved through regulatory legislations both in the United States (US) and the European Union (EU), including the implementation of US FDA GL 209 and 213. The EU is now taking measures to phase out the routine use of antibiotics for disease prevention, reserving prophylactic use for exceptional circumstances.

In May 2020, the European Commission adopted the Farm to Fork Strategy, a tool to help shape the EU's path towards sustainable food systems. Its objective is the reduction of 50% of the overall EU sales of antibiotics for farmed animals and in aquaculture by 2030. The achievement of this objective will be supported by the implementation of the new *Regulation (EU) 2019/4 on Medicated Feed* (MF, prescription required) and *Regulation (EU) 2019/6 on Veterinary Medicinal Products* (VMP regulation, prescription required). These provide for a wide range of measures to fight antimicrobial resistance (AMR) and promote a more prudent and responsible use of antibiotics in animals.

Regulation 2019/6, commonly known as the *New Veterinary Regulation*, legislates for the authorisation, use and monitoring of veterinary medicinal products in the EU. The legislation came into effect on 28 January 2019 and applies in all EU member states on 28 January 2022. The regulation followed the adoption of a proposal in 2014 to develop fit-for-purpose veterinary legislation which would no longer be based on the equivalent human medicines authorisation system.

The legislation repeals *Directive 2001/82/EC* and is intended to:

- Harmonise the internal EU market for veterinary medicinal products.
- Reduce the administrative burden on companies and regulatory authorities.
- Enhance the availability of veterinary medicinal products.
- Stimulate innovation of new and existing medicines.
- Strengthen the EU response to fight antimicrobial resistance.

Specifically, regarding antibiotic resistance the new regulation strengthens the existing EU framework in fighting antimicrobial resistance. To this end, the new regulation mandates the following in relation to medically important antibiotics that are approved as veterinary medicines:

- Preventive use of antibiotics in single animals and small groups is allowed following veterinary assessment.
- Restricts the metaphylactic use of antibiotics.
- Permits EU member states to reserve specific antibiotics for humans only.
- Oblige EU member states to collect data on the sale and use of antibiotics.
- Prohibits, for imported animals and products from outside the EU, antimicrobial veterinary products for promoting growth and places restrictions on antibiotics reserved for human use.

Key articles and recitals from 2019/6

Under Recital 47 veterinarians have a key role in ensuring responsible use of antimicrobials. Prescribing should be based on antibiotic resistance, epidemiology and clinical knowledge and the amount of antibiotic prescribed should be limited to the amount required for treatment of the animal under their care. Furthermore, veterinarians should not be influenced by financial incentives when prescribing.

Under Article 105, which relates to veterinary prescriptions, prescriptions should only be issued following a proper clinical assessment. The justification for any prescription, especially for metaphylaxis or prophylaxis should be provided. The quantity of antibiotics prescribed for treatment should only be sufficient for the disease condition present at the time. If the prescription is

for disease control or prevention, then the quantity prescribed should be limited to cover the 'at risk' period.

Of particular note is Article 107, which has resulted in some confusion relating to metaphylaxis and prophylaxis. Article 107 explicitly specifies that antimicrobial medicinal products shall not be applied routinely nor used to compensate for poor hygiene, inadequate animal husbandry or lack of care or to compensate for poor farm management.

With respect to metaphylaxis and prophylaxis, Article 107 of Regulation 2019/6 specifies:

- Antimicrobial medicinal products shall not be used for prophylaxis other than in exceptional cases, for the administration to an individual animal or a restricted number of animals when the risk of an infection or an infectious disease is very high, and the consequences are likely to be severe.
- Antimicrobial medicinal products shall be used for metaphylaxis only when the risk of spread of an infection or of an infectious disease in the group of animals is high and where no other appropriate alternatives are available. Member states shall actively support the development and application of guidelines which promote the understanding of risk factors associated with metaphylaxis and include criteria for its initiation.
- In addition, Article 107 of 2019/6 reaffirms Regulation 1831/2003 i.e., antimicrobial medicinal products shall not be used in food animals to promote growth nor to increase yield.

Regulation 2019/4, commonly known as the medicated feed regulation applies in all EU member states on 28 January 2022 and as the title suggests, relates to medicated feed. Medicated feed is a mixture of a veterinary medicinal product(s) and feed(s) which is prepared for marketing and intended to be fed to animals without additional processing.

Medicated feed is mainly used to treat large groups of animals, where individual veterinary treatment would not be possible or be difficult to administer. The main advantage of medicated feed is the ease of administration and is generally used for livestock, notably pigs and poultry.

The extent to which medicated feed is used depends on factors such as cost-effectiveness, availability of the feed, and regulations at the national level. All of these vary significantly between member states.

Medicated feed regulation

The scope of the proposed medicated feed regulation is being extended to non-food-producing animals and includes medicated feed for pets. To reduce the risk of antimicrobial resistance, rules on carry-over and preventive use of antibiotics are being proposed. The limits for the carry-over of veterinary medicines into non-target feed will be set by delegated acts for specific active substances.

The legislation repeals *Council Directive 90/167/EEC*. Three points of particular interest relate to prescription, metaphylaxis and prophylaxis.

Regarding prescriptions of medicated feed, Regulation 2019/4, under Article 16, requires:

- The supply of medicated feed will be by presentation of a prescription only. The prescription will only be issued after a clinical assessment and only for diagnosed diseases.
- Validity of prescriptions for medicated feed from the date of issue will be six months for non-food-producing animals and three weeks for food-producing animals. However, if the medicated feed contains antibiotics, then the validity from the date of issue will be limited to a maximum period of five days.
- Duration of treatment and the amount of antibiotic-containing feed that can be produced/supplied should be for a maximum of two weeks unless the summary of product characteristics (SPC) specifies differently.
- If it is not possible to confirm the presence of a diagnosed disease, a veterinary prescription for medicated feed containing an antiparasitic may be issued based on the knowledge of the parasitic infestation status in the animal or group of animals.

With regard to prescribing medicated feed containing medicinal antibiotics for prophylaxis, Regulation 2019/4, under Article 17, requires that:

- Medicated feed containing antibiotic veterinary medicinal products shall not be used for prophylaxis.
- Medicated feed containing antiparasitics may be used for prophylaxis based on a prescription in accordance with Article 16 of 2019/4, as specified previously.
- Medicated feed containing immunological veterinary medicinal products can be used for prophylaxis based on a prescription in accordance with Article 16 of 2019/4, as specified previously.

Feed additives and record keeping

With respect to metaphylaxis use of medicated feed, Regulation 2019/4 specifies that medicated feed containing antimicrobials for metaphylaxis should only be allowed when the risk of spread of an infection or an infectious disease is high, in accordance with Regulation 2019/6, as assessed by a veterinarian.

In addition, it should be noted that Regulation 2019/4 Article 17 and Regulation 2019/6 Article 108 specify that the keeper of food-producing animals shall keep records of the medicinal products they use for a period of at least five years.

For clarity, it should be noted that anticoccidials (including ionophores) that are used in feed to kill and inhibit the coccidian parasites (these products are known as coccidiostats in Europe) are registered as feed additives under Regulation 1831/2003. Coccidiostats are approved as feed additives only for the species in which coccidias are ubiquitous in all production systems – whether free range or confined, small scale or large scale.

The species for which they may be approved are chickens, turkeys, rabbits, guinea fowls, pheasants, quails and partridges. As such they may be used as feed additives and therefore routinely in feed for these species without prescription. For all other species in which coccidiosis and the associated risk of outbreaks are not always present, antiparasitic veterinary medicines are used to prevent, control or treat infections and this must be accompanied by a veterinary prescription.

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Understanding the problem is half the solution

By Dr Kirsty Gibbs, Dr Sasha van der Klein and Dr Ceinwen Evans, IFF, and Louma Mostert and Natasha Snyman, Chemuniqué

Concerns regarding antimicrobial resistance continue to grow, with associated deaths surpassing many other causes. The use of antibiotics in animal production has long been associated with rising resistance traits. The global industry continues to respond with more local guidelines and/or legislation to reduce antibiotic use, but available alternatives are believed to lack consistency and comparable efficacy.

Antibiotics have helped mitigate the negative production impacts of numerous poorly understood intestinal and health challenges. These include, but are not limited to, necrotic enteritis (the causative agent being *Clostridium perfringens*) and colibacillosis (a syndromic systemic infection caused by avian pathogenic *Escherichia coli* or APEC), both of which could be considered as expert opportunistic micro-organisms.

Exposome influence

Looking deeper, these production challenges are the negative result of very complex host:microbe relationships that are highly dependent on the exposome (diet, stress, microbial pressure, etc.). These relationships are dynamic and ever-changing, meaning that:

- The presence of the microbe does not always result in infection.
- The severity of the disease and type of pathologies observed are variable.

Infection levels can range from subclinical (indicated by a decline in performance, for example) to clinical in mild, moderate, or severe forms. Finally, the genetic diversity of these opportunists is vast. For example, mechanisms associated with virulence may not be common among these microbes (i.e., defining virulence traits such as toxins), and the genetic relatedness between infection-causing micro-organisms of the same species may also not be similar (for example, they cannot be tracked through epidemiological studies and traditional fingerprinting techniques), along with a high chance of polyclonal infections in a single host.

This is without considering the heterogeneity of the host response. All these elements make elucidating the aetiology of infections more challenging versus true pathogens and the development of solutions to combat these issues in an era of reduced antibiotic use.

Antibiotics have taken a blanket approach to reducing the overall microbial or pathogen burden in a relatively non-specific manner, but the actual situation as described is more complex than that.

The *Clostridium perfringens* example

Clostridium perfringens is a normal inhabitant of the distal intestinal tract of birds, yet it is also the causative agent of one of the costliest intestinal challenges in modern production: necrotic enteritis (NE). *C. perfringens* has a fluid relationship with its avian host, significantly influenced by the host status, the type of *C. perfringens* and the environment.

While there is substantial research on the aetiology of NE in poultry, and predisposing factors have been associated with an increased likelihood of developing NE (including, but not limited to, high levels of undigested protein reaching the distal gut and high coccidiosis pressure), there is still much to unravel. Not all birds develop NE, NE can be mild or moderate, and even cause death in severe cases, and not all cases of NE are associated with a high *C. perfringens* burden.

Measuring the outcome

So what decides the outcome of this interaction and how do we measure it? Significant advances in our analytical capabilities have led to the realisation that clonal populations of a single *C. perfringens* presence may contain subclusters that are responsible for different tasks. This differentiation includes the identification of distinct subpopulations of *C. perfringens* being responsible for NetB production (*Figure 1*), where NetB is a major toxin associated with the development of NE.

This discovery would not have been possible without IFF scientists' development of single-cell RNA sequencing technologies for prokaryotic organisms, which was published in *Nature Microbiology* (McNulty *et al*., 2023). Resolution at this highly granular level provides us with a deeper understanding of how these single-celled organisms behave.

We also know that other micro-organisms can change the behaviours of these subpopulations, affecting the gross cytotoxicity of *C. perfringens* (data

Figure 1: Uniform manifold approximation and projection (UMAP) analysis of all transcripts of a single *C. perfringens* clone (left) and highlighting the subcluster 1 responsible for NetB toxin expression (right).

under review). Such findings aid our understanding and the development of potential solutions.

The APEC challenge

In vivo infection models are frequently used for screening and developing solutions to challenges, but which parameters does one have to measure to capture the essence of the infection or the impact of the solution? These models typically vary between research facilities. Diversity can arise due to differences in, among others, predisposing factors, bird genetics, diet type, strain of pathogen used, day of challenge and the applied dose of challenge strain.

With increased awareness of biomarkers, researchers are evaluating an increased number of measurable parameters related to the host and the microbe, and questions remain as to how these metrics relate. Additionally, we need to know how to extrapolate these infection models into real production systems and how we continue to measure the efficacy of solutions if the microbial burden remains.

A study recently presented at the 2023 Poultry Science Association Annual Meeting (Van der Klein *et al*., 2023), for the first time reports on a meta-analysis that accounts for over nine different NE challenge models and compares metrics from non-challenged control birds (NC) and challenged control birds (CC). This study reports that when you only consider performance-based metrics (including feed intake, body weight gain, final body weight and/or feed conversion ratio), models fail to differentiate clearly between NC and CC groups.

However, when you consider including health-based parameters (including coccidiosis pressure, gut integrity markers, lesion scores and NE induction), differentiating between NC and CC becomes more apparent (*Figure 2,* where the figure on the left represents *performance only* and figure on the right represents *performance* + *health-based* metrics). As these parameters become more available in the field it will become easier to address such challenges.

Intestinal populations

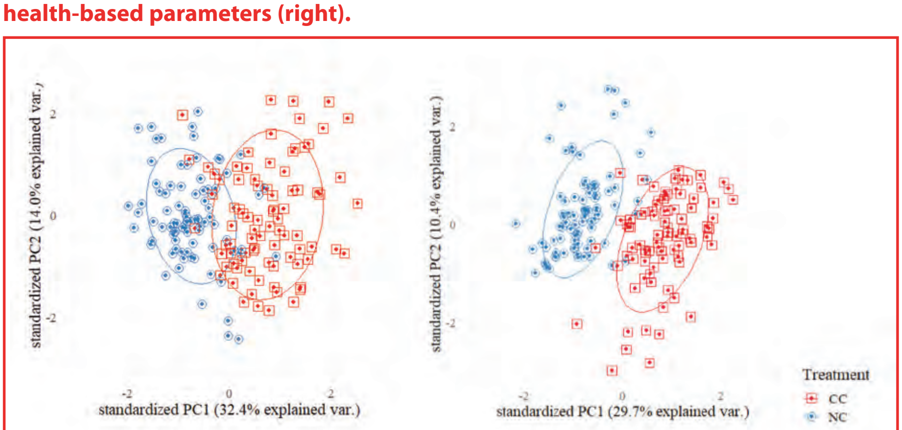
Not only is the intestinal tract home to *C. perfringens*, but it also harbours the largest APEC reservoir – a group of *E. coli* that produce a poorly defined and highly variable microbial challenge. Previous studies have demonstrated that a significant proportion of the *E. coli* population colonising the naïve intestinal tract of a newly hatched chick is potentially APEC, meaning it harbours the machinery required to survive outside of the intestinal tract in sites normally hostile to microbial growth.

This machinery refers to virulence-associated mechanisms that allow *E. coli* to spread opportunistically if the avian host becomes susceptible, leading to colibacillosis. During the first few days post-hatch, reportedly 50% of chick mortalities are associated with systemic *E. coli* infections. The *E. coli* takes advantage of a susceptible host; the young chick is lacking a mature microbiome, lacks a mature immune system, and has undeveloped gut structures, resulting in poor gut integrity and high microbial competition. Routine application of gentamycin at the hatchery has helped mitigate this issue in the past, but for many producers, this is no longer an option.

Extensive work has been done in the field to better understand the potential risk these intestinal populations pose to the development of systemic infection and the impact of feed-additive-based technologies developed to reduce these non-beneficial subpopulations in the intestinal tract. It is also accepted and demonstrated in the field that addressing the APEC reservoir in the intestinal tracts of breeders has a positive effect on early chick carriage.

In conclusion, as technologies advance, our understanding of these complex host:microbe interactions follows suit. This improves our ability to translate science to the field and develop more consistent solutions, because, after all: Understanding the problem is half the solution.

Figure 2: Principal component analysis (PCA) plots demonstrate the separation of non-challenged treatment groups (NC) and challenged treatment groups (CC) using performance-based parameters (left) and a combination of performance- and health-based parameters (right).



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Vitamin D-elight

By Gerhard Claassen, University of Pretoria, Chemuniqué (Pty) Ltd

Vitamin D nutrition does not demand the same amount of attention at the table of nutritionists as its more 'important' nutrient counterparts such as carbohydrates, amino acids, minerals, and enzymes. Vitamin D is often formulated into diets as a one-size fits-all solution; however, there is much more to the story. Contrary to popular belief, vitamin D is not a single entity, but rather a description for a group of analogues that share a similar structure and function.

All vitamin D analogues perform the same functions in the body, although they differ physiologically in their metabolism and their homeostatic regulation. The purpose of this review is to highlight the importance of vitamin D in animal nutrition and to give new insight into vitamin D analogues, their metabolism, regulation, and their application in industry.

Background

Vitamin D is a series of fat-soluble steroid derivatives that have the physiological ability to perform hormonal functions when in their active state (Adams and Hewison, 2010; De Paula and Rosen, 2012). Vitamin D can be broadly grouped into ergocalciferol or vitamin D_2, which is the predominant form in plants, and cholecalciferol or vitamin D_3, which is the predominant form in animals.

Vitamin D_2 and D_3 are only the precursor molecules for 1α,25-dihydroxyvitamin D_3, the active form of vitamin D in mammals – better known as calcitriol. Calcitriol exerts its effects by binding to the vitamin D receptor (VDR) of target genes that are located on numerous types of cells and tissues across the body (Pike *et al.*, 2017).

The complete scope of vitamin D target genes has not been defined in animals; however, it has been shown that approximately 3% of the human genome is regulated by VDR (Caprio *et al.*, 2017), which includes numerous cells and tissues such as those of the bone (Goltzman, 2018), kidney (Yang *et al.*, 2018), intestine (Wang *et al.*, 2012), immune system (Colotta *et al.*, 2017; Koivisto *et al.*, 2020; Martens *et al.*, 2020), cardiovascular system (Wu-Wong *et al.*, 2006; Norman and Powell, 2014), and brain (Eyles *et al.*, 2014).

Although vitamin D is used by the body for a variety of purposes and in many tissues, its role in the absorption of calcium (Ca) and phosphorus (P) is one of its most vital functions and is of the greatest importance to the animal nutrition industry. Several analogues of vitamin D are commercially available, all of which differ in their efficacy and ability to regulate intestinal Ca and P absorption. The rest of this review will focus on the different analogues of vitamin D and how producers can benefit from vitamin D supplementation.

Vitamin D metabolism

Vitamin D_3 is non-essential and can be naturally synthesised in the skin from cholesterol upon radiation by ultraviolet (UV) light (Jäpelt and Jakobsen, 2013). In the skin, previtamin D_3 is formed from 7-dehydrocholesterol upon radiation from UVB light (Tian and Holick, 1995). This presents a problem in most modern poultry and pig production systems where animals are kept entirely indoors and only receive limited, if any, UV exposure, and thus diets must be supplemented with synthetic forms of vitamin D_3 to meet vitamin D requirements.

After the formation of previtamin D_3, the molecule undergoes thermal isomerisation to produce vitamin D_3 (Tian and Holick, 1995), which is biologically inactive. The hydroxylation of vitamin D_3 to 25-hydroxyvitamin D_3 is the first of two hydroxylation steps required to transform vitamin D_3 into 1α,25-dihydroxyvitamin D_3, the hormonally functional form of the molecule. This step can be mediated by several hydroxylase enzymes; however, the CYP2R1 enzyme has been identified as the main responsible enzyme and is located in the liver. This enzyme is not regulated, but rather is reliant on a substrate-dependent mechanism (Saponaro *et al.*, 2020).

The second hydroxylation step involves the addition of a hydroxyl group in the 1α-position to the 25-hydroxyvitamin D_3 molecule to create 1α,25-dihydroxyvitamin D_3, the physiologically active and functional metabolite of vitamin D. This is done mainly in the kidney by the 1α-hydroxylase enzyme, CYP27B1 (Bikle *et al.*, 2018). Only after the second hydroxylation step is complete the molecule is able to bind to vitamin D receptors and perform the distinct functions of vitamin D.

25-Hydroxyvitamin D_3

An advantage of 25-hydroxyvitamin D_3 (25-D_3) is that it is a polar molecule, affording it a higher solubility in aqueous solution and allowing the molecule to be passively absorbed in the small intestine, which improves its bioavailability (Guo *et al.*, 2018; Vazquez *et al.*, 2018). This is in contrast with vitamin D_3, which requires micelle formation for absorption.

Furthermore, vitamin D-binding proteins – the carrier proteins responsible for vitamin D transportation in the blood – have the highest affinity for 25-D_3, meaning that it is more effectively transported through the blood than vitamin D_3 (Soares Jr *et al.*, 1995); 25-D_3 also has a longer serum half-life than calcitriol, and is commonly used to evaluate an animal's vitamin D status (Sezer and Behzat, 2021).

The biological activity of vitamin D_3 is dependent on its ability to raise the circulating level of 25-D_3. When fed at the same rates, 25-D_3 supplementation consistently results in significantly greater blood concentrations when compared to vitamin D_3 alone (Turner, 2013). Vitamin D supplied in the form of 25-D_3 is also not dependent on hydroxylation by 25-hydroxylase enzymes; however, 25-D_3 requires hydroxylation by 1α-hydroxylases in the kidney, which is considered the rate-limiting step in the synthesis of the biologically active metabolite, calcitriol (Portale and Miller, 2000).

This is a result of the kidney's 1α-hydroxylase enzymes, which are tightly controlled by several hormones and serve as the primary site of 1-hydroxylation. Renal 1-hydroxylase enzymes have been reported to be upregulated by parathormone and calcitonin, while the enzyme is inhibited by fibroblast growth factor-23, calcitriol, and leptin (Saponaro *et al.*, 2020). However, 1α-hydroxylase activity have been reported in tissues of the skin, parathyroid glands, the macrophages of the immune system, and in bone mesenchymal stem cells (Adams *et al.*, 1983; Bikle, 1994).

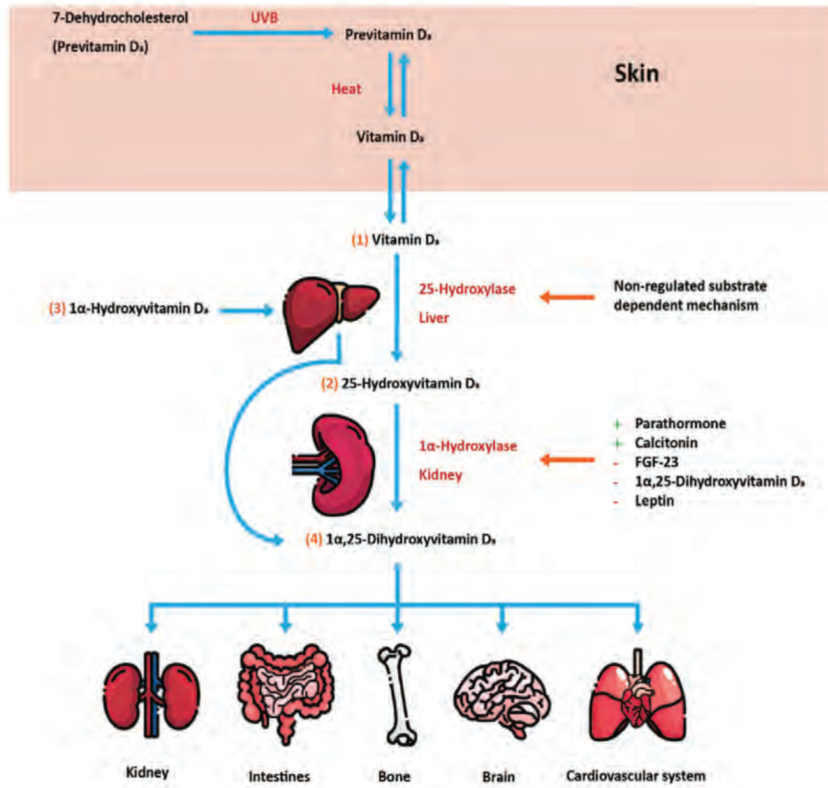
Most producers aim to benefit from the advantages of 25-D_3 without completely replacing existing vitamin D_3 in diets and, therefore, 25-D_3 is commonly added to broiler diets as a supplement in addition to vitamin D_3, although it rarely serves as a complete replacement for vitamin D_3. 25-D_3 can potentially improve performance and cellular immune response, reduce the incidence of TD, and improve bone mineralisation in broilers (Fritts and Waldroup, 2003; Koreleski and Swiatkiewicz, 2005; Michalczuk *et al.*, 2010; Gomez *et al.*, 2012; Vazquez *et al.*, 2018)

1α-Hydroxyvitamin D_3

1α-Hydroxycholecalciferol (1α-D_3) is a synthetic form of vitamin D_3 that differs from vitamin D_3 in that it has been hydroxylated in the 1α position. After ingestion, 1α-D_3 is rapidly hydroxylated by liver 25-hydroxylase enzymes to produce the biologically active vitamin D metabolite, 1α,25-dihydroxyvitamin D_3 (Bouillon and Reid, 2013).

A great benefit of 1α-D_3 is that the metabolite has equal efficacy as the active metabolite, but is less expensive to synthesise (Warren *et al.*, 2020). 1α-D_3 has been used clinically for decades in patients with chronic kidney disease and to treat bone abnormalities and mineral imbalances (Vervloet, 2014).

Figure 1: The metabolism, regulation, and target tissues of 1α,25-dihydroxyvitamin D_3 (adapted from Saponaro *et al.*, 2020).



Vitamin D that is supplied in the form of 1α-D_3 requires 25-hydroxylation by the 25-hydroxylase enzymes of the liver, and therefore bypasses 1α-hydroxylation by 1α-hydroxylase enzymes in the kidney, which is regarded as the rate-limiting step in the synthesis of 1α,25-dihydroxyvitamin D_3 (Portale and Miller, 2000; Ringe *et al.*, 2005).

This is a benefit as 1α-D_3 can rapidly increase calcium uptake into the blood. However, in doing so, the molecule bypasses a critical regulatory step in the metabolism of vitamin D, thereby increasing the probability of hypercalcemia and vitamin D toxicity (Warren *et al.*, 2020). Because of the possible undesirable effects of 1α-D_3, the typical dosage is between 2,5 µg/kg and 10 µg/kg, which is considerably lower than that of vitamin D_3 and 25-D_3.

1α-D_3 has been shown to improve blood-ionised calcium status during the starter phase, reduce the incidence of TD, improve bone mineralisation and performance, as well as upregulate genes responsible for calcium and phosphorus absorption (Ebrahimi *et al.*, 2016; Han *et al.*, 2016; Han *et al.*, 2017; Han *et al.*, 2018; Yang *et al.*, 2019; Landy *et al.*, 2020; Warren *et al.*, 2020).

1α,25-Dihydroxyvitamin D_3

1α,25-Dihydoxyvitamin D_3 (1α,25-D_3) is the physiologically active metabolite and is also commercially available. 1α,25-D_3 is unregulated and able to bind to VDR of several target genes across the body and immediately initiate the physiological effects of vitamin D. However, it is more costly to produce than the other analogues that offer similar benefits (Warren *et al.*, 2020).

The benefits of including 1α,25-D_3 include improved performance and bone mineralisation, reduced bone abnormalities, and mitigation of the effects of calcium and phosphorus restriction on bone development (Roberson and Edwards, 1996; Vieites *et al.*, 2018; Wu *et al.*, 2022).

Conclusion

Vitamin D is a series of fat-soluble steroid derivatives that perform hormonal functions when in their active state. Vitamin D_3 is the most common analogue of vitamin D that is supplied in broiler diets and requires two hydroxylation steps before becoming physiologically active. Several other analogues are commercially available, including 25-D_3, 1α-D_3 and 1α,25-D_3, which differ in their regulatory pathways and can therefore provide an additional benefit when supplemented into broiler diets. Producers should consider both the benefits and drawbacks, the recommended supplementation levels, and the cost associated with each product before deciding which will benefit their production system the most.

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Innovation with Integrity

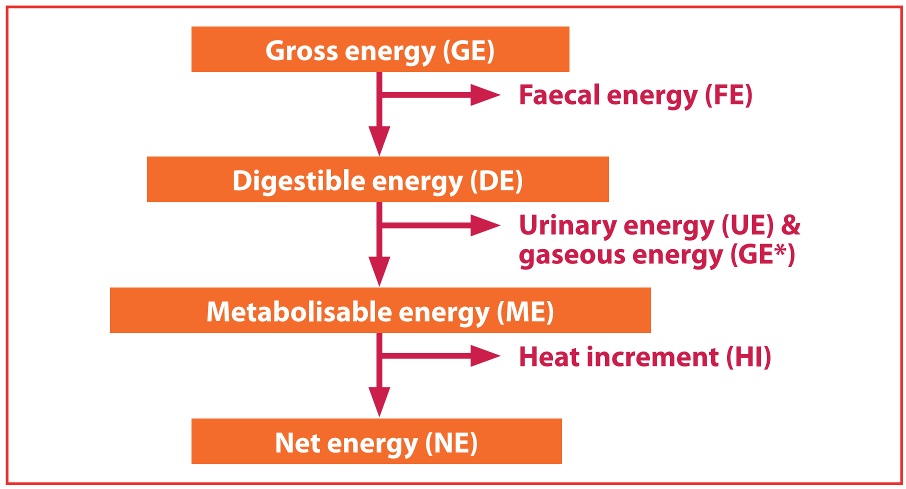
Recent developments in energy systems for poultry

By Pierre Cozannet, Angélique Cayzac, Céline Gras, Juan-Louis Fourie, Rick Kleyn and Yves Mercier

The global animal nutrition industry is moving rapidly towards precision livestock feeding to better manage natural resources. Sustainability is all about retrieving the most accurate nutritional values to better match animals' needs and better predict animal responses to the formulated diets.

Having the most reliable data available is crucial in times of high raw materials prices, but also to enlarge ingredient usage in poultry diets and avoid oversupply. Energy is one of the costliest nutrients of the diet; hence, this article aims to highlight the benefits of applying net energy system to better optimise broiler diets and better predict poultry performance.

Figure 1: The energy flow diagram.



Energy flow

Raw material energy content can be expressed in different systems from gross energy to net energy that require using more refined *in vivo* methods. As it is obvious for all formulating on an SID amino acid basis instead of crude protein (CP), getting more accurate energy systems that account for animals' physiological and metabolic particularity is key.

ME is the remaining energy amount in the feed after subtracting energy losses in the faeces and urine (mixed in poultry). Metabolisable energy was often corrected for a zero N balance of the birds' MEn, to standardise the ME values obtained from growing broilers or from adult cockerels that do not retain any N (Bourdillon *et al.*, 1990a). A coefficient of 8,22kcal/g N gain (or 34,4kJ) corresponding to the energy content of uric acid per g of N is used (Hill and Anderson, 1958). However, the N gain can be estimated from BW gain considering that BW gain contains 20% crude protein or 3,2% N (i.e., 20/6,25) (Carre *et al.*, 2014).

It would then be more accurate to use a standardised ME value (MEs) for a positive N balance, and in growing broilers it is admitted that the average N retention is 60% of the N intake, allowing us to calculate MEs = MEn + 8,22 (0,60 [N intake – N gain]).

However, heat production through digestive and metabolic processes, or 'heat increment', is still not included in this value. Then, to formulate energy level by focussing mainly on the production of energy (i.e. protein and fat deposition), it is worth going to a net energy (NE) system which represents the better prediction of retained energy. Measuring NE energy is difficult and time consuming, but thanks to previous work and modelling approaches, NE value can be calculated from the ME values. The transformation of GE to NE can be described by three steps *Figure 1*.

Following the swine example

In the feed industry, many energy systems evaluation are coexisting and the NE system is actually not a new one. This system has been commonly used in pig feed formulation for many years and adopted by several countries. The use of NE values in swine has been successfully adopted and showed its robustness and cost-effectiveness. Up to now, the incentive to move to NE in poultry nutrition was not as obvious since raw materials used were more 'traditional' and based on a few ingredients such as maize, soya bean meal and maize DDGS. Consequently, the ME system was considered 'good enough' and the NE system did not offer a big advantage.

However, new considerations for sustainable poultry production push looking at a wider usage of ingredients. Obviously, heat production is needed for homeotherm animals, and the NE system would not prevent it, but better knowledge of ingredients' energy thermal dissipation allows focussing feed formulation on 'productive energy'. Using the NE value for ingredients offers more possibilities than the ME value, leading to reduced feed cost and maintained performances by supplying an accurate level of productive energy.

Easy calculation of NE values

NE measurement requires huge expertise, dedicated material, time and money,

preventing the routine and systematic assessment of ingredients. Hence, and considering these former considerations, equations have been developed based on complete feed measurement. They have been obtained with complete feeds and were based on nutrient content expressed in % dry matter (DM). The residue is the difference between organic matter and other nutrients (i.e., CP, ether extract [EE], starch and neutral detergent extract [NDF]).

More precise equations for ME and MEn were obtained by Carre *et al.* (2014).

- ME (kcal/kg DM) = 54,3 CP + 77,8 EE + 38,3 starch – 15,6 NDF + 16,7 residue (RSD = 62 kcal).
- MEn (kcal/kg DM) = 49,5 CP + 77 EE + 37,6 starch – 15,1 NDF + 16,3 residue (RSD = 59 kcal).

Equations for heat increments in poultry and long-standing knowledge of feed formulation and precision nutrition allowed us to provide recommendations for NE for poultry. These equations were recently published by Wu *et al.* (2019) and were based on MEs, CP and EE content (% DM): NE (kcal/kg DM) = 0,781 MEs – 6,7 CP + 6,9 EE (RSD = 50 kcal).

New insight for low protein diets

The reduction of CP content in feed increased animal protein retention efficiency and would reduce dependency on vegetable protein sources. The larger availability of crystalline amino acids allows nutritionists to formulate broiler diets with reduced CP. Therefore, greater reductions of dietary CP (40 to 50g/kg) invariably compromise broiler performance.

A meta-analysis was performed on 28 studies evaluating low protein diets in iso metabolisable diets in broilers. The objective was to evaluate the potential of NE and amino acids to NE balance to explain the difference in animal performance. On average, a decrease in CP content in broiler diets was associated with a decrease in body weight of 19g and an increase in FCR + 0,04 units per unit CP ($P < 0,01$).

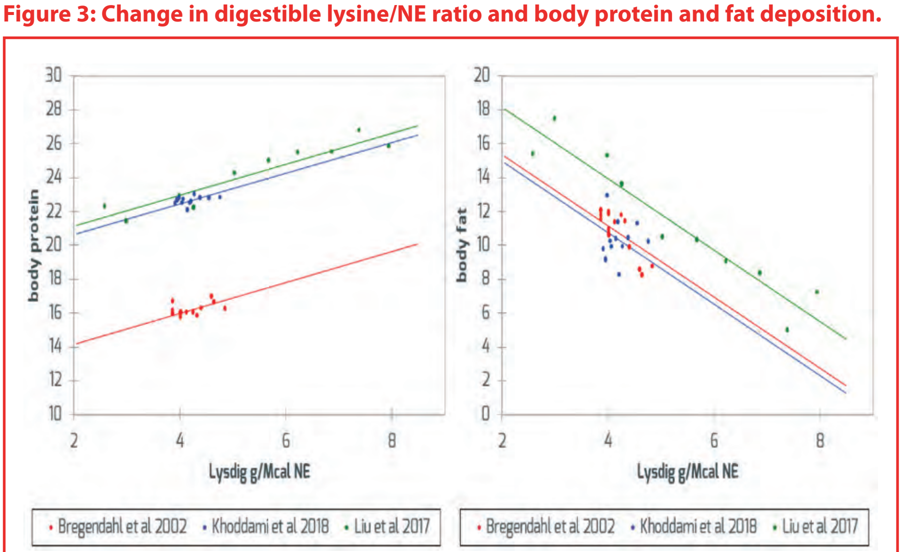
No variation in feed intake was observed. Net energy was calculated based on diet chemical composition. Data showed a positive correlation between CP content and digestible lysine/NE ratio ($r^2 = 0,83$; $P < 0,001$). This result suggested an imbalance between energy and digestible amino acid not detectable in metabolisable energy systems. Body protein and lipid deposition were also significantly correlated with digestible lysine/NE ratio ($r^2 = 0,98$ and $r^2 = 0,77$, respectively). Correlations were positive for body protein gain and negative for body fat gain.

These results explain the increase of fat deposition in low CP diet-fed broilers that can be linked with FCR alteration. Thus, formulations in the NE system might allow better energy to protein balancing and hence facilitate the application of low protein diets in poultry.

Figure 2: NE values provide a new hierarchy for feed.

Ingredients	ME	NE	NE/ME
Soya bean meal	2 257	1 629	72
Maize DDGS	2 390	1 782	75
Barley	2 842	2 088	73
Feather meal	2 861	2 164	76
Wheat	2 865	2 166	76
Sorghum	3 324	2 527	75
Fish meal	3 351	2 560	76
Maize	3 354	2 565	77
Fat	9 000	7 920	88

Figure 3: Change in digestible lysine/NE ratio and body protein and fat deposition.



Conclusions and applications

- Correct assessment of dietary energy is key for effective feed formulation and ingredient selection for poultry diets. The NE system appears as the more robust and accurate to predict performance.
- The NE system changes raw materials' ranking compared with ME system, enlarging the possibilities for ingredient usage and managing feed cost.
- Net energy gives new insights into the application of low-protein diets in poultry nutrition by reinforcing the relationship between nitrogen and energy metabolism.

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New perspectives and essential functions of key fat-soluble vitamins in animal nutrition

By Drs Yauheni Shastak, Ute Obermueller-Jevic and Alvaro Gordillo

The availability of essential vitamins plays a pivotal role in ensuring optimal animal performance and well-being, as these micronutrients are involved in critical physiological processes. However, mammals and birds lack the ability to internally synthesise these vital organic molecules, requiring their feed inclusion (Shastak and Pelletier, 2023a).

The global consumption of vitamins has reached staggering levels, with an estimated 460 000 metric tons being utilised annually, keeping animal feed as its largest consumer. Resulting animal proteins are an important contribution to the nutrition of the growing world population.

In this article, our main objective is to shed light on the latest trends and advancements related to animal nutrition, specifically focussing on the indispensable roles played by two significant fat-soluble vitamins: vitamin A, also known as retinol, and vitamin E, commonly referred to as α-tocopherol. These vitamins are of particular interest in the context of poultry and swine nutrition, as they have been found to exert profound effects on the overall health and performance of these animals.

Furthermore, we will briefly explore the topic of vitamin stability in premixes and the production of complete pelleted feed together with the importance of vitamin microencapsulation to address the specific needs of the active ingredient.

Retinol and α-tocopherol supply

Designing balanced animal diets that maximise the potential benefits of vitamins is extremely important, especially in practical conditions. Retinol, an essential animal micronutrient, plays a vital role in functions such as vision, immune system regulation and embryonic development (European Food Safety Authority, EFSA, 2013). Because of its critical involvement in immune modulation, it is also referred to as 'the anti-infective vitamin' or an immuno-micronutrient (Green and Mellanby, 1928; Shibley and Spies, 1934; Stephensen and Lietz, 2021; Shastak and Pelletier, 2023b).

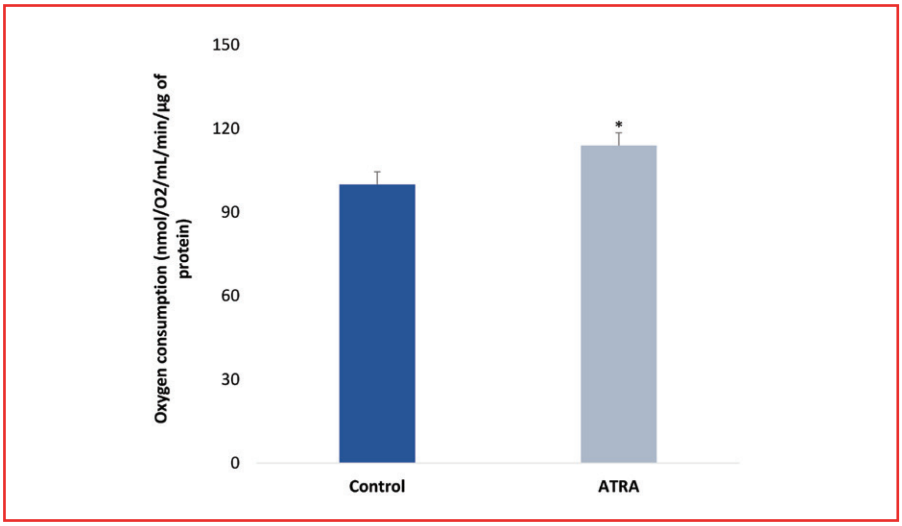
Similarly, α-tocopherol, known for its essential role in reproduction, is occasionally called the 'anti-sterility vitamin'. It also plays a crucial part in maintaining cell integrity and protecting cell membranes from oxidative damage (Xu *et al*., 2021). Ensuring optimal supplementation of these fat-soluble vitamins is vital to promote animal health, growth and productivity (Shojadoost *et al*., 2021).

Vitamin A deficiency in poultry can result in reduced growth rates, impaired immune responses and increased susceptibility to diseases (Guo *et al*., 2019; Yang *et al*., 2020; Li *et al*., 2022; Wan *et al*., 2022; Shastak and Pelletier, 2023b). Recent insights into the antioxidative capacity of vitamin A have emphasised the need for further research on the functions of fat-soluble vitamins, despite existing knowledge (Tourniaire *et al*., 2015, *Figure 1*; Brigelius-Flohe and Flohe, 2020). Additionally, inadequate intake of vitamin E can lead to muscular dystrophy, reduced hatchability and poor meat quality (Rengaraj and Hong, 2015; Kanat and Cerci, 2022).

By incorporating optimal levels of retinol and α-tocopherol in poultry diets, producers can enhance bird performance, immune function and overall welfare (Idamokoro *et al*., 2020; Shastak and Pelletier, 2023a, b). Furthermore, understanding the interactions between these vitamins and other nutrients is crucial for achieving optimal efficacy.

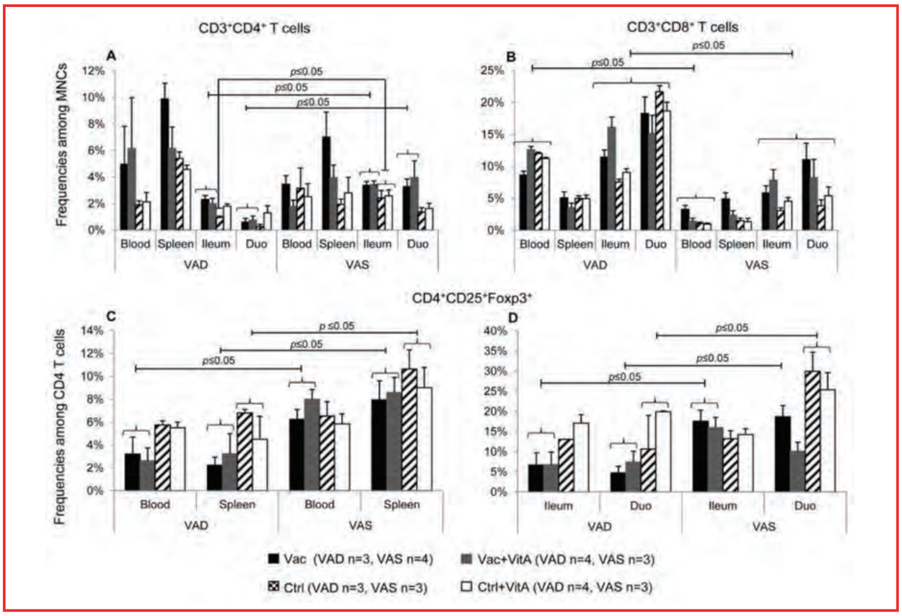
Swine nutrition also presents unique challenges, particularly in modern intensive production systems. Vitamin A deficiency in swine can result in impaired reproductive performance, disrupted haematopoiesis and compromised

Figure 1: Oxygen consumption in adipocytes.



*Oxygen consumption in adipocytes exposed to 2µM of all-trans-retinoic acid (ATRA: a biologically active form of vitamin A) was measured using Clarke's electrode (adapted from Tourniaire et al., 2015). Control refers to control cells, which received the vehicle (dimethyl sulfoxide). Data is the mean ± SEM of three independent cultures per treatment condition. The assessment compared ATRA-treated cells to untreated cells and measured their oxygen consumption rates to determine if ATRA-induced gene expression changes altered cellular metabolism. ATRA increased oxygen consumption by 15% (*P < 0,05) (doi:10.1194/jlr.M053652).*

Figure 2: Vitamin A in swine post-rotavirus challenge.



Following a human rotavirus (RV) challenge, the groups that were both vaccinated and had sufficient levels of vitamin A exhibited higher levels of intestinal and systemic T regulatory cells (Chattha et al., 2013). The graph compares frequencies of T helper cells (CD3+CD4+; A), cytotoxic T cells (CD3+CD8+; B) and regulatory T cells (CD4+CD25+Foxp3+; C,D) in vitamin A deficient and sufficient pigs; MNCs=mononuclear cells. Pigs were vaccinated with attenuated human RV (AttHRV) vaccine or given a placebo, with or without vitamin A supplementation. Data was collected from blood, spleen, ileum and duodenum post-RV challenge. Bars show mean values and standard error of the mean, with capped lines indicating significant differences (p ≤ 0,05). Lables: Vac=AttHRV vaccinated, Vac+VitA=AttHRV vaccinated + vitamin A, Ctrl=non-vaccinated/non-vitamin A pigs, Ctrl+VitA=vitamin A only (doi.org/10.1371/journal.pone.0082966.g005).

immune function (Chattha *et al*., 2013, *Figure 2*; Shastak and Pelletier, 2023a).

Significantly, it has been revealed that perturbed haematopoiesis can occur in both humans and neonatal piglets as a consequence of vitamin A deficiency (Shastak and Pelletier, 2023a). Similarly, insufficient levels of vitamin E can cause muscular disorders, reproductive problems and reduced piglet viability (Wang *et al*., 2022; Papakonstantinou *et al*., 2023).

It is crucial to provide swine with well-formulated diets that include adequate levels of retinol and α-tocopherol to maintain animal health, reproduction and productivity (Lee and Han, 2018; Hartmann *et al*., 2020). Furthermore, considering the impact of these vitamins on meat quality and oxidative stability is essential for meeting consumer expectations (Xu *et al*., 2021; Chen *et al*., 2022).

Quantifying vitamin losses

While formulating diets with appropriate vitamin levels is crucial, understanding the vitamin losses incurred during storage in a premix or the feed manufacturing process is equally important. A recent study (Hirai *et al*., 2023) highlights the significance of characterising and quantifying vitamin A losses at all stages of feed production, including storage in the premix or after the pelleting process.

These losses can occur due to various factors such as exposure to heat, moisture, oxygen, and interactions with other premix and feed ingredients. Accurately assessing and minimising these losses can ensure that animals receive the intended levels of vitamins, optimising their nutritional status and well-being.

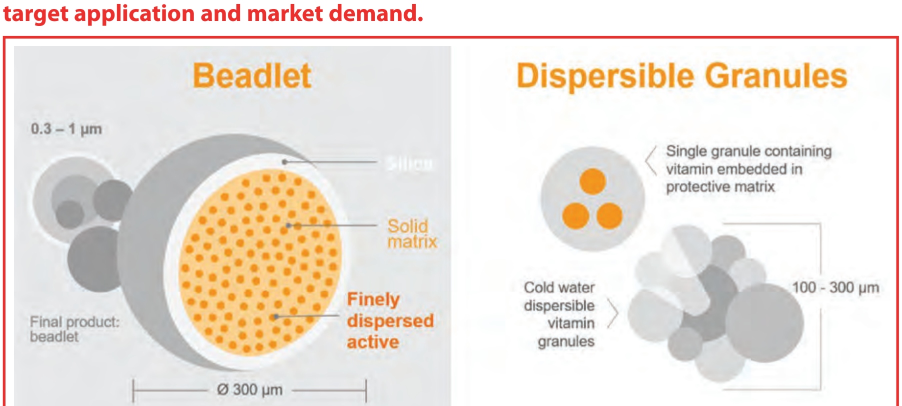
In addition, advanced vitamin microencapsulation heavily increases the stability of the active ingredient due to the longer time needed for oxygen diffusion, maintaining integrity even under challenging pelleting conditions (*Figure 3*).

Conclusion

It is crucial to optimise the supplementation of fat-soluble vitamins, such as retinol (vitamin A) and α-tocopherol (vitamin E), to promote the development and well-being of animals. This is particularly important in poultry and swine nutrition, where providing balanced diets that meet the animals' specific vitamin requirements is essential for maximising productivity, immune function and overall welfare. It is also vital to understand and minimise vitamin losses during the premix and feed manufacturing process to ensure that animals and birds receive the intended levels of these vitamins.

By implementing appropriate formulation techniques and employing strategies to minimise vitamin losses, producers can significantly enhance animal nutrition and contribute to the overall health and well-being of animals.

Figure 3: Microencapsulation delivers a spectrum of products with the active ingredient embedded in a protective matrix with specific characteristics for each target application and market demand.



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Coccidiosis management in broilers: A comparative *in vivo* study between 100% botanical-based active compounds and conventional coccidiostats

By Dr Mohammed el Amine Benarbia, R&D manager, Nor-Feed SAS (France)

As the intensity of broiler chicken production increased, it brought forth several challenges to productivity, with coccidiosis being one of the major concerns. This disease is caused by a parasitic organism called *Eimeria*, which belongs to the apicomplexan group (Shivaramaiah *et al*., 2014). Infestation of birds by this parasite significantly impairs their growth performances, resulting in reduced bodyweight and decreased feed efficiency. Additionally, it negatively impacts the overall health and welfare of the birds (Butterworth and Weeks, 2009).

Apart from the health and welfare implications, coccidiosis also imposes a considerable economic burden on poultry producers. This impact is attributed to the expenses associated with chemoprevention measures and the losses incurred due to reduced growth performances in infested birds (Dalloul and Lillehoj, 2006; Chapman, 2009). According to Blake *et al*., the estimated cost of managing coccidiosis amounts to approximately US$0,21 per bird (Blake *et al*., 2020).

The poultry industry has effectively utilised synthetic molecules for coccidiosis prevention, achieving high levels of productivity while effectively preventing the disease (Chapman, 2009). However, the extensive use of these synthetic compounds over the years has resulted in the emergence of resistant strains of *Eimeria* worldwide (Peek and Landman, 2003).

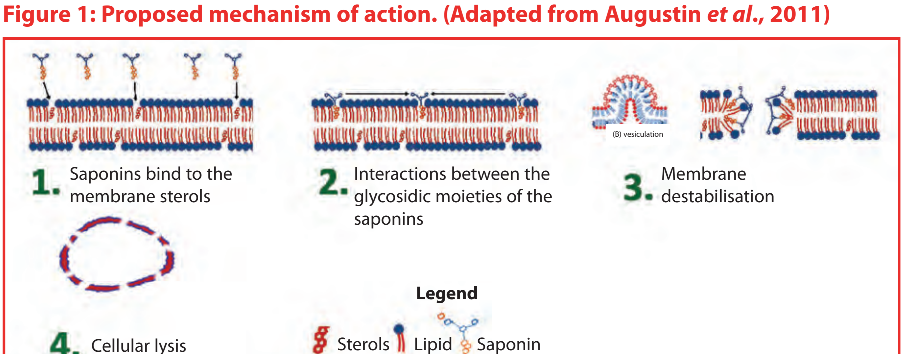
Additionally, concerns about the residues of these molecules in animal products and the environment have arisen (Mortier *et al*., 2005). In light of these challenges, poultry producers are seeking efficient alternative tools to enhance their overall coccidiosis management strategies (Quiroz-Castañeda and Dantán-González, 2015).

Botanicals as a solution

Plant-based feed additives have emerged as interesting approaches to control coccidiosis in broiler flocks (El-Shall *et al*., 2022). Saponins, known for their ability to disrupt cellular membranes, hold promise as a potential solution for managing coccidiosis in broiler chickens (Bozkurt *et al*., 2013).

However, the perception of their effectiveness among poultry producers is not always as positive as conventional solutions based on synthetic molecules, as indicated by a recent market survey (internal data). This perception is mainly attributed to the scarcity of data providing evidence of their efficacy using standard experimental methods and a lack of understanding of their mode of action.

Figure 1: Proposed mechanism of action. (Adapted from Augustin *et al*., 2011)



The objective of this study was to generate scientific evidence regarding the effectiveness of Norponin XO2® (NPXO2), a patented formula based on *Yucca schidigera* and *Trigonella foenum-graecum*, in the management of coccidiosis. The aim was to evaluate the performance of NPXO2 in comparison to conventional solutions, specifically synthetic molecules (monensin, nicarbazin, salinomycin), and to demonstrate its potential as an efficient tool in coccidiosis management.

The study aimed to contribute valuable scientific data that could support the use of NPXO2 as a natural and efficient solution for coccidiosis prevention in broiler production.

In vivo coccidiosis trial

Two types of models were used for this evaluation: the experimental challenge model and the commercial conditions trial model. Each model has its advantages and its limits.

Experimental challenge model: This model offers the advantage of precise control over the infestation process. By using this model, we can ensure that all birds receive the exact number of parasites needed to replicate the undesirable effects of coccidiosis accurately. Another advantage is the possibility to have an untreated infested control. Thus, gives the possibility to confirm that the challenge model worked properly when a significant difference is obtained between the untreated uninfested control and the untreated infested control in performances and/or intestinal lesion score.

However, one significant drawback is that this model might be somewhat disconnected from the reality of coccidiosis infestations in commercial poultry houses. In commercial settings, infestations by *Eimeria* occur more

naturally and sporadically, not as massive and simultaneous as in the experimental challenge model.

***Commercial conditions trial model*:** The advantage of this model is its ability to closely mimic 'real-life' poultry farming conditions. The results obtained from this model have a higher likelihood of being reproducible in other commercial settings. However, in this model, it is very difficult to fully control the infestation process. Infestations occur naturally, and it cannot be ensured that all birds have encountered the parasite. Another challenge is that it is uncommon to have a group without any coccidiosis management treatment in commercial conditions.

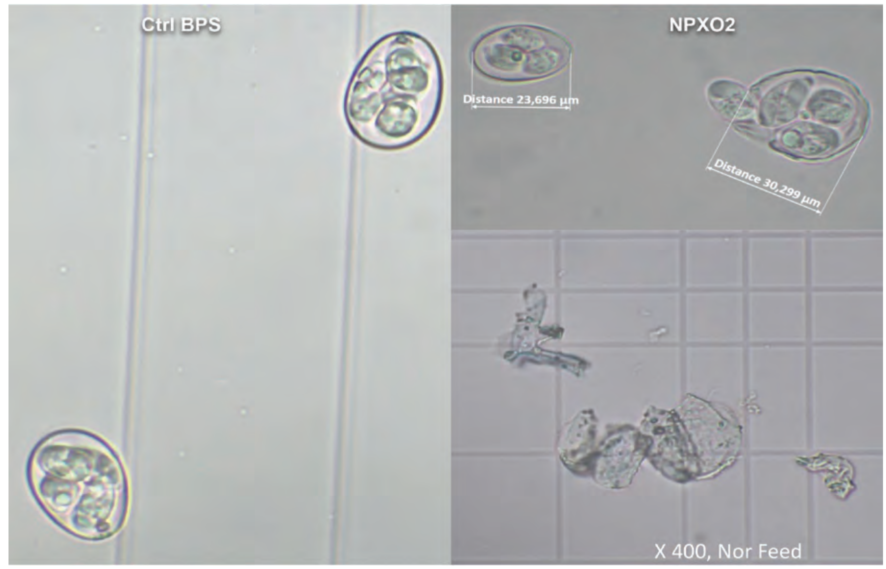
To strengthen the study's reliability and applicability, both models were combined, offering robust and reproducible results. By using the experimental challenge model, the efficacy of NPXO2 under controlled infestation conditions was precisely assessed. Additionally, by conducting the trial under commercial conditions, the study's findings become more relevant to real-world poultry farming scenarios. Thanks to the obtained results, it was shown that the patented saponin premixture supplementation (NPXO2) is as efficient as synthetic molecules in managing poultry coccidiosis.

Yucca schidigera and *Trigonella foenum-graecum* mechanism of action

The cited plants are rich in steroidal saponins. The structure of saponins consists of a hydrophilic sugar moiety and a hydrophobic steroidal or triterpenoid aglycone. This amphiphilic nature of saponins allows them to insert themselves into lipid bilayers, which are the main components of cellular membranes. The hydrophilic sugar part faces the aqueous environment, while the hydrophobic aglycone interacts with the hydrophobic tails of the lipid molecules in the membrane (sterols).

When saponins interact with cellular membranes, they can disrupt the integrity of the lipid bilayer. They create pores or micelles within the membrane, leading to increased permeability. This disruption alters the normal function of the cell membrane, affecting its selective transport of ions, nutrients and waste products.

Figure 2: Effect of Norponin XO2® (patented saponin-rich premixture) on *Eimeria* after two hours of incubation.



As a result, essential cellular processes are compromised, and the cell may eventually lyse or undergo cell death.

In addition to *in vivo* studies, an *in vitro* study was performed to assess the effect of NPXO2's saponins on the *Eimeria* membrane. Results from this study showed that the parasite membrane was altered after only two hours of exposure (*Figure 2*).

The observed alteration of the parasite membrane caused by NPXO2's saponins is of significant importance in the context of coccidiosis management. By targeting the parasites' membranes, saponins interfere with their normal physiological processes, leading to the disruption of their homeostasis and eventual death.

Botanicals yes, but not without standardisation

Saponins from the patented formula of NPXO2 based on *Yucca schidigera* and *Trigonella foenum-graecum* are promising natural feed additives in animal nutrition, including poultry production, due to their potential benefits in improving gut health and providing protection against coccidiosis. However, it is crucial to emphasise the importance of standardisation when using these plant-based solutions.

Standardisation refers to the process of ensuring consistent and reliable levels of active compounds in the plant extract or product. The concentration of saponins can vary significantly depending on factors such as the plant's species, part used (leaves, seeds, roots, etc.), harvesting period and processing methods. Inconsistent levels of saponins can lead to variable results and efficacy, making it challenging to compare different studies and draw accurate conclusions.

For optimal and reliable results, it is essential to standardise the saponin-rich plant extracts used in animal nutrition. This involves carefully selecting the appropriate plant source, harvesting at the right stage of growth, and employing consistent extraction and purification methods. By standardising the saponin content, we can better control the doses administered to the animals and ensure consistent effects on gut health, coccidiosis management and other targeted outcomes.

Standardisation also helps to address the concerns of poultry producers regarding the efficacy of plant-based solutions compared to conventional synthetic molecules. When saponin-rich plant products are accurately standardised, poultry producers can have more confidence in their effectiveness and incorporate them into their coccidiosis management strategies with greater assurance.

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Precision feed formulation: Strategies to utilise marginal raw materials to drive production efficiency

By Dr Thomas Tylutki, CEO, AMTS LLC

Remember the days when feeding dairy cows or feedlot cattle or sheep was easy? Maize silage, lucerne hay, ground maize, chop, soya, veld, a mineral pack and be good to go. What happened? Competition for resources. Be it human food directly, biofuels, changing climate, regulations, etc., the ruminant industry has had to evolve and adapt. One (of many) beautiful things about ruminants is their ability to convert non-monogastric species edible ingredients to high-quality protein sources.

Let us be clear – feeding by-products (co-products) and other marginal raw materials is nothing new to the ruminant industry. For example, from maize we have ground maize (non-human grade), gluten feed and gluten meal (from high fructose syrup production), hominy ('American' grits production), chop ('African' grits production), germ meal (oil extraction), distiller grains (from either ethanol or whiskey production), and starch (off spec from processing for human grade). Many of these materials are produced in such large volumes that guaranteed specifications have been developed.

Many by-products are regional. Examples I have fed or seen fed include cotton burrs (basically lint, leaves, stems and dirt), peanut hulls, whole oranges, soya sauce by-product, tofu by-product, candy (gummy worms, lollipops, etc.), yeast fermentation residue, maize stover, oat hulls, grain screenings, green beans, tomatoes, potatoes in various forms, and many more. A memorable one I fed was dog food to lactating dairy cows!

Risks

We can classify risks in three categories: logistics/availability, non (or anti-) nutritional factors and nutritional.

Logistics/availability

We all know the importance of diet consistency. What happens when that load of wet brewer's grains does not show up? Or apple pomace? Or you get the phone call "the plant is going to shut down for ten days for maintenance". How many people have 'emergency' diets to address the 'no-show' days? We can see the impact as milk production will vary the next day.

Small by-product producers are a massive challenge. For example, if only one ton of by-product is produced per week, is it worth the hassle? It depends. Remember, there is no such thing as 'free'. Be it trucking, inconsistent supply, variable availability, handling, potential waste disposal – costs are added.

Non (anti-) nutritional factors

This is the largest animal health risk. The simplest component are mycotoxins. Off spec grains, bin cleanouts and grain screenings are the top of the mycotoxin risk list. There are companies in the United States (US) that deal exclusively in distressed grains, plant cleanouts, etc. Almost all of it enters the animal feed market. The question people must ask themselves is if the financial reward is large enough.

Mycotoxin control/binding can be extremely expensive and can quickly displace any feed cost savings. As an example, assume maize is R3 960/t and someone offers distressed maize for 70% market price (R2 772). Feeding 4kg would reduce feed cost with R4,76 per cow. Without considering any difference in nutritional characteristics, adding R4,50 worth of mycotoxin control results in our feed cost savings per animal vanishing. Add to that losses in production, health, repro and the like and our 'cheap' maize is costing us substantially.

The most difficult component in this category is what we do not know. In the mid-1990s, while working for Extension, I received a panicked call from a dairy producer. His cows were urinating blood. Cows appeared normal with no loss in milk production. The herd veterinarian was perplexed.

Speaking with the feed company, a small family-owned business that specialised in sourcing small batch by-products, we learned other farms were starting to observe a similar issue. They recently brought in a new protein meal: mustard seed meal. Upon investigating, we learned mustard (a member of the brassica family) has many non-nutritional compounds including glucosinolates.

Glucosinolates degradation leads to liver, kidney, and thyroid hypertrophy. The better the quality mustard (i.e. stronger taste), the higher the glucosinolate concentration. The feed company had purchased the highest quality mustard meal possible. Cows recovered relatively quickly upon removing the mustard meal from the diets. Now, when presented with an unfamiliar alternative raw material, I spend a significant amount of time researching it for non/anti-nutritional factors.

Nutritional risks

Nutritional attributes are the largest risk. We are routinely asked to help define a by-product. Historically, this was simple: find a similar product or submit a series of samples for basic analysis (crude protein, NDF, fat, ash). This has become more difficult (and expensive) as our nutritional understanding has evolved.

Suddenly the analysis has expanded to include fatty acids, aNDFom digestibility (dNDF), protein intestinal digestibility, amino acids and more. Worse, given many analytes' correlations, simple averages are invalid. Thus, where we felt comfortable with three to five samples to 'define' a feed, ten times those amounts may be required now. As an example, let us evaluate two feeds using data from two commercial labs (DairyLand an DairyOne) in the US.

Figure 1 illustrates the distribution of aNDFom (% dry matter [DM]) and the 12, 72, 120hr dNDF %aNDFom for wet maize gluten feed. aNDFom %DM averaged 36,7% (±6,4); values consistent with what 'tabular' values. The darker bars represent the samples where the dNDF 120hr was greater than 90%. Notice where those same samples are in the aNDFom and 12hr dNDFom graphs: distributed throughout the data. Determining correlations for these components we find aNDFom and 12hr dNDFom are poorly correlated (r=0,32). Between 12hr and 120hr dNDFom, r=0,36.

Canola/rapeseed meal is typically considered a uniform raw material. Data from DairyLand Labs illustrates crude protein uniformity (*Figure 2 a*). Intestinal protein digestibility (*Figure 2 b*) varies tremendously.

To illustrate the impact, an example diet was formulated in AMTS.Cattle.Professional (version 4.18.4) for a mid-lactation dairy cow producing 35kg. Wet maize gluten feed or canola meal was included at 10% of DM (2,3kg). Changing gluten feed dNDF values representing the lower values from *Figure 1* and then the higher values suggest ~0,25kg variance in energy and protein allowable milk. With canola meal, low intestinal protein digestibility predicted 35,4kg milk versus high digestibility predicting 39kg. These are considered 'standard' raw materials, yet we formulate with imperfect data.

How can we manage this nutritional risk? First is sampling using the correct analysis. We no longer can rely solely upon basic chemistry (crude protein, NDF, fat, etc.). We must fully implement newer analysis (dNDFs, intestinal digestibility, fatty acids, etc.). The analyses selected must be related to what the raw material brings to the formula. For example, a protein meal may require intestinal digestibility and amino acids whereas a low protein by-product (e.g. apple pumice) would require sugar and dNDF timepoints.

Figure 1: Distribution of wet maize gluten feed aNDFom (%DM), 12, 72, and 120hr dNDF.

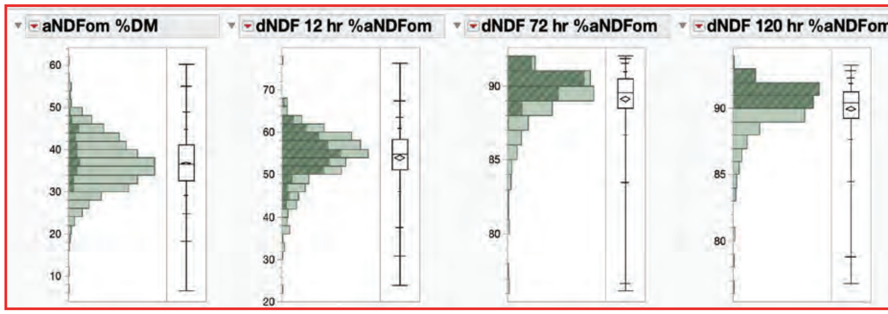
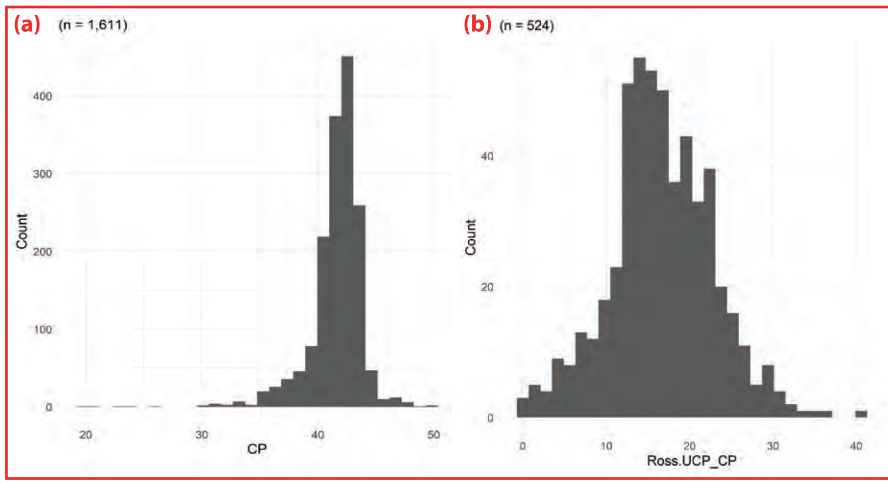


Figure 2: Canola/rapeseed meal distributions for crude protein %DM (a) and intestinal indigestible protein %CP (b). (Source: DairyLand Laboratories)



Adequate samples must be collected to determine overall variance and variance by supplier. We have observed many times between supplier variance being equal, or greater, then within supplier. Home mixers can be particularly vulnerable to these variabilities. This is due to people not sampling incoming raw materials. Additionally, home mixers typically have a limited raw material selection on-farm. Thus, larger amounts of individual raw materials are used versus a blend increasing animal production variability. Blends tend to smooth the variability making a more nutritionally consistent feed.

There is no standard recommendation relating to raw material sampling frequency. Frequency depends upon raw material usage and nutrient variability. This is site dependent.

There are other risk management strategies to consider as well. Some (DCAD, yeast, trace mineral/vitamin supplementation) are used routinely. Inclusion rates and sources should be evaluated routinely.

Summary

Ruminant animals are natural recycling systems. Our reliance upon by-products and marginal raw materials allows us to provide high-quality human food in environmentally beneficial ways. Risks exist, but generally are manageable via planning and appropriate feed analysis. Feed producers (companies and home mixers) need to recognise risks, develop SOPs/budgets, and conduct appropriate feed analysis.

For more information, send an email to tom@agmodelsystems.com or visit *www.agmodelsystems.com*.

Reducing systemic inflammation in dairy cows

Dairy cows in transition face high nutritional demands immediately after calving, often creating a state of negative energy balance (NEB) during the time before the impact of high-energy post-calving diets take effect. This can cause cows to struggle in terms of milk production and body condition, with metabolic disease pressures, such as subclinical ketosis, presenting a major health challenge.

At the same time, most cows can exhibit systemic inflammation with no clear signs of infection. This inflammation might be triggered partly by the NEB, but is assumed to be related also to calving stress and associated physiological changes which can lead to suboptimal immune function and inadequate immune activation.

NEB and systemic inflammation around calving can cause cows to struggle with milk production, reproductive performance, body condition and pressure of infectious diseases. An abnormally increased concentration of non-esterified fatty acids (NEFA), β-hydroxybutyrate (BHBH) and inflammatory biomarkers such as haptoglobin (Hb) in the blood may reflect a status of systemic inflammation.

Main parameters and consequences

Systemic inflammation plays into this high-stress period. While it is an immune response that is beneficial in recruiting innate immune cells as a defence against bacterial growth, inflammation still comes at a high energy cost to the animal.

Research data shows that cows with systemic inflammation require an average of 1kg more glucose during a 12-hour period than cows that are free of inflammation. To mitigate these negative outcomes, actions are required to reduce systemic inflammation after calving to help promote faster metabolic adaptation and higher milk production in affected cows.

The challenge for dairy producers is to quickly and effectively deliver essential nutrition to transition cows. Researchers at Phileo by Lesaffre addressed this requirement by examining the impact of adding the yeast probiotic, Actisaf Sc 47, to transition diets.

Recent scientific studies have clearly identified the benefits of supplementing a yeast probiotic during transition at a rate of 10g/cow/day, as well as in early lactation at a rate of 5g/cow/day, resulting in reduced systemic inflammation.

Performance and rumen health

In a recent study, where Actisaf Sc 47 supplementation was at 10g/cow/day, results clearly demonstrated improvements in energy balance and performance, culminating in an average milk production increase of +2kg/cow/day.

Significantly lower concentrations of blood Hb and BHB levels in the Actisaf Sc 47 group (*Table 1*) also reflected a reduction of lipo-mobilisation processes and systemic inflammation and a lowering of the risk of sub-clinical ketosis.

A second study, where Actisaf Sc 47 supplementation was at 5g/cow/day, focussed on rumen fermentation and serum metabolic profile, with measurements taken from weeks three to 19 of lactation. Results showed beneficial effects on rumen health, with rumen lactate levels being significantly reduced.

This led to the conclusion that Actisaf Sc 47 helped to reduce acidosis risk in cows fed a basic/rich-concentrate ratio. The study also clearly demonstrated a reduction of lipo-mobilisation and systemic inflammation during early lactation, with blood concentration of NEFA and BHB being reduced significantly in the Actisaf Sc 47 group (*Table 1*).

The improvement of ruminal fermentation within the Actisaf Sc 47 group, alongside reduced systemic inflammation, created an increased energy supply for milk production. These results explain why average milk production increased by +1,6kg/d in the Actisaf Sc 47 group.

Positive impact

Both studies showed that the yeast probiotic supplement helped to improve energy status and metabolism, thereby increasing the supply of energy for milk production. In addition, both factors were seen as impacting positively on reproductive performance, as reported in another recent study, based on a major French analysis, spread over three years, and involving 14 dairy farms and approximately 2 500 dairy cows.

Compared with a control group, cows in this study, which were supplemented with the yeast probiotic during transition, had a significantly higher artificial insemination success rate – 38 vs 34%; a significantly higher first insemination success rate – 46 vs 31%; and a significantly lower number of inseminations per pregnancy – 2,7 vs 3,1.

This led to the overall conclusion that Actisaf Sc 47, given as a daily supplement to high-yielding dairy cows, helped to reduce the risk of systemic inflammation, mitigating negative energy balance in the process, and impacting physiological parameters during transition and the subsequent lactation, all of which explains the better productive and reproductive performance of supplemented cows.

Table 1: Effects of Actisaf Sc 47 on cows' systemic inflammation and milk production. (Source: Study 1: Minuti *et al*., 2018; Study 2: D Kumprechtova *et al*., 2019)

Study 1 during transition period					Study 2 during early lactation			
Blood concentration	Control	Actisaf Sc47	P value		Blood concentration	Control	Actisaf Sc47	P value
Hb (g/L)	0,78	0,41	P<0,05		NEFA (Mm)	0,48	0,4	P<0,05
BHB (mmol/L)	1,24	0,57	P<0,05		BHB (Mm)	0,58	0,47	P<0,01
Average milk yield (kg/day)	33,8	35,8	P<0,05		Average milk yield (kg/day)	37,4	39	P<0,05

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Maintenance of gut health in cattle

By Prof Gregory B Penner, centennial enhancement chair in ruminant nutritional physiology, Department of Animal and Poultry Science, University of Saskatchewan

The gastrointestinal tract (GIT) is a key organ system regulating feed intake, feed digestion and passage, nutrient absorption, host-microbial communication, and must limit permeation of antigens and pathogens into lymphatic and systemic circulation. Maintenance of the GIT to perform these functions has a large metabolic cost estimated at 20 to 30% of consumed energy (Cant *et al*., 1996). Not surprisingly, nutrient intake consequently alters the size and function of the GIT.

Significant research has been conducted to explore factors that stimulate proliferation of the ruminal epithelium as a key region of the GIT, and early research demonstrated that providing diets with greater fermentability stimulated surface area enlargement of the ruminal papillae, along with increased rates for absorption of short-chain fatty acids (SCFA) (Dirksen *et al*., 1985). It is well known that SCFA, particularly butyrate, have a stimulatory role to promote development of the whole GIT (Ploeger *et al*., 2012; Gorka *et al*., 2018).

Interestingly, while ruminal supply of butyrate is expected to increase as diet fermentability increases, providing added butyrate in milk replacer for calves and infusing butyrate into the abomasum for growing cattle (Watanabe *et al*., 2023) stimulates development of the whole GIT including the rumen; a region proximal to the butyrate supply.

Despite knowledge on factors that stimulate proliferation, increases for size of tissues within the GIT and expansion of regional surface area are relatively slow to occur, with estimated timelines ranging from four to eight weeks for maximal papillae absorptive surface area (Dirksen *et al*., 1985; Bannink *et al*., 2008; Etschmann *et al*., 2009) suggesting these are longer-term adaptive responses. To compensate, cell activity, at least in the reticulo-rumen, increases rapidly (within one week) to partially facilitate greater nutrient absorption (Etschmann *et al*., 2009; Schurmann *et al*., 2014) independent of the morphological adaptation (Gabel and Aschenbach, 2007).

While proliferative adaptation has been well investigated, few studies have evaluated retrogressive adaptation of the GIT and the subsequent recovery required.

Effects of LFI on GIT function

Beef and dairy cattle are often, albeit inadvertently, exposed to periods of low feed intake (LFI). An example of a transient period of LFI is dairy calves during the weaning transition where the increase in starter intake may not compensate for the reduction in milk or milk replacer DMI (Wood *et al*., 2015). It has been reported that abrupt weaning procedures reduce the barrier function of the GIT (Wood *et al*., 2015; Fischer *et al*., 2019; Pisoni *et al*., 2022).

Newly received beef calves certainly experience extended periods of LFI. For example, Hutcheson and Cole (1986) reported that calves in the first, second, and third week after arrival at a feedlot often only consume DM at a rate of 0,5 to 1,5; 1,5 to 2,5%; and 2,5 to 3,5% of BW respectively. Thus, newly received cattle experience an extended duration of LFI and variable extents for the magnitude of intake depression (Hutcheson and Cole, 1986; Loerch and Fluharty, 1999).

Transition dairy cattle also experience LFI around calving. In fact, a literature review reported that the severity of FR ranges from a reduction of intake up to 68% on d1 pre-partum relative to d21 pre-partum for dairy cattle (Hayirli *et al*., 2002). Although the range in LFI is large, on average, cattle reduce their feed intake by 33%, with nearly 90% of that reduction occurring in the last week prior to calving and these findings continue to be supported (Penner *et al*., 2007; Janovick and Drackley, 2010).

The extent of LFI can be exacerbated for transition cows in association with infectious diseases or metabolic and digestive disorders (e.g., displaced abomasum, ketosis; Van Winden *et al*., 2003; Goldhawk *et al*., 2009) and numerous studies have been able to identify associations between risk for metabolic disease and low feed intake pre-partum (Huzzy *et al*., 2009).

Environmental conditions can also induce LFI. Heat stress has been reported to lead to marked reductions in DMI (Maust *et al*., 1972; Knapp and Grummer, 1991; Holter *et al*., 1996) with the magnitude based on the severity of the heat stress exposure (Baumgard *et al*., 2011; Wheelock *et al*., 2010).

SCFA and ruminal pH

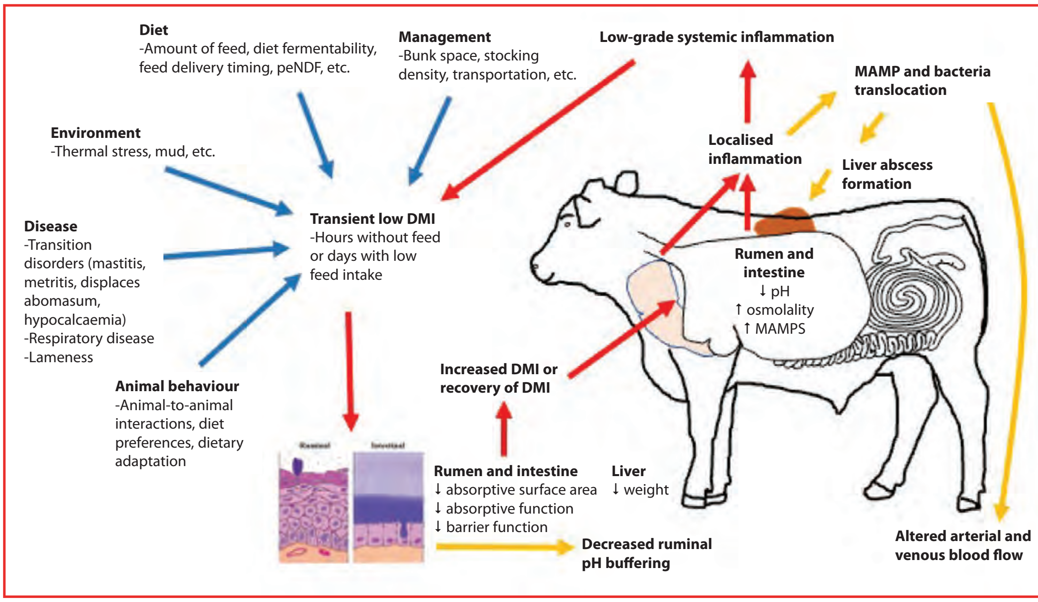
Although LFI may be transient, past studies in sheep have demonstrated that short-term periods of complete feed deprivation (48 hours) can reduce the transport of Na^+, Cl^-, Mg^2+, and SCFA by approximately 50% (Gäbel *et al*., 1993). With respect to barrier function, Gäbel and Aschenbach (2002) demonstrated that the passive passage of a small hydrophilic molecule (3-O-methyl-α-D-glucose) was increased following feed deprivation in sheep.

More closely resembling production scenarios, Zhang *et al*., (2013a) assessed the effect of differing severities of LFI by restricting cattle to 75, 50, or 25% of their *ad libitum* DMI for a five-day duration followed by three weeks of *ad libitum* consumption of the same diet. In response to LFI, the concentration of SCFA in the rumen decreased in a dose-dependent manner as heifers restricted to 75% had concentrations that were less than when fed *ad libitum*, heifers restricted to 50% were less than 75%, and those restricted to 25% had concentrations less than those restricted to 50%.

Corresponding to the reduction in DMI, there was a dose-dependent increase in mean ruminal pH, with greatest increases occurring with the most severe LFI. The consequence of the LFI resulted in a tendency for reduced SCFA absorption across the reticulo-rumen and the rate of absorption tended to be reduced as the severity of the LFI increased. Moreover, permeability of the GIT was increased for heifers exposed to 25% of their *ad libitum* intake. A second study (Albornoz *et al*., 2013a,b) also reported that exposure to LFI (25% of *ad libitum* DMI) reduced SCFA concentration in the rumen, increased ruminal pH, and reduced SCFA absorption across the reticulo-rumen.

It should be recognised that not only did exposure to LFI reduce dietary nutrient supply, but capacity for nutrient absorption was also compromised and permeability was increased. This suggests that exposure to low feed intake, regardless of the cause (i.e. weaning, heat stress, parturition, transportation, etc.), is likely to reduce metabolisable energy and protein absorption and may predispose cattle to systemic inflammation (*Figure 1*).

Figure 1: Potential causes of transient LFI, and the effect that transient LFI has on the GIT and risk for secondary disorders.



Nutrient absorption

Investigation into causes for the reduced potential for nutrient absorption and barrier function have revealed rapid retrogressive adapational responses as the primary candidate. For example, Pederzolli *et al*. (2018) reported that the absorptive surface area of the ruminal epithelium was reduced by almost 60% within five days of being restricted to 25% of voluntary feed intake. Others have also reported that exposure to LFI decreases intestinal absorptive surface area (Kvidera *et al*., 2017) and increases permeability (reduced barrier function) of the GIT (Horst *et al*., 2020).

More recently, an investigation was conducted into regional impacts and while unpublished, it appears that heat stress initiates a reduction in barrier function that is primarily driven by increased intestinal permeability (Bertens *et al*., unpublished), and a similar response occurs for LFI challenges such that permeation across the intestine appears to have increased (Lambert *et al*., unpublished).

More recently, we have observed that the rate of retrogressive adaptation is rapid as lambs exposed to five or ten days of LFI had a lighter abomasum, colon and liver, and tended to have lighter reticulo-rumen, duodenum, jejunum, and ileum weights (Lambert *et al*., unpublished). This is the first data known to document changes throughout the GIT and highlight that total splanchnic tissues adapt rapidly to reduced nutrient supply.

It is likely that these are conserved evolutionary adaptations to minimise energy consumption and thereby maintenance energy requirements when feed availability is low; however, under intensively managed production systems, it is likely that these retrogressive adaptations increase risk for secondary diseases and disorders. It should also be noted that diseases and disorders likely induce LFI (*Figure 1*).

Recovery after LFI

While it is clear that LFI reduces aspects of GIT function, there is a paucity of data evaluating recovery after LFI. Zhang *et al*. (2013b) reported that heifers exposed to LFI at 25% of their voluntary intake required three weeks to return to pre-LFI DMI, while those restricted to 75% of their voluntary intake only required one week. This suggests that in the absence of other challenges (parturition, weaning, heat stress, etc.), the severity of LFI can affect the recovery rate for DMI.

During recovery, it also appears that cattle are at high risk for ruminal acidosis despite still having LFI and being fed a moderate forage diet (Zhang *et al*., 2013b; Albornoz *et al*., 2013b). It is likely that increased risk for ruminal acidosis is a result of reduced SCFA absorption and delayed recovery as the severity of LFI increases (Zhang *et al*., 2013a,b; Albornoz *et al*., 2013a,b). This data collectively suggests that cattle may require up to three weeks for the GIT function to recover after exposure to LFI, depending on the severity of the LFI event.

Given that greater severity of LFI required more time for recovery, transition dairy cattle experiencing metabolic, or infectious diseases or feedlot cattle experiencing infectious disease will likely be affected to a greater extent. Moreover, as cattle start to return to their *ad libitum* intake, they are susceptible to ruminal acidosis, even with low initial feed intake and diets with a substantial forage content.

Conclusion

Transient exposure to LFI negatively affects absorptive and barrier functions of the GIT and reduces total splanchnic tissue weight. It appears that the majority of barrier function loss can be attributed to intestinal regions. Moreover, as cattle start to return to *ad libitum* intake, they are at high risk for ruminal acidosis.

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ALLIED NUTRITION
Nutraceuticals, by choice

Health-LinQ 2023: Where veterinarians and nutritionists collaborate

They say that the only constant in life is change and, in the past few years, this has certainly been proven true. The Covid pandemic has been a catalyst for change. In the agricultural industry, increased scrutiny has been directed at animal diseases, health, immunity, biosecurity, and how this impacts human health.

> The One Health approach is taking centre stage and the responsible and moderate use of antibiotics in South Africa is becoming a reality, independent of state regulations.

The Health-LinQ Conference held by Allied Nutrition in May 2023 highlighted the significant milestones that have been achieved in the measurable application of scientific concepts in animal production.

Epigenetics

Epigenetics examines the expression of desirable genes and allows us to understand how gene expression is influenced by environmental factors such as diet, stress and management practices. In addition, it provides the industry with a tool to develop improvement strategies for performance, health and welfare before the animal is even born.

Recent epigenetic papers include the effect of supplementing curcumin (an active found in Xtract Nature) on growth genes, stress markers and immunity of broilers under high stocking density (Hafez *et al*., 2022), or another on the impact of protein and amino acid level in the feed on fat deposition and marbling (Malgwi *et al*., 2022; Fonesca *et al*., 2023).

Maternal transfer

Maternal transfer of nutrients can also have a significant impact on animal production on the farm, as it can influence the health, growth and productivity of the offspring. Gong *et al*. (2020 and 2023) proved that feeding a blend of curcumin, beta carotene, allicin and sodium butyrate to the hens resulted in chicks that hatched with a stronger immune system and more stable microbiome. These chicks outperformed the group of chicks fed an antibiotic.

Further examples include the effect of dietary fibre on intestinal development, antioxidants on acquired immunity, and the source of zinc and selenium (minerals found in B Traxim) on growth rate and mortality (Wang *et al*., 2022; Mou *et al*., 2020; Li *et al*., 2022).

Microbial endocrinology

Microbial endocrinology allows us to understand how bacteria in the digestive tract respond to hormonal and stress molecules. This reaction can cause changes in microbial composition as well as changes in expression of virulence factors such as adhesins and toxins (Lyre and Lyte, 2019; Villageliu and Lyte 2017). Recent data also shows the impact that antibiotics have on the microbial community and their metabolites (Parent *et al*., 2020; Da Silva Pires *et al*., 2022; Kairmi *et al*., 2022).

This insight allows us to make better managerial decisions: focussing on reducing stressful situations on-farm, reducing the need for antibiotics and focussing on the development of a microbiome replenishing programme post-antibiotic administration.

One Health

The One Health approach is taking centre stage and the responsible and moderate use of antibiotics in South Africa is becoming a reality, independent of state regulations. However, developing an economical strategy to reduce antibiotic usage in animal production which is specific to South Africa is a complex process with no single strategy that can be implemented across all farms overnight.

Health-LinQ
Where Veterinarians & Nutritionists collaborate

The Health-LinQ Conference held by Allied Nutrition allowed for the discussion of the scientific strides mentioned and highlighted the need for interdisciplinary co-operation between geneticists, nutritionists, veterinarians and producers. For more information on how we can shape the future of animal production, send an email to Allied Nutrition at technical@alliednutrition.com or visit our website at *www.alliednutrition.com*.

The first extensive biomarker survey of South African farms

By Dr Arnau Vidal, global technical manager: toxins and stress, Innovad (Spain)

Mycotoxins are toxic fungal secondary metabolites and they contaminate agricultural commodities during cultivation, harvesting, transport, processing and storage. Mycotoxins are present in a wide range of agricultural crops (rice, wheat, rye, barley, maize, soya beans, sorghum, nuts and spices) and feed products (Marin *et al*., 2013). Recent estimations pointed out that 80% of agricultural crops contain mycotoxins (Eskola *et al*., 2019).

Despite several prevention strategies on the field and adequate grain storage and transport, the presence of mycotoxins cannot be avoided. There is no doubt that livestock are highly and continuously exposed to mycotoxins causing adverse health effects and reducing animal performance and consequently causing an unavoidable huge economic impact.

Even low concentrations, below the limits described by the European Commission (EC) (EC 2002, EC, 2006, EC 2013), can have a significant effect on animal performance (Alizadeh *et al*., 2015).

Reliable exposure assessment

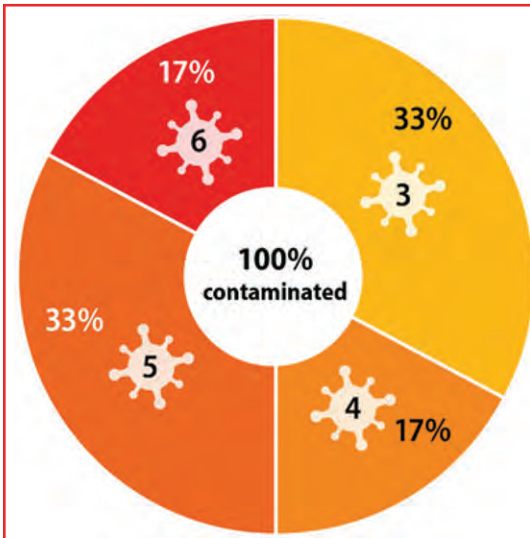
Therefore, it is of crucial importance to establish reliable tools to elucidate the real exposure. Up to now, feed analysis has been the main tool to monitor mycotoxin exposure. However, it is generally accepted that it is difficult to determine accurately and precisely the exposure because of the large variability associated with the overall test procedure in feed, mainly caused by sampling.

As feed analysis presents important limitations to performing an accurate and precise risk assessment, biomarker analysis has been proposed as an effective tool to assess the risk of exposure through an analysis of their metabolites in biological fluids. Recently a targeted UHPLC-MS/MS method including 36 mycotoxin biomarkers using dried blood spots was validated.

The method here allowed, for the first time, the possibility to analyse mycotoxin biomarkers on an industrial scale through small blood volumes. Thus, blood spots from 320 animals – 160 poultry (layers, breeders and broilers), 96 swine (fattening pigs) and 60 ruminants (dairy cows and sheep) – from randomly selected sub-Saharan African farms were analysed.

Moreover, feed consumed at the moment of blood collection was also analysed for 16 mycotoxins with LC-MS/MS to establish a more complete mycotoxin risk assessment. Also, a brief questionnaire to capture the health status was collected for each analysed farm. Results demonstrated that livestock is continuously exposed to multi-mycotoxins as all the studied animals were exposed to three or more mycotoxins simultaneously, and remarkably, 50% of them were simultaneously exposed to five or more mycotoxins (*Figure 1*).

Figure 1: Distribution of the total number of mycotoxins detected on each farm considering feed and blood analyses.



The large co-exposure is of concern as exposure to two or more mycotoxins has a synergistic negative toxic effect; in other words, the co-exposure has a higher toxic impact than individual exposure. Nine different mycotoxin biomarkers were detected in the blood.

Emerging mycotoxins

Enniatin B1 (65%) and tenuazonic acid (61%) produced by *Alternaria* and *Fusarium* spp. were the predominant ones, followed by deoxynivalenol (deoxynivalenol-sulphate in poultry and deepoxy-deoxynivalenol in ruminants), enniatin B and beauvericin, all of them produced by *Fusarium* spp. The persistent presence of emerging mycotoxins confirms the need to include emerging mycotoxins in the routinary control programmes as they are as toxic as famous or legislated mycotoxins.

If emerging mycotoxins are not controlled, a big part of the mycotoxin risk will be ignored. Additionally, biomarker analysis was able to uncover risks ignored by feed analysis, as in 60% of the cases blood analysis identified mycotoxin

Table 1: Trends between mycotoxin exposure and clinical symptoms detected on different farms.

Animal species	Detected symptom	Percentage of cases (%)	Mycotoxins detected
Poultry	Necrotic enteritis	81%	Deoxynivalenol + fumonisins
Poultry	Kidney	67%	Ochratoxin A
Poultry	Increased presence of other infections	83%	Deoxynivalenol + fumonisins + zearalenone
Swine (sows)	Agalactia	75%	Zearalenone

exposure missed in the latter. The requested questionnaire allowed us to detect trends between clinical symptoms and mycotoxin exposure. Interestingly, 81% of the poultry farms suffering necrotic enteritis were exposed to deoxynivalenol and fumonisins, while only 41% of the farms without necrotic enteritis were exposed to deoxynivalenol and fumonisins.

Recently, several scientific studies demonstrated that chronic exposure to deoxynivalenol and fumonisins at low concentrations increases the incidence of necrotic enteritis. Also, poultry farms suffering from kidney lesions were more exposed to mycotoxins (67%) than farms without kidney lesions (35%). It is well-known that the kidney is the target toxic organ for ochratoxin A. Another relevant trend was detected on poultry farms – on 83% of the farms with a higher susceptibility to other infections, birds were co-exposed to deoxynivalenol, fumonisins and zearalenone.

The co-exposure to deoxynivalenol, fumonisins and zearalenone was only detected on 23% of the farms without a higher susceptibility to other infections. All mycotoxins reduce the immune response and the co-exposure to the mentioned three mycotoxins could be the reason for the higher susceptibility to infections. Regarding swine farms, 75% of the swine farms exposed to zearalenone was suffering agalactia. Zearalenone is a well-known estrogenic mycotoxin and exposure to it could be the main reason for the agalactia episodes (*Table 1*).

All these detected trends confirm the importance of biomonitoring programmes to elucidate the real impact of mycotoxins on clinical symptoms.

In conclusion, the first-of-its-kind extensive mycotoxin exposure survey elucidated that livestock under real farming conditions are dominantly exposed to multi-mycotoxins and that biomarker analysis can be key in optimising animal health and performance and is an essential tool to optimise the mitigation strategies.

For more information, email the author at A.Vidal@innovad-global.com or visit *www.innovad-global.com*.

Saving energy in animal feed grinding and pelleting processes

By Arthur Vom Hofe, business segment manager, CPM Industrial Solutions

The concept of energy saving does not require an in-depth explanation, especially in South Africa where the shortage of electrical energy is noticeable on a daily basis. Globally, the feed industry is feeling the heavy burden of rising energy prices as well. But maybe more important than economic reasons is our personal responsibility to reduce our carbon footprint and work towards a more energy-efficient, sustainable, and environmentally friendly feed industry.

With this in mind, we will explore grinding and pelleting processes to highlight instances that can prevent energy wastage and even better, identify opportunities to save energy.

Firstly, we need to note the fact that a 250kW hammer or pellet mill costs R1,8 million in energy per year. This is based on R1,30/kW and we know that this price will increase. This means that the cost of energy consumption during the lifespan of the equipment may be 25 to 50 times the initial purchase price. Low initial cost (inefficient machines) will dramatically increase the life cycle costs of equipment. One might be surprised how short payback cycles can be when exchanging older inefficient machines for newer technology.

Roller versus hammer mill

Let us first focus on the grinding process. In the feed industry, this is typically done with a hammer or roller mill. A roller mill grinds by shear, provides a narrow particle size range, will leave fibres intact and uses a very low energy input. A hammer mill grinds by impact, provides a high fines content, grinds non-selectively but uses a high energy input.

Therefore, our first consideration is to decide what grinding process is used for what type of feed. For coarse grinding relatively brittle products such as grains and seeds, roller mill technology is the most optimal; for fine grinding fibrous materials the hammer mill is the best option.

Since the hammer mill is one of the larger energy consumers in a feed mill, let's focus on what is going on inside the machine and what performance parameters play a role in the grinding process. The speed differential between the particle and the tip of the hammer is of importance. The higher the speed differential, the larger the impact and the greater the particle size reduction effect. This means that hammer mills designed to maintain this speed differential are more efficient than others.

However, these machines are not a one-size-fits-all solution. Each grinding application has its own ideal design parameters such as speed, screen surface and hammer count. Selecting the wrong machine results in higher operational costs.

Another parameter, which is often underestimated, is the aspiration system. Filters that are too small or are clogged reduce the amount of aspiration air, resulting in an enormous loss of energy. Moreover, if the product has difficulty exiting the grinding chamber, it heats up, resulting in the loss of moisture.

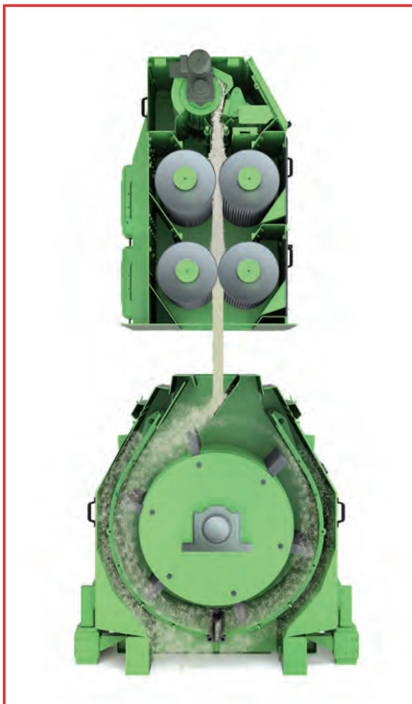
An aspect that wastes a lot of money is when non-original equipment manufacturer (OEM) parts are used, or used for extended periods, during the grinding process. The purchase price might seem attractive, but screens that have a low hole count or incorrect stagger have devastating effects on energy efficiency.

Being energy efficient

Another important factor to consider is the hammers. When there is wear and tear on a hammer, energy consumption increases, and particle size reduction widens. When making use of hard-faced hammers that have an extremely long lifespan, energy consumption is reduced, and grind consistency is improved.

The important thing to realise is that energy costs are usually ten times higher than maintenance costs, increasing by 50% when maintenance fails. Therefore, trying to save some cents on maintenance will cost more in the end.

Figure 1: The grinding process in a roller and a hammer mill.



When your current grinder is worn out, or its capacity is no longer adequate, or you have a requirement for a different machine, it is time to consider implementing the most energy-efficient system. This means a combination of a roller and hammer mill. The machines can be used in parallel to increase capacity, improve structure and increase flexibility. Another possibility is to implement a so-called step grinding system.

The roller mill will produce coarse mashes or will pre-break the materials before they are processed by the hammer mill. Pre-breaking the material with the roller mill before it goes to the hammer mill results in an energy saving of more than 25%. This also means that when placing a roller mill before an existing hammer mill, capacity is increased by 30 to 40%.

A positive aspect is that the lifetime of the hammer mill wear parts (and with it the consistency of the grind) is enormously extended (four times or more) due to the pre-breaking action of the roller mill.

The pellet mill

When looking at the pellet mill process, correct preparation (conditioning) is the starting point for optimal production. Steam is costly, so it is best for the conditioner to be fitted with a steam lock and for steam to be injected in a manner that allows for maximum absorption, thus heating the product and not the environment.

CPM introduced a new conditioning technology which makes it possible to fill the conditioner up to 70%. Due to the extensive mixing of product particles with liquids and steam, higher temperatures are possible. This results in improved pellet quality and lower energy and operational costs. Another benefit of the technology is that it allows for optimal product clean-out after each run. With the Hot-Start feature the line efficiency is improved, which is beneficial especially if frequent product changes are foreseen.

It goes without saying that the pellet mill should be fitted with a gear drive transmission, which is much more energy efficient than belt-type drives. Especially at higher motor powers, the savings surpass the total investment cost of the machine.

Fitting the pellet mill with (remote) roll adjustment gives you the flexibility to adjust the mechanical energy input from the pellet mill and optimise pellet quality. This is an excellent piece of equipment, and functions best when paired with a roll speed measurement system.

The roll speed measurement system prevents pellet mill chokes, reduces downtime, and increases efficient production capacity. Equally important is that this system prevents heavy roll contact with the die surface. This saves not only on die maintenance costs, but also on production and energy costs. When the surface of the die is in good condition, the capacity of the mill is much higher and energy consumption lower.

The die is the key factor in the pelleting process. Driven by quality demands, a mistake often made is installing on the machines a die that is too thick. This limits the temperature at which the feed can be pelletised, which results in higher energy costs and lower capacity.

We often see that the economic life of the die is gone before the end of its technical service life. Even worse is that overused, lower-cost roll shells will damage the surface of the much more expensive die.

Figure 2: Conditioning area in a pellet mill.

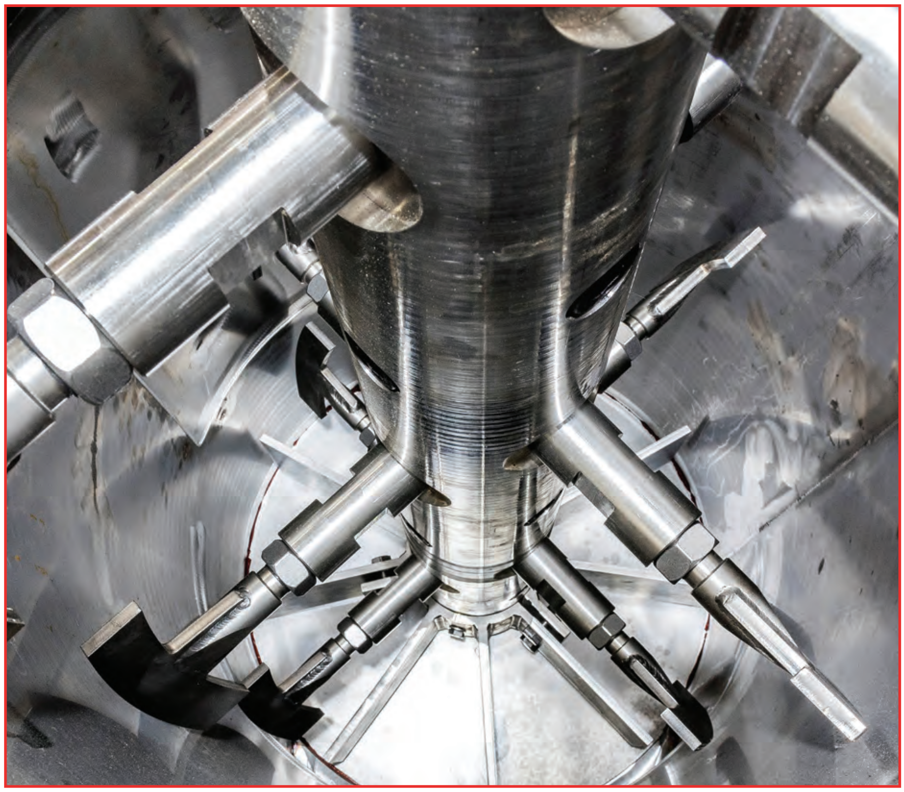
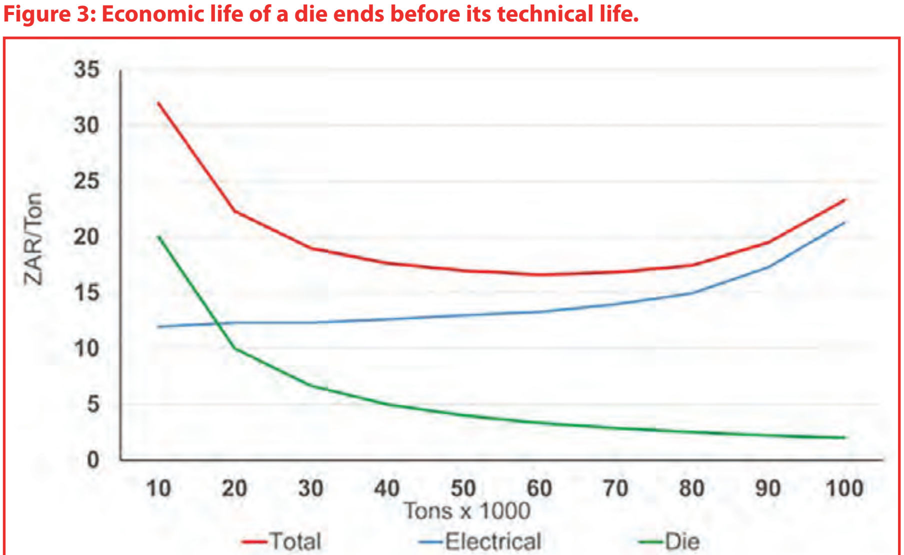


Figure 3: Economic life of a die ends before its technical life.



In conclusion

In a sustainable and competitive feed industry, it is essential to optimise production processes and reduce energy consumption where possible.❖

For more information, send an email to arthur.vom.Hofe@cpmeurope.nl, visit *www.cpmeurope.nl/en* or visit us at booth 35 at the AFMA Forum.

Twin screw extrusion:

A more appropriate food processing technology to combat load shedding

By Prof LJ Grobler, director of CFAM Technologies and professor in mechanical engineering, North-West University, Potchefstroom

Load shedding, which is a controlled power outage implemented by Eskom to prevent a total grid collapse, has become an unfortunate reality for many South Africans. Extrusion processors, specifically those involved in food production, are significantly affected by load shedding. These companies rely heavily on a consistent and uninterrupted power supply to maintain their operations. The erratic power cuts disrupt production schedules, lead to equipment downtime, product quality issues and financial losses, ultimately impacting their efficiency and profitability.

Extrusion plays a pivotal role in the food and feed processing industry, offering numerous advantages for product development and processing. It involves the application of heat, pressure and mechanical force to transform raw ingredients into a wide range of textured and functional food and feed products. It enhances digestibility, improves nutritional value, enhances texture and taste, facilitates ingredient blending, and provides efficient processing with high production rates, making it a valuable tool in the food and feed processing industry.

Extrusion in the food and feed processing industry is a continuous high pressure and temperature cooking process that offers remarkable efficiency and speed. Grains and pulses, such as maize, wheat, rice and soya beans, undergo rapid cooking within the extruder in a mere 30 to 40 seconds. This process involves subjecting the raw ingredients to elevated temperatures of up to 165°C and pressures of up to 200 bars while being mechanically sheared and mixed.

The combination of heat, pressure and mechanical force results in the gelatinisation of starches, denaturation of proteins, and structural transformations that contribute to the desired texture, flavour, and nutritional characteristics of the final product. The ability to achieve complete cooking within such a short timeframe is one of the key advantages of extrusion technology, allowing for high production rates and consistent product quality.

Impact of load shedding

Extruders used in the food and feed processing industry are highly vulnerable to load shedding. These machines rely heavily on a consistent and uninterrupted power supply to maintain their operations. Load shedding disrupts the stable power source required for extrusion, leading to various consequences.

Firstly, the sudden power cuts result in unexpected shutdowns, causing downtime and production delays. Restarting an extruder after a power outage requires time and resources, affecting overall productivity. This is especially true for single screw extruders. Secondly, the interruption in power supply leads to temperature fluctuations within the extruder, affecting the precise control required for cooking and shaping the food or feed products. This results in inconsistencies in product quality and texture.

Additionally, the halt in power supply may also cause ingredient blockages or jams within the extruder, leading to mechanical damage and further downtime for repairs.

Single and twin-screw extruders

Single and twin-screw extruders differ in their operation and capabilities. Single-screw extruders have a single rotating screw that transports and processes the material, relying on shear and pressure to process the product.

Twin-screw extruders feature two intermeshing screws and operate like a positive displacement screw pump. It provides better mixing, conveying and heat transfer capabilities. Twin-screw extruders offer higher throughput, improved process flexibility, enhanced product consistency, and better control over the extrusion process parameters, making them more suitable for a wider range of applications compared to single-screw extruders.

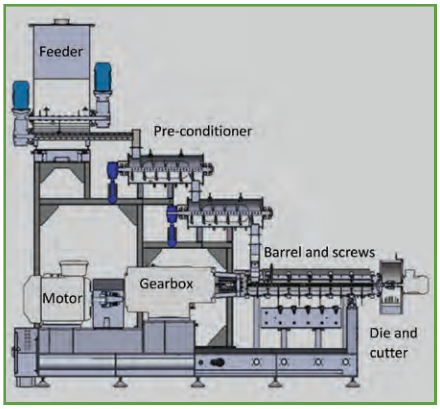
A twin-screw extruder consists of several key components that work together to process raw material and shape it into the desired product. The following main components are involved in the process (*Figure 1*):

- **Weight loss feeder** which precisely measures and controls the flow rate of raw milled material into the extruder. It ensures a consistent and accurate feed of the material.
- Raw material is fed into a **steam pre-conditioner**, where it is exposed to steam and heat. This process helps in softening the material, increasing its moisture content and improving its plasticity, which aids in better processing and shaping in the extruder.
- The softened material is then fed into the **barrel** of the twin-screw extruder. The barrel houses the two intermeshing **screws**. These screws are responsible for conveying the material, mixing it thoroughly, and applying shear and pressure to facilitate cooking, shaping and transforming the raw material.
- At the end of the barrel, the processed material is forced through a **die**. The die determines the shape and size of the final product. Simultaneously, a **cutter**, typically rotating at high speed, trims or cuts the extruded material into the desired lengths.

Latest technological advances

The latest advances in twin-screw extrusion technology have addressed the challenges posed by load shedding and interrupted

Figure 1: Twin-screw extruder layout with pre-conditioner, die and cutter assembly.



power supply, making it more suitable for regions facing such issues. Here are some notable advancements:

***Energy-efficient designs*:** These machines incorporate features such as advanced motor control systems, energy recovery systems, and optimised screw designs to minimise power consumption during operation. This ensures that the extruders can continue running efficiently even during power fluctuations or interruptions.

***Integrated power backup systems*:** Some twin-screw extruders now come equipped with integrated power backup systems. These systems include uninterruptible power supply (UPS) units or battery packs that provide a temporary power source during load shedding or power cuts. This allows the extruder to continue operating for a certain duration, minimising downtime and maintaining production continuity.

***Intelligent control systems*:** These systems can automatically adjust process parameters, such as screw speed, temperature and throughput, to compensate for power fluctuations. By optimising the extrusion process in real-time, these control systems help maintain product quality and minimise the impact of power interruptions.

***Remote monitoring and troubleshooting*:** Using sensors, data acquisition systems and connectivity technologies, operators can monitor the extruder's performance, diagnose issues remotely and implement corrective actions. This remote monitoring capability enables timely response and minimises the need for on-site technical assistance during power disruptions.

***Process optimisation for reduced downtime*:** Twin-screw extruders now feature improved designs that minimise downtime during power interruptions. Quick start-up and shutdown procedures, efficient cleaning mechanisms and easy maintenance access help to reduce the time and effort required to resume production after a power outage.

Smart control systems

The latest smart control systems in twin-screw extruders have been developed to enable automatic restarts after load shedding events when the power backup system becomes available within a short timeframe, typically two to three minutes.

Here's how these systems work:

- **Power monitoring:** The smart control system continuously monitors the power supply status. It detects load shedding events and registers the duration of the power outage.
- **Power backup activation:** When the power supply is interrupted, the control system activates the power backup system, which could be an uninterruptible power supply (UPS), a battery pack. The backup system provides temporary power to keep essential components operational during the outage.
- **Shutdown and safety measures:** Upon detecting a power outage, the control system initiates a safe shutdown process. It stops the rotation of the screws, halts the feeding of raw material and ensures that all heating elements are turned off. This helps prevent damage to the extruder and ensures operator safety.
- **Power restoration:** When the power supply is restored within the specified timeframe, the smart control system verifies the stability of the power source. It ensures that the power is within the required voltage and frequency range to avoid any issues during operation.
- **Automated restart:** Once the power stability is confirmed, the control system initiates the automatic restart process. It gradually brings the extruder back to operational conditions, ramping up the screw speed, re-establishing heating elements and resuming the feeding of raw material.
- **Process parameter optimisation:** During the restart process, the smart control system optimises process parameters based on the extruder's condition before the power interruption. It utilises historical data or pre-set recipes to ensure consistency in the product quality and processing parameters.

Benefits of twin-screw extrusion

In addition to the operational differences mentioned earlier, there are several other advantages of using twin-screw extrusion over single-screw extrusion. Here are some notable benefits:

- Improved mixing and homogenisation.
- Enhanced process flexibility.
- Precise temperature control.
- Enhanced product quality.
- Higher throughput and efficiency.
- Better control over product parameters.

In conclusion

Twin-screw extruders, with their advanced features such as smart control systems, are particularly well-suited for food and feed processing in regions prone to load shedding and power interruptions. The automatic restart capability of smart control systems ensures seamless operation, allowing the extruders to restart automatically once power is restored. This feature minimises downtime, eliminates the need for manual intervention and maintains production continuity.

Combined with their other advantages such as improved mixing, precise temperature control and higher throughput, twin-screw extruders provide a reliable and efficient solution for food and feed processing, even in challenging power conditions.

ExtruAfrica is a non-profit training initiative of CFAM to bring stakeholders together and inform them on topical issues related to extrusion and the industry. Visit *www.ExtruAfrica.org.za* for more information on these events.

Mitigating the negative challenges alternative feed ingredients place on gut health with Ecobiol®

EVONIK
Leading Beyond Chemistry

By Natasha Davison, business manager, Evonik Africa

Poultry production faces a number of challenges which compromise profitability. One of the biggest drivers for farm profitability is input costs and because feed makes up 70% of production costs, it is necessary to consider the raw materials we are using.

The poultry industry is currently experiencing considerable fluctuations in raw material prices and quality, and often faces uncertainty regarding the availability of common feed ingredients. One possible way to mitigate the erratic supply and cost implications thereof, is to consider the use of alternative raw materials such as rye, barley or rice bran.

Challenge of using alternatives

Unfortunately, alternative raw materials such as rye or rice bran pose their own unique sets of challenges, one of these being the presence of anti-nutritional factors. These include high levels of non-starch polysaccharides (NSP) which increase the viscosity of digesta, thus interfering with digestion and causing gut health issues. The level of insoluble versus soluble fibre in these raw materials also impact gut health, thereby causing apprehension surrounding their utilisation.

Evonik conducted a trial in Brazil exploring the effect of partially substituting maize with either rye or rice bran in the diets of broilers. During this trial, utilising either rye or rice bran did not negatively impact bodyweight when compared to breeder standards (denoted by the red line in *Figure 1*). However, it was noted that rye (which is higher in soluble fibre) resulted in reduced performance compared to rice bran.

Possibly the best determinant of 'good gut health' would be microbiota diversity in the gut. Diversity is determined by both the species richness (how many different microbial species are present) and species evenness (how equally each species is represented). During the Evonik trial, it was noted that rye not only reduced performance, but also resulted in a reduced diversity in the gut microbiota (in particular the species richness).

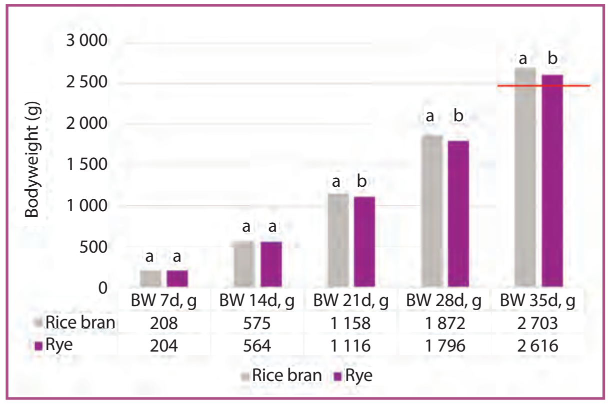
Ecobiol® as a solution

Ecobiol® is a single-strain probiotic containing *Bacillus amyloliquefaciens* CECT 5940, and supports the maintenance of an intestinal microbial balance in poultry, compatible with the commonly used coccidiostats, antibiotic growth promotors and organic acids. Ecobiol® has shown to reduce pathogenic microflora in the intestine of broiler chickens as well as improve broiler performance.

Within the mentioned trial, Evonik further explored whether the inclusion of Ecobiol® can counter some of the negative consequences of including rye or rice bran into the diets of broilers. The supplementation of Ecobiol® resulted in earlier maturation of the gut microbiota (*Figure 2*) denoted by similarities in the family level microbiota composition between d7 probiotic-supplemented groups versus d14 un-supplemented groups. The same trend can be noticed at d14 and d21.

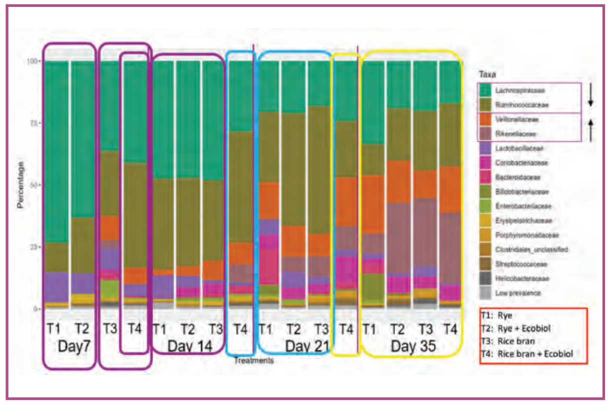
Earlier maturation of the gut microbiota is related to increased diversity at a younger age, resulting in improved gut health and enhanced capacity to prevent the colonisation of harmful pathogenic bacteria such as *Salmonella*, *E. coli* and *Clostridia perfringens*. Supplementation of Ecobiol® into the diets of broilers can encourage the positive earlier maturation of the gut microbiota, thereby ensuring increased performance and profitability of the flock, whether broilers are fed a typical maize-soya diet, or when experiencing challenging conditions such as alternative feed ingredient utilisation.

Figure 1: Bodyweight of broilers either fed rye or rice bran.



**Differing superscripts indicate significance (p<0,05). Red line denotes Cobb standard.*

Figure 2: Microbiota composition at family level with rye or rice bran with and without Ecobiol® supplementation.



References available on request. Email natasha.davison@evonik.com for any enquiries.

Fibre fermentation in the chicken: An important opportunity to extract extra value from feed ingredients

By Rob AHM ten Doeschate and MR Bedford, AB Vista

For monogastrics, and especially poultry, fibre has traditionally been seen as a nutrient with little relevance, something of a diluent (or even an antinutrient in the case of viscous fibres) which should be held below a threshold so as not to cause problems, rather than something to consider as a positive element of the diet: Because chickens are not cows!

Over recent years this attitude has been changing, with fibre nutrition in the chicken being studied in greater detail as its importance has increased with the removal of prophylactic antibiotics. This paper intends to give an overview of the subject area, focussing on how modulation of fibre fermentation in the chicken can help improve performance and intestinal resilience.

Fibre definition and analysis

When talking about fibre, there are various challenges with respect to definition and analysis which are partly the reason why, historically, fibre may not have received the attention it deserves. Most people have a conceptual understanding of what fibre is, but a detailed and precise definition and analysis is more difficult to achieve.

The definition of the term 'fibre' varies, depending on the author as well as the purpose of the definition. A conceptual, physiological definition would be something like "The fraction of the diet not digested by the animal's digestive enzymes but can potentially be fermented by the microflora" (Bach Knudsen, 2014) or "Dietary fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the (…) small intestine with complete or partial fermentation in the large intestine" (American Association of Cereal Chemists, 2001).

The problem with this is that while this covers the concept of fibre, it doesn't match analytical procedures.

Methods to analyse fibre

In most countries, feed materials are still analysed to get a crude fibre (CF) measure for labelling purposes. The CF method (Henneberg and Stohmann, 1859) measures the residue after solubilising the sample in strong acid and alkali solutions, and weighing the residue. This provided nutritionists with a vague idea of the quantity of the fibre components, cellulose and lignin. As conditions used in this method are very aggressive, the true fibre content is underestimated, and it also does not serve as a way to identify the fibre structure or composition.

A more advanced method was developed by Van Soest *et al.* (1963) using graded solubilisation of the sample in a series of neutral/acid solutions, then drying and weighing the sample and, lately, discounting ash content. This method effectively measures what is insoluble in every step of the method, giving neutral detergent fibre (NDF) as a measure for hemicellulose, cellulose and lignin; acid detergent fibre (ADF) as a measure for cellulose and lignin; and acid detergent lignin (ADL) as a measure for lignin.

This detergent fibre method is commonly used in ruminant and pig nutrition, but the method has not been widely used in poultry nutrition. While these parameters give a better estimate of fibre content, it doesn't help in determining the functional effect of the fibre and also underestimates total fibre as soluble fractions are drastically underestimated.

Measuring constituent sugars

To improve the understanding of fibre, the analytical method of Englyst *et al.* (1994) is based on measuring the constituent sugars from both soluble and insoluble fibre components, thus providing a more complete understanding of fibre composition and structural content in feed materials. This method focusses on the understanding of non-starch polysaccharide (NSP) content which, combined with lignin, gives a value for total dietary fibre (TDF).

NSPs are composed of hemicellulose, cellulose and pectin and vary in their monomeric sugar compositions.

Having a greater understanding of fibre's components will help us to understand how to optimise its use. For example, hemicellulose is a combination of arabinoxylans (AX), β-glucans, xyloglucans, mannans and fructans. The AX backbones within hemicellulose are, however, composed of arabinose and xylose and can vary in their substitutions along the xylan backbone.

> While a better understanding of the constituents of NSPs can benefit in the long run the improvement of the performance and/or health of animals, we still do not know exactly which components of fibre are most important for intestinal health.

In cereals, the vast majority of the arabinose and xylose sugars determined in this assay are derived from arabinoxylans. These two sugars can be used to determine the degree of substitution which is important, as the higher the substitution the more challenging it is for enzymes to hydrolyse the xylan backbone and generate smaller arabino-xylo-oligosaccharides (AXOS).

While a better understanding of the constituents of NSPs can benefit in the long run the improvement of the performance and/or health of animals, we still do not know exactly which components of fibre are most important for intestinal health. For example, the size, solubility, sugar composition and degree of lignification are all topics which need further attention. But using dietary fibre analysis on a routine basis in research and development will eventually give us the opportunity to link performance results with analytical parameters.

Soluble or insoluble fibres

Fibre has historically been considered at best a diluent or even an anti-nutritional factor (ANF), which meant controlling maximum levels in diets rather than looking for opportunities to utilise fibre as a source of useful nutrients. In some respect this attitude is correct. For example, it is well known that soluble NSPs (β-glucans and AX) can influence viscosity in the small intestine (Choct *et al.*, 1996; Bach Knudsen, 2014) leading to negative effects in animal performance.

In poultry, increasing viscosity is reported to raise the incidence of wet litter, dirty eggs and foot-pad lesions, and reduce nutrient availability. Across the cereals, AX is the main NSP component followed by cellulose and β-glucans. From the A:X ratios, it is also apparent that there are big variations in the structural features of AX molecules caused by the type of grains and the relative proportions of the different tissues in the grains. Today, however, using enzymes, we are able to break these longer chain NSPs into smaller fragments, reducing this effect of viscosity (Bedford, 1996).

As mentioned by Bach Knudsen (2014), both soluble AX and β-glucan can increase viscosity. The viscosity of both polymers is directly related to the molecular structure (molecular conformation, weight and weight distribution) and the concentration of the polymer.

One thing to take into consideration is that in vitro and in vivo viscosities may not correlate. For example, the molecular weight of β-glucan is higher than that of AX, which causes higher in vitro viscosity for the former. However, AX is more resistant to degradation than β-glucans, and once it enters the gut (especially under gastric conditions), the viscosity caused by β-glucans will largely reduce while the viscosity from AX will be more resistant.

Xylanases alleviate viscosity in the animal by reducing AX molecular weight consequently allowing better diffusion of digestive enzymes and substrates thus improving nutrient digestion and absorption.

Fermentation in the lower gut

On the positive side, fibre can be seen as the main nutrient driving fermentation in the lower gut. Dietary fibre can be utilised by fibre fermenting microbes and be converted to a range of useful nutrients, supporting both microbial growth and the host organism.

As fibre fragments are depolymerised into smaller and smaller molecules, they

are more rapidly attacked and even absorbed by some resident species of the microbiota. In this regard, NSPases can directly 'feed' the large intestinal microbiota by taking insoluble and poorly fermented, large molecular-weight, soluble fibre and converting it into fermentable smaller components.

> Dietary fibre can be utilised by fibre fermenting microbes and be converted to a range of useful nutrients, supporting both microbial growth and the host organism.

The prebiotic concept envisaged the production of a series of oligosaccharides by NSPases which are quantitatively fermented to VFAs. More recent work has suggested, however, that while NSPase can produce oligosaccharides from some cereals, the quantity produced is limited and certainly not enough to sustain the incremental volatile fatty acid production noted in many studies.

Stimulating fibre fermentation

The use of xylanase has been shown to lead to a change in the ability of the caecal microbiome of broiler chickens to ferment NSP as evidenced by gas production in an ex-vivo model. When caecal content from broilers fed with a xylanase containing diet was incubated with a range of NSP sources, there was an increase in gas production compared to caecal content from broilers fed a control diet (Bedford and Apajalahti, 2018).

This effect, and the resultant increase in SCFA production, takes time to establish, as shown by Lee *et al.* (2017) where increased SCFA in caecal content resulting from xylanase in the diet became obvious at 42 days of age, whereas increases in fermentable sugar content in the caeca was already seen at 21 days of age.

The term 'stimbiotic' (STB) has been introduced recently and is defined as non-digestible but fermentable additive that stimulates fibre fermentability, but at a dose that is too low for the stimbiotic itself to contribute in a meaningful manner to volatile fatty acid (VFA) production (Cho *et al.*, 2020). The idea is that an STB would accelerate the development of a fibre fermenting microbiome whereby a small amount of a target oligosaccharide acts not only as a substrate, but also as a signalling molecule to encourage the relevant bacteria to produce fibre-degrading enzymes to accelerate fermentation and increase SCFA production. Various trials have been carried out with this concept in both pigs and poultry.

Using an STB has been shown to result in upregulation of oligosaccharide transporters in caecal bacterial cell walls (Amir, 2021), suggesting an increased ability of the microbiome to utilise fibre.

Potential benefits

The products of fibre fermentation can be beneficial to the chicken in various ways. Firstly SCFA, and especially butyrate, can be utilised by the chicken as a source of energy. Butyrate has been studied widely as a feed additive, but the potential yield of butyrate from fibre fermentation widely exceeds the typical supply of butyrate from butyrate-based feed additives, suggesting that stimulation of fibre fermentation may be more effective than butyrate addition to the diet.

Secondly, a shift towards fibre fermentation can reduce the putrefactive fermentation of protein (Apajalahti *et al.*, 2015). As protein fermentation results in production of branched chain fatty acids (BCFA) this effect can be seen in an increased ratio of VFA:BCFA, which has been measured several times across a range of STB studies (AB Vista internal data, 2020).

Stimulation of a fibre fermenting microbiome has been demonstrated in a study where an STB product was compared to a commercial enzyme blend containing xylanase and beta-glucanase in a diet rich in β-glucans due to inclusion of 30% barley (Morgan *et al.*, 2021). In this study, β-glucan levels measured at ileal level at 21 days of age were decreased either when the STB product was included or when the enzyme blend was used. This resulted in reduced viscosity and improved performance for both products.

Total caecal SCFAs, acetic acid and propionic acid were significantly increased in the STB-fed group at 21 and 35 days of age, but the enzyme blend only had a significant effect on these parameters at 35 days of age. This indicates that the objective of stimulating a fibre fermenting microbiome at an earlier age was achieved by the inclusion of the STB product.

A further hypothesis is that a fibre fermenting microbiome would be more resilient to challenge, and thus use of an STB would be more beneficial under challenging conditions. This was reported in piglets where, under poor sanitary conditions, the use of STB resulted in improved performance as well improvements in biomarkers indicating better gut health (Cho *et al.*, 2020).

In broilers the use of STB or STB combined with a suite of additive products based on phytogenic, yeast (MOS, glucans), prebiotics and probiotics was tested in a necrotic enteritis challenge model (Lee *et al.*, 2022). Challenged birds showed increased intestinal lesions, increased serum levels of TNF-α and endotoxin, resulting in impaired performance as well as increased foot pad dermatitis.

Use of the STB product reduced the impact of the challenge for all these parameters. There was also a shift in caecal bacteria, with more *Lactobacillus* and less *Escherichia coli* present when the STB product was fed. In challenged birds there was a clear reduction in *Clostridium perfringens* in STB fed birds.

Adding the suite of other additive products did not improve the response of the birds (Lee *et al.*, 2022). This study shows that stimulating fibre fermentation may result in birds that are more resilient to challenge, suggesting better results in commercial practice where a higher level of challenge than in typical research trials is to be expected.

Conclusion

Stimulation of fibre fermentation in the chicken can give substantial benefits, both in terms of productivity as well as resilience of the chicken.

Paper based on a presentation given at the WPSA SA meeting of 8 March 2023.
For more information and complete references, email Rob.TenDoeschate@Abvista.com or dean@avipharm.co.za.

Homeostasis: The golden path to efficient poultry production

Phileo by Lesaffre

By Dr Ruth Raspoet, poultry R&D manager, Phileo by Lesaffre

The most well-known function of the largest organ, the gastrointestinal tract, is digestion and absorption. The intestinal mucosa also functions as a barrier, preventing the passage of toxins and pathogens into the blood. The gut contains most of the cells of the immune system, as well as a wide variety of commensal bacteria. It is becoming globally accepted that gut health is an important physiological condition for overall health and performance (Bischoff 2011).

In 2016, gut health was defined as "the absence/prevention/avoidance of disease so that the animal can perform its physiological functions in order to withstand exogenous and endogenous stressors" (Kogut 2016). Celi *et al*. proposed that gut health be defined as "a steady state, where the microbiome and the intestinal tract exist in symbiotic equilibrium, and where the welfare and performance of the animal are not constrained by intestinal dysfunction".

Maintaining homeostasis results in good gut health (Wickramasuriya *et al*., 2022). A variety of factors including management, pathogen pressure and diet affect gut health status. Microbiome dysbiosis disturbs intestinal homeostasis, causing gut mucosal barrier leakage and inflammation (Zhu *et al.,* 2021). It is critical to boost gut health by promoting nutritional strategies focussing on intestinal barrier strengthening, oxidative stress reduction, pathogen prevention, microbiota and immune modulation.

Phileo by Lesaffre has developed a dedicated gut health programme focussing on the four key pillars mentioned above, to help birds maintain homeostasis, be more resilient to stress and reach greater production performance.

Epithelial barrier strengthening

The physical intestinal barrier depends on a variety of mucosal structural components that confer the property of selective permeability with the free exchange of water, ions and macromolecules between the intestinal lumen and the underlying tissues. The luminal surface of the intestinal mucosa is lined by a hydrated gel, composed of mucins secreted by goblet cells. This layer prevents large particles and intact bacteria from coming into direct contact with the underlying epithelium.

An intact epithelium restricts the passage of hydrophilic solutes but to further limit transmucosal flux, the paracellular space needs to be sealed as well. This task is regulated by a series of intracellular junctions (tight junction, adherens junctions and desmosome) forming the apical junctional complex (Odenwald and Turner 2017).

An experiment performed in 2020 by Pascual *et al*. showed that supplementation of the yeast postbiotic Safmannan® containing >20% mannans and >20% β-glucans could increase the goblet cell density (*Figure 1*).

Oxidative stress reduction

Oxidative stress disrupts physiological processes and causes disease. Intestinal oxidative stress plays an important role in the early stages of intestinal injury, triggering abnormal cell proliferation, growth stagnation and apoptosis leading to intestinal barrier dysfunction and inflammation (Wang *et al*., 2020).

Seleno-enzymes, such as glutathione peroxidase (GPx), are known for their actions in the antioxidant system and require the trace element, selenium, for their activity. The highly consistent organic selenium-enriched yeast, Selsaf®, contains SeCysteine and SeMethionine. The high selenium values in blood after Selsaf® administration show that the active selenium components in Selsaf® are efficiently absorbed by the gut. This leads to a higher bioavailability of

Figure 1: Goblet cell numbers are significantly increased by yeast postbiotic Safmannan® at different time points (adapted from Pascual *et al.,* 2020).

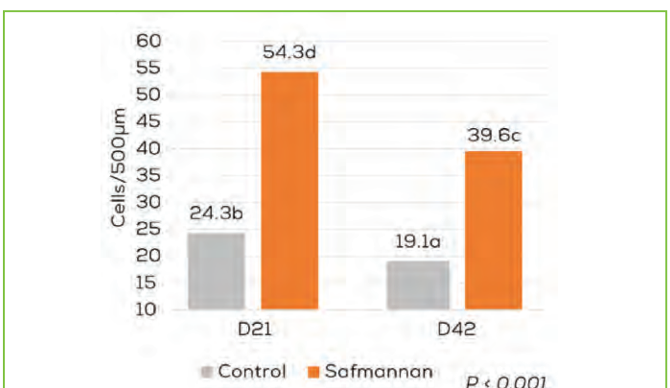
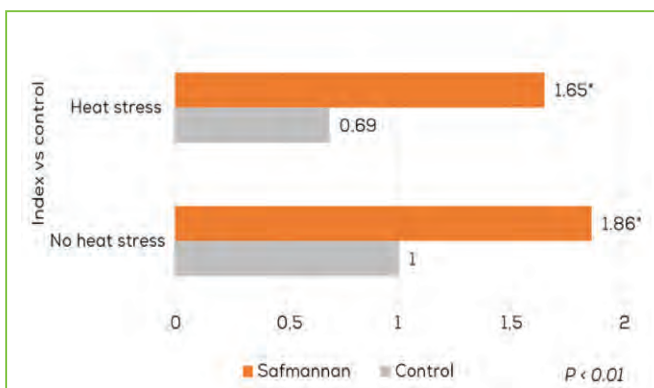


Figure 2: Mucin 2 expression is significantly increased by Safmannan® under challenging or normal experimental conditions.



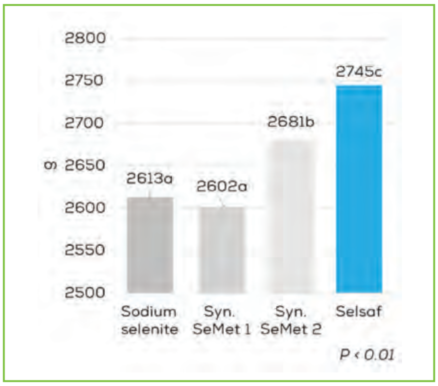


Figure 3: Broiler final bodyweight (d42) is significantly increased by organic selenium-enriched yeast Selsaf® compared to other mineral and organic sources of selenium.

selenium for seleno-enzymes such as GPx and thus a higher functionality of the antioxidant system.

Microbiota modulation

The microbial inhabitants of the intestine mediate key physiological processes for the health of the host. They assist with digestion, development and regulation of the gut-associated lymphoid tissue (GALT). They also compete with pathogenic invaders. At the phylum level, over 90% of the phylogenetic categories in the caecum either belong to the phylum *Firmicutes* (*Clostridium*, *Enterococcus*, *Lactobacillus* and *Ruminococcus* genera) or to the phylum *Bacteriodetes* (*Bacteroides* and *Prevotelle* genera). A healthy microbiota is characterised by high diversity.

Within the host, the composition of the microbiota is influenced by a variety of factors. In some cases, this can lead to dysbiosis, an undesirable alternation of

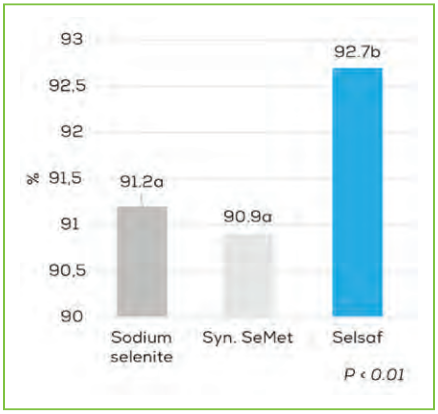


Figure 4: Laying performance is greatly improved by Selsaf® compared to other mineral and organic sources of selenium.

the microbiota, resulting in an imbalance between protective and harmful bacteria populations. Dysbiosis was practically unknown until the ban of antibiotic growth promoters, but now is one of the most challenging problems in broilers (Ducatelle *et al*., 2015). Dysbiosis can also be caused by the diet, especially when low-quality raw materials are used.

A study performed in Brazil showed that Safmannan® was able to increase the microbiota diversity of broilers receiving a low-quality diet. Significant increases in beneficial genera such as *Roseburia*, *Ruminococcus torques*, *Eubacterium hallii* and *Shuttleworthia* were observed, while Enterobacteria numbers decreased (*Figure 5*).

Pathogen prevention

Decreases in *Enterobacteriaceae* when using a yeast probiotic can partially be explained by the presence of α-mannans

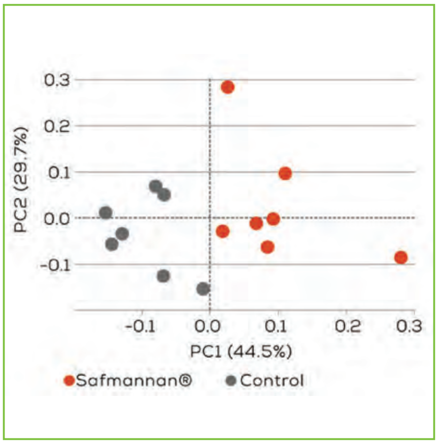


Figure 5: Higher microbiota diversity (d21) observed in broilers in the Safmannan® group.

in yeast cell walls which adhere to type-1 fimbriae of pathogenic bacteria including *Salmonella*, making it more difficult for these pathogens to colonise the intestinal epithelium (Posadas *et al*., 2017) (*Figure 6*).

This is confirmed in a *Salmonella Typhimurium* challenge model where administration of Safmannan® reduced the *Salmonella* colonisation in caeca (P = 0,001) on D28 of the trial. Reduced colonisation of *Salmonella* in the liver (P = 0,038) also indicates that better intestinal health reduced the translocation of the pathogen to systemic organs (*Figure 7*).

Vaccine potentiation

The GALT plays a major role in the gut immune response, including both innate and adaptive functions. The GALT includes organised lymphoid structures such as the bursa of Fabricius, caecal tonsils, Peyer's patches, Meckel's diverticulum and lymphocyte follicles. Normally, a fully

Figure 6: The faeces of turkeys in the Safmannan® group showed a higher abundance of health promoting micro-organisms in comparison to the control group.

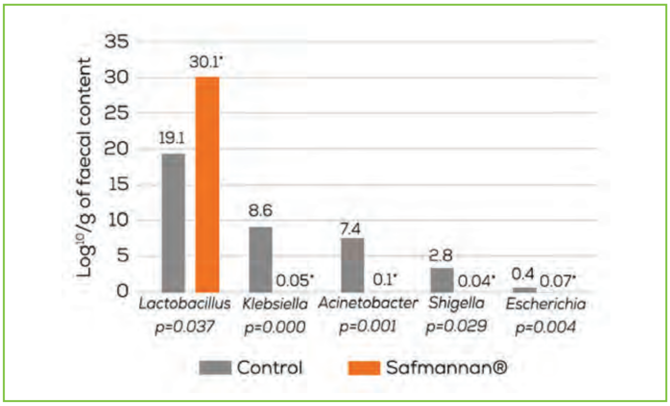
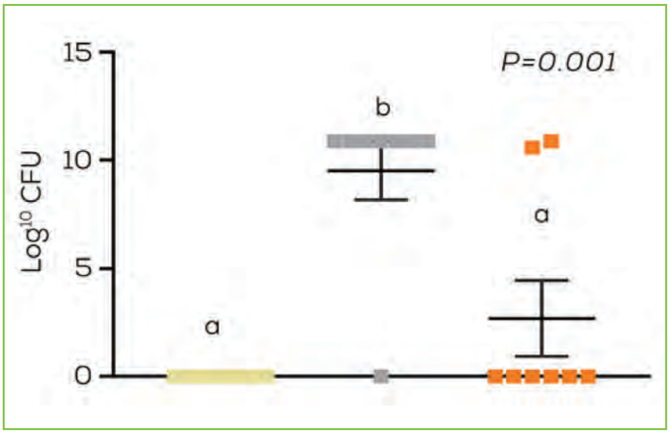


Figure 7: *Salmonella* colonisation in caeca (d28) was significantly reduced in the Safmannan® group.



functional immune system is formed within four weeks after hatch.

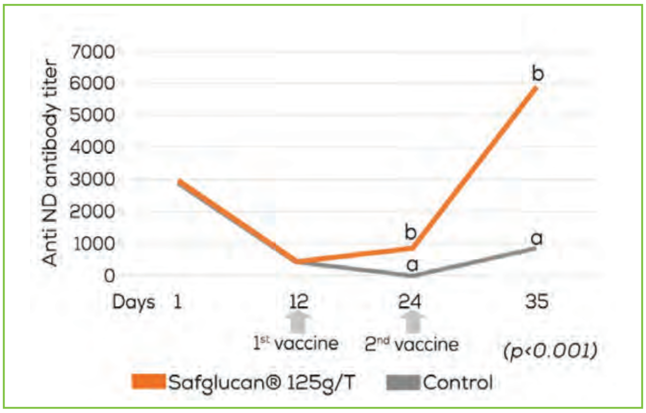
Enterocytes express pattern recognition receptors (PRRs) which sense conserved pathogen molecular signatures and initiate protective measures against these while remaining non-responsive to commensal microbes. Enterocytes secrete a large variety of antimicrobial peptides into the intestinal lumen and plasma cells secrete IgA to neutralise pathogens and facilitate their removal from the gastrointestinal tract (Kogut *et al*., 2017; Wickramasuriya *et al*., 2022).

To modulate the immune system and improve intestinal health, yeast β-glucans have been shown to be very effective. β-glucans from yeast are natural polysaccharides consisting of a (1,3)-beta-glycosidic backbone with β-(1,6)-linked side chains of various lengths that are recognised by innate immune cells as microbial-associated patterns through the Dectin-1 receptor (Walachowski *et al*., 2017). β-glucans also increase phagocytic activity and production of antibody titres (Jacobs *et al*., 2017).

The effect of β-glucans on the production of antibody titres was seen in a *Salmonella* challenge experiment, where administration of Safglucan® containing more than 50% of β-glucans led to higher production of secretory IgA against *Salmonella* LPS and flagellin.

Safglucan® is also a very efficacious vaccine potentiator. This is demonstrated in several vaccination trials, where the administration of Safglucan® led to the increase in titres against Newcastle disease (ND). Safglucan® increased anti-ND specific antibodies in serum when supplemented through the diet (*Figure 8*).

Figure 8: Antibody titres against Newcastle disease (d21 to d35) were increased in birds in Safglucan® group compared to the control group.



Conclusion

The withdrawal of antibiotics from the poultry industry has made it clear that gut health is an important factor determining animal performance and health. Specific yeast-based solutions have shown to be able to modulate gut health and immunity. These products maintain animal performance to meet global demands for high quality animal proteins while also improving animal health and welfare.

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