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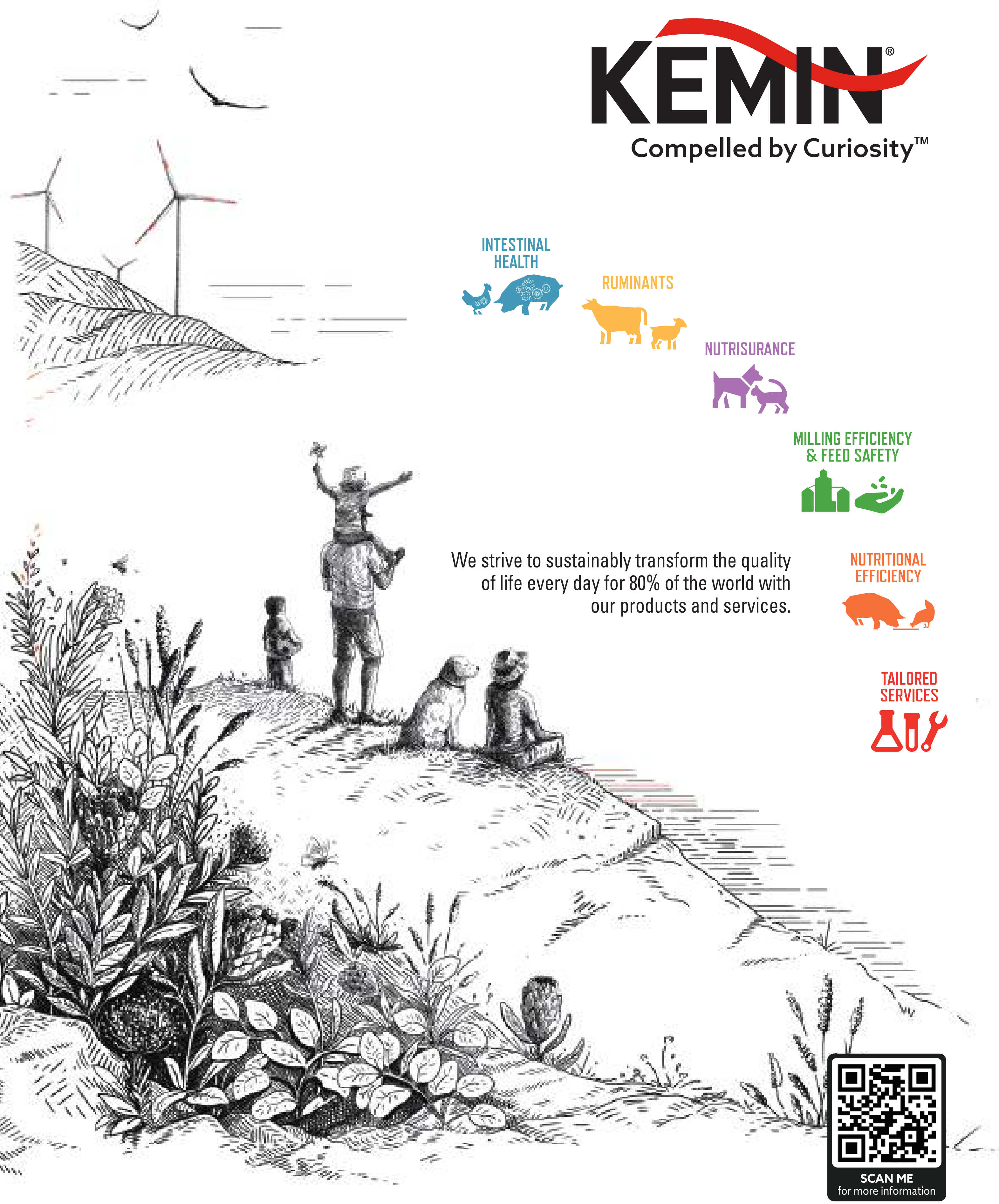
Matrix

AFMA
Animal Feed Manufacturers Association

Quarterly magazine of the Animal Feed Manufacturers Association

Feed mill biosecurity • Feed miller short course • Raw grain procurement • 2025 feed outlook
AFMA student outreach • Enteric methane emissions • Post-weaning diarrhoea in piglets
Prebiotics • Black soldier fly larvae • Vitamin D • AFMA IWC round 3 winners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Grounded in purpose

By Liesl Breytenbach, executive director, AFMA

While grain producers are busy harvesting, wet conditions are causing delays in certain areas and placing strain on already low opening stock levels. With an expected shortfall of approximately 720 000 tonnes of yellow maize, imports will be necessary to meet local demand, placing upward pressure on South African futures exchange (Safex) prices, which are around R1 000/t below import parity.

In contrast, soya bean production recovered compared to the previous production season, positioning South Africa to become self-sufficient – we are expected to export almost 370 000 tonnes. For feed manufacturers, careful cost management and strategic procurement will be key in the coming months.

A highlight this quarter was the Animal Feed Manufacturers Association's (AFMA) media and industry day. It was a privilege to host representatives from government, the media, our members, and broader industry partners. The day provided a platform to share AFMA's four strategic focus areas and to reflect on how we remain grounded in our purpose, even as industry challenges continue to shift. The energy in the room, quality of the conversations, and collective commitment to progress reminded us of the important role AFMA plays in connecting the grain sector to the consumer's plate.

Liesl Breytenbach.

Training and development

In this issue of *AMFA Matrix*, we pay tribute to a valued contributor in the industry. Earlier this year, Ernst Nef presented his final feed miller short course after nearly a decade of leadership. His mentorship has impacted and influenced hundreds of feed professionals and strengthened the industry's knowledge in feed milling technology. We thank him sincerely for his dedication and lasting contribution.

AFMA's commitment to developing talent remains a core focus. A recent student outreach event, hosted in partnership with Meadow Feeds, welcomed students from the University of Zululand. These engagements remind us of the value of linking students directly with industry role-players. The students' enthusiasm and curiosity made it clear: investing in young talent is not optional; it is essential.

Our efforts to deepen collaboration with tertiary institutions are also ongoing. A recent engagement with nine animal science departments across South Africa focussed on aligning research and skills development with industry needs. These partnerships are critical to strengthening the future pipeline of expertise for feed manufacturing.

Dynamics, tensions, priorities

Global dynamics are shifting. As highlighted in Alltech's *2025 Agri-Food Outlook*, feed volume growth is gaining momentum, although patterns differ significantly across regions and species. With affordability being a major factor in consumer decisions, feed manufacturers are re-evaluating protein formulation and cost efficiency. At the same time, rising trade tensions and shipping delays continue to disrupt supply chains, affecting both the availability and cost of critical feed inputs. In response, strategic sourcing and supply diversification are becoming increasingly vital for managing risk.

Feed safety and biosecurity remain non-negotiable priorities. From ingredient sourcing to on-farm practices, each step in the value chain matters. AFMA continues to support members through the promotion of good manufacturing practices and communication on biosecurity best practices. To explore this further, see our featured article in this edition.

Together into the future

Looking ahead, we encourage you to save the dates of two major events. This September, AFMA celebrates 80 years of service to the feed industry at our annual general meeting that will be hosted at Zimbali in KwaZulu-Natal. Planning is also well underway for the 2026 AFMA Forum, which will bring together thought leaders and innovators from across the value chain.

Our sincere thanks to every member and partner who continue to believe in the value of what we do. While the future may hold uncertainty, one thing is clear: When we are grounded in purpose, we move forward together, with clarity, commitment, and a shared vision for the road ahead.

For more information, send an email to liesl@afma.co.za or visit *www.afma.co.za.*

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NEWS & VIEWS

Emulsifier GFLI certified

Excential Energy Plus, one of Orffa's leading innovations, has been officially certified under the Global Feed LCA Institute (GFLI) Branded Data Methodology. This recognition positions Excential Energy Plus as the first nutritional emulsifier globally to be independently validated for its environmental footprint.

The certification confirms the product's contribution to sustainable livestock production and supports feed manufacturers and integrators in reaching their climate goals. It also offers peace of mind for technical teams and purchasing managers seeking proven, low-footprint solutions without sacrificing animal performance.

The GFLI database is a globally recognised reference for environmental impact data in animal nutrition. By achieving this certification, Orffa takes a leading role in aligning product innovation with transparency and measurable sustainability performance. *– Press release*

Vietnam imports US animal feed

Vietnam has signed a memorandum of understanding (MoU) to import over US$600 million worth of animal feed from companies in Ohio, United States (US). The deal was affected during an official visit to Ohio by a delegation from Vietnam's ministry of agriculture and rural development, led by minister Đỗ Đức Duy, who met with state leaders and local businesses to enhance agricultural cooperation.

The MoU covers essential commodities such as maize, soya beans, soya bean meal, and other feed-related products. Vietnam excels in tropical agricultural products, such as coffee, pepper, cashew nuts, fruits, and wooden furniture, while Ohio is a strong supplier of goods such as soya beans, maize, beef, dairy products, and timber – items that Vietnam does not produce at a competitive scale. *– avinews.com*

Leaf Services appointment revoked

The National Department of Agriculture announced on 13 June that it has revoked the appointment of Leaf Services as an assignee. The minister of agriculture revoked the appointment in terms of section 2(3) of the *Agricultural Products Standards Act, 1990 (Act 119 of 1990)*. The revocation is effective from 27 May this year and was announced in the *Government Gazette* by way of *Notice 3304 of 2025*.

The products that were originally allocated to resort under the services of the assignee included canola, dry beans, groundnuts, maize and maize products, malting barley, rice, soya beans, sorghum, sunflower seeds, wheat and wheat products, and other grains and grain products for which regulations could be promulgated. While no reason was given for the revocation, the announcement comes after substantial pressure from industry to revoke the appointment of Leaf Services as an assignee. *– Plaas Media*

Insect meal impacts climate

Research in the United Kingdom has found that insect meal has a much higher climate change impact than either soya bean or fish meal. The results are a setback to the animal feed sector and its attempts to decarbonise the industry.

The project aimed to understand and quantify the potential environmental impacts of insect protein (black soldier fly larvae) in the form of meal compared to soya bean meal and fish meal, for use as poultry and pig feed through a life-cycle assessment (cradle-to-grave).

The study found that insect meal has a total climate change impact of between 12,9 to 30,1kg of CO_2 equal per kg of protein, depending on the feedstock the larvae are raised on. This is approximately 5,7 to 13,5 times the climate change impact of soya bean and 1,8 to 4,2 times the impact of fish meal. *– Poultry World*

Alternative proteins need funding

Interest is growing in the global development and production of alternative proteins, but it is going to take more capital investment to fulfil their promise. So concludes a new series of state-of-the-industry reports from the Good Food Institute (GFI). Total 2024 global funding for the sector reached US$1,1 billion, which was down 29% from 2023.

Fermentation companies drew the largest capital infusion last year at US$651 million (up 43% from 2023), followed by cultivated meat and seafood producers at US$139 million (a year-over-year drop of 40%) and plant-based projects with US$309 million in investment (down 64% from 2023). Privately held plant-based meat, seafood, eggs, or dairy companies now have raised a total of US$8,4 billion since 2006, the report said, while publicly traded plant-based protein companies have raised US$2,5 billion.

This more positive area is likely the result of continuous demand for plant-based ingredients, even in the pet food industry, as plant-based proteins appeared in 52% of pet foods in the United States market last year, according to NielsenIQ data. *– Pet Food Processing*

Decrease in EU feed production

Market experts for the European Feed Manufacturers' Federation (FEFAC) forecast continued stability in the European Union (EU) compound feed production market for 2025. The total industrial compound feed production in the EU27 is expected to reach 146,1 million metric tonnes (MMT), marking a slight decrease of 0,34% compared with 2024.

In 2025, EU cattle feed production is forecast at 41,285MMT, a decrease of 1,4% compared with 2024. Pig feed production in the EU is expected to reach 46,960MMT in 2025, a marginal decrease of 0,8%. The poultry feed sector is expected to grow further in 2025, with production forecast to increase by 0,9% to 50,368MMT. *– FEFAC Press Release*

US animal feed supply in danger

Farmers and livestock producers across the US face mounting challenges as drought tightens its grip on key forage and feed commodities. According to recent US Department of Agriculture data through 3 June, approximately 21% of US maize and 16% of soya bean acreage are experiencing moderate to exceptional drought conditions.

Cattle operations are particularly vulnerable. USDA Economic Research Service data show that drought-induced pasture degradation leads to decreased herd sizes and higher feed expenses. A one-unit rise in average drought intensity correlates with a 1% drop in herd size, a 12% decrease in hay output, and a 5% hike in hay prices – reducing overall farm income by approximately 4%. *– Grainjournal*

Second to none Milling Academy

Bühler announced it has opened a new state-of-the-art Milling Academy – a 1 800 m^2 training centre for food and feed millers – at the heart of its headquarters in Uzwil, Switzerland.

Designed to meet the evolving needs of the industry, the facility combines decades of expertise with the latest technology and modern teaching methods. Direct access to research and training centres enables course participants to gain unique hands-on insight into key industry areas.

The Milling Academy also integrates advanced digital learning tools and features two laboratories: one for analytical training and another for electronics training and experimentation. *– Feedstuffs*

Additives cut cattle methane

Anti-methane feed additives can reduce the methane emissions from indoor held cattle by 10 to 28%, research funded by the Department of Agriculture in Ireland shows. Experiments conducted on a calcium-peroxide-based feed additive known as RumenGlas have demonstrated the potential reduction in methane in an indoor setting, depending on the animal type, the diet, and the inclusion rate of the additive.

In addition, one study conducted in conjunction with the Global Research Alliance demonstrated the potential for both an animal performance benefit as well as a reduction in methane for the first time ever in an Irish setting.

The results were presented during the Agriculture and Climate Change: Science into Action conference at Dublin Castle. The ROADMAP project has developed one of the largest databases in the world for methane production in animals. This has demonstrated that there is potential to select and breed animals that can produce 10 to 20% less methane.

This is allowing Irish farmers to select bulls for lower methane emissions with no impact on other desirable traits such as animal performance. *– All About Feed*

Feed mills halt maize purchases

Thailand's animal feed industry faces mounting criticism after mills across the country announced an immediate halt to maize purchases, in what farmer representatives denounce as a calculated attempt to depress prices and facilitate cheaper genetically modified maize imports from the US.

The co-ordinated purchasing freeze, announced by the Feed Mill Association on 9 June, has sparked fierce opposition from agricultural groups who fear it will pave the way for tariff-free GMO maize imports that could devastate domestic producers.

Thailand's animal feed production reached 21,8 million tonnes in 2023, requiring 13 million tonnes (60%) of energy raw materials, including 9,2 million tonnes of feed maize, 1,7 million tonnes of broken rice, and 1,8 million tonnes of cassava chips. *– The Nation, Thailand*

Strategy to eliminate aflatoxins

The Kenyan government, in partnership with key national institutions and with funding from the Danish International Development Agency has launched a five-year initiative aimed at eliminating aflatoxins from the country's food systems.

Bringing together stakeholders from both the public and private sectors, the initiative was formally introduced during the Kick-Off Meeting on Aflatoxin Surveillance and Management, held at the Kenya Bureau of Standards headquarters in Nairobi.

In addition to the hot and humid tropical climate, which creates a favourable climate for fungal growth and toxin production, other key drivers included poor agronomic practices, low educational levels, and inadequate statutory regulations and sensitisation. *– Milling Middle East & Africa*

Biosecurity in feed mills: Safeguarding the chain

By Bonita Cilliers, technical and regulatory advisor, AFMA

Biosecurity in feed mills may sound technical, but at its core it is about keeping germs and pests out of animal feed and preventing them from spreading. A feed mill is more than just a factory; it is a critical link in the entire food chain.

Every bag of feed that leaves the mill can either support animal health or, if contaminated, spread disease. Contaminated feed can lead to severe livestock illness, resulting in significant economic losses and food safety risks – because what goes into the feed ultimately reaches the animal and, eventually, our plates.

Biosecurity is more than just a requirement; it is a daily commitment and mindset. By enforcing rigorous hygiene and process controls, feed mills play a vital role in safeguarding animal health, protecting livelihoods, and ensuring the safety of our food supply.

Disease outbreaks

Recent animal disease outbreaks in South Africa underscore the importance of biosecurity in feed mills. In 2023, highly pathogenic avian influenza (AI) led to the culling of 7,5 million chickens in the Western Cape, severely disrupting the poultry industry and demonstrating how rapidly disease can spread.

Similarly, African swine fever (ASF) – a deadly viral disease affecting pigs – has persisted in South Africa since 2019, with multiple outbreaks reported each year. One notable ASF outbreak in the Eastern Cape began in April 2020 and, by late 2023, had resulted in 43 farm outbreaks, affecting over 27 000 pigs.

Meanwhile, foot-and-mouth disease (FMD), which affects cattle and other cloven-hoofed animals, has spread in several provinces since 2021, with KwaZulu-Natal particularly hard-hit, with over 160 outbreak sites reported by early 2025, despite control efforts.

Few countries contend with all these diseases at once, yet the consequences for producers and trade have been severe. These outbreaks underscore the urgency of sealing every potential entry point, with feed mills playing a crucial role in preventing disease transmission. For instance, ASF can be introduced via contaminated ingredients, while AI can be carried in on truck wheels.

Not just exotic threats

It is not only high-profile epidemic diseases that matter. Everyday hazards such as *Salmonella*, *E. coli*, and mould toxins (mycotoxins) also pose serious risks. While not infectious, mycotoxins can impair animal health and performance. Feed mills must guard against a wide spectrum of biological hazards, from high-profile viruses such as AI and ASF to microscopic bacteria, toxins and pests.

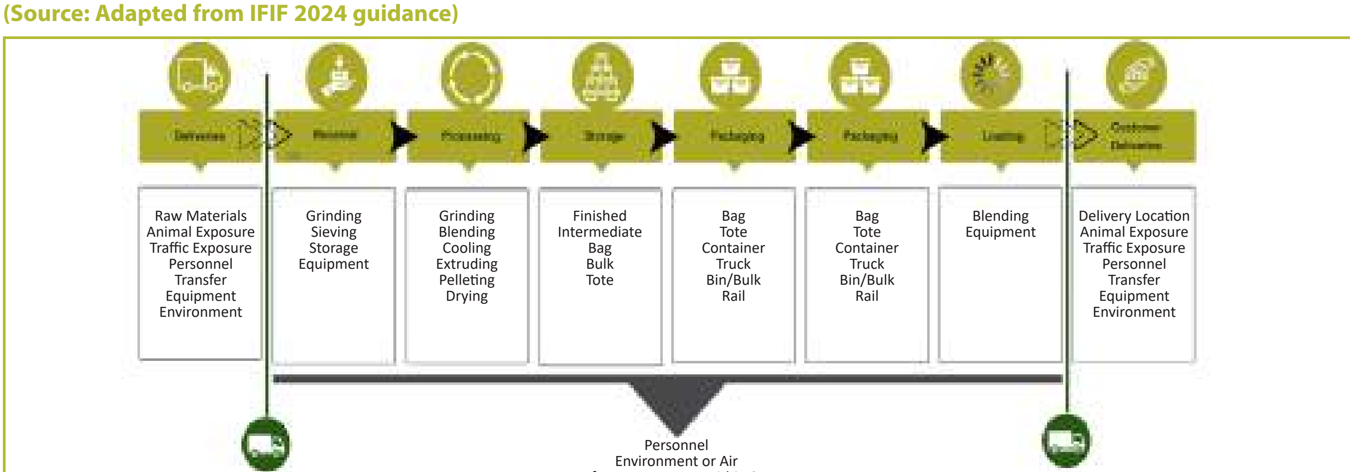
Strong biosecurity measures are essential in preventing a single contaminated ingredient or pest intrusion from triggering a chain reaction that spreads across farms nationwide.

Practical biosecurity measures

To protect feed from contamination, feed mills can implement a wide range of biosecurity measures from gate to gate. The *International Feed Industry Federation (IFIF) Biosecurity Guidance for Feed Mills* (2024) and *Stock Feed Manufacturers' Council of Australia (SFMCA) National Biosecurity Manual* (2021) offer globally recognised frameworks that support biosecurity implementation. Drawing from these resources, the following practical measures are considered essential for feed safety:

Controlled access and vehicle flow: Manage who and what enters the site. Log and screen all vehicles, deliveries, and visitors at the gate. Use wheel washes

Figure 1: A simplified feed mill processes flow chart, highlighting points of exposure where pathogens or pests could enter. (Source: Adapted from IFIF 2024 guidance)



***Pre-manufacturing (left)**: Deliveries of raw materials bring risks from external sources (animals, people, equipment, environment). **Manufacturing (centre)**: Each step from receiving, processing and storage to packaging and loading must be controlled to prevent cross-contamination. **Post-manufacturing (right)**: Delivery to farms introduces risks at the destination.*

and truck disinfection on entry and exit. Separate routes for raw materials and finished feed help prevent cross-contamination. Restrict movement in clean zones – drivers and visitors must stay in designated areas. Use barriers and signage to ensure a clear one-way flow: raw materials come in at one end, clean feed goes out at another end.

Personnel hygiene and movement control: People carry pathogens too. Use footbaths, protective gear (such as overalls, hairnets), and separate 'dirty' and 'clean' zones. Train staff to follow hygiene protocols and avoid crossing zones without proper precautions.

Ingredient quality and equipment cleanliness: Test high-risk ingredients (such as moist grains and byproducts) for *Salmonella* or mycotoxins. Only source from approved suppliers. Clean mixers, silos, and conveyors regularly – dust can carry harmful microbes. Use pelleting and other heat treatments to reduce contamination risk.

Pest and wildlife control: Rodents, birds, and insects pose a serious risk. Seal buildings, use traps and bait stations, and remove standing water or feed spills. Keep pets and livestock away from feed processing areas to maintain a pest-free environment.

Biosecurity culture, awareness, and training: Biosecurity is only as strong as its weakest link – often attributed to human error. Train all new and existing staff on hygiene, cleaning, and reporting procedures. Refresh training regularly and make biosecurity a daily priority, not just a policy. Encourage open communication so issues are reported early and build a culture where everyone understands their role in promoting feed safety.

Collaboration with producers also matters. If there is an outbreak on-farm, mills must be informed so they can adjust their protocols accordingly. Transparency and teamwork between the mill, its suppliers and customers ensure that biosecurity breaches are handled swiftly, and trust is maintained.

GMP + biosecurity: A dual defence

Good manufacturing practices (GMP) and feed safety protocols are the foundation of a well-run feed mill, ensuring product quality and consistency. Biosecurity builds on this foundation by introducing a critical layer of disease prevention – proactively identifying and addressing potential points of pathogen entry to stop transmission before it begins. Together, GMP and biosecurity offer a strong, integrated approach to safeguarding the feed-to-food chain.

A simplified feed mill processes flow highlights key exposure points, namely **pre-manufacturing** as raw material deliveries may bring pathogens; **manufacturing** which can introduce cross-contamination risks during receiving, processing, and storage; and **post-manufacturing** as risks arise during transport to farms. Controls are needed at every stage (adapted from IFIF 2024).

Continuous improvement

Biosecurity is not a one-size-fits-all process, as no feed mill is identical, and biosecurity measures must be tailored to each facility's unique situation. That is why performing a site-specific risk assessment is so important – evaluating every phase from raw material intake to feed dispatch. Tools such as the IFIF biosecurity risk assessment checklist and SFMCA's biosecurity planning tool help mills navigate this evaluation process effectively.

These frameworks classify biosecurity into routine daily practices (such as hygiene, pest control), incident response (such as product recall or pathogen detection), and heightened measures during regional outbreaks (regional disease response).

Adopting such frameworks help feed mills to follow a structured approach to identify risks, address operational gaps, implement targeted mitigation strategies, and maintain a high level of preparedness. Yet effective biosecurity goes beyond ticking boxes and checklists; it requires practical insight from within the operation. Engaging internal staff, especially those directly involved in daily operations, provides invaluable firsthand insights into what works and where challenges arise. Their input helps identify blind spots in formal assessments while fostering a culture of accountability and shared responsibility.

Where in-house expertise is limited, engaging external specialists such as veterinarians or biosecurity specialists can provide a fresh, objective perspective and help validate or strengthen current practices. The most effective biosecurity strategies often combine internal knowledge and external expertise. This balanced approach is a smart investment that supports continuous improvement and builds long-term resilience.

AFMA's role in biosecurity

In South Africa, the Animal Feed Manufacturers Association (AFMA) plays a leading role in promoting feed safety, with biosecurity integrated as a core principle. All new member mills undergo a code of conduct audit, ensuring adherence to 12 core principles that cover safety, quality, and regulatory compliance – not as a formality, but as a real-world performance check.

AFMA membership offers real value as it signals trust to producers, customers, and regulators, provides access to training, technical support, and peer learning, and encourages proactive risk management and continuous improvement. Through regular audits, peer engagement, and strategic collaboration, AFMA helps members strengthen their operational systems, stay ahead of risks, adapt to emerging challenges and regulatory changes, and align with evolving global standards.

A joint effort

Strong biosecurity safeguards the entire feed-to-food system, as it not only shields feed manufacturers' operations but also secures the broader agricultural sector. As South Africa's past experiences with AI, ASF, and FMD outbreaks have shown, we are all interconnected and a weakness at any point, whether farm or feed mill, can have serious consequences.

The good news is that by embracing a biosecurity mindset of 'every day, every batch' and by aligning with AFMA's standards and international guidance, feed mills can significantly reduce these risks. Investing in biosecurity is an investment in the future of animal agriculture, keeping our livestock healthy, our food supply safe, and our industry strong. As the World Health Organization reminds us: Prevention is better than cure, and that principle holds especially true in biosecurity.

For more information, send an email to Bonita Cilliers at technical@afma.co.za.

Mauritian student takes top honours in feed miller short course

By Susan Marais, Plaas Media

Hemant Kumar Ramdowar, head of production at Meaders Feeds in Mauritius, emerged as this year's standout student after successfully completing the prestigious Animal Feed Manufacturers Association (AFMA) feed miller short course. This marks the ninth edition of the course, presented by AFMA in collaboration with Nef Feed Milling Consulting.

Spanning ten days, the intensive programme blends theoretical knowledge with practical, hands-on training, equipping participants with the skills to enhance feed mill efficiency and optimise production quality. Ernst Nef, former director of the Swiss Institute of Feed Technology (SFT), facilitated the course for the final time.

The course has earned legendary status in the local feed milling industry for its high standards, catering specifically to experienced professionals. This year, all 55 available spots were filled, with participants from South Africa, Botswana, Zimbabwe, and the United Kingdom proudly receiving their well-deserved certificates of completion.

The event attracted a diverse group of attendees, including plant and production managers, shift and maintenance leaders, nutritionists, and additive suppliers. Their goal was to deepen their understanding of feed mill processes, enhance their research, and expand their knowledge to support the development of their products.

Saluting a legend

Liesl Breytenbach, executive director of AFMA, expressed deep appreciation as they bid farewell to 72-year-old Nef. "Ernst has dedicated over 50 years to the industry, leaving behind an extraordinary legacy. Having had him as a facilitator has been a tremendous honour, and his mentorship has consistently enhanced our feed milling operations year after year. We are sincerely grateful for the invaluable knowledge he has shared with the South African feed milling industry over the past 15 years."

Reflecting on his journey with AFMA, Nef shared that his involvement began in 2006 when he met De Wet Boshoff, AFMA's executive director at the time, in Switzerland. They remained in contact, leading to Nef acting as a speaker at the AFMA Symposium in 2008. It was there that the idea for a short course partnership took shape, culminating in Nef teaching the first group of 35 students in 2010.

Over the years, around 400 students from diverse countries attended the prestigious course, including participants from Kenya, Saudi Arabia, and Mauritius – though the majority came from South Africa. "I will leave this place with one eye laughing and the other crying," Nef reflected. "It was a great class, but standing in front of 55 people, speaking for seven hours a day over ten days is no small feat – especially at 72!"

Improved quality and control

Jacques Prinsloo, sales director of Automill, said the feed milling technology company has supported this course for three years, recognising its ingenuity and contribution

Every year the course concludes on a high note as participants form teams to design, build, and race their own boxcars. This year, the winning team was NEF Car (team 5). In the front left, kneeling, is Jerobiam Julies, sales manager at R-Biopharm AG and the main sponsor of the boxcar event. Seated in the car is Charles Williams, managing director of Promtek. Kneeling beside Julies is Jan Kriel, a feed miller from Zambia, while on the right, also kneeling, is Buks van Helsdingen, general manager at JR Feed Mill. (Photograph: Susan Marais)

Liesl Breytenbach, executive director of AFMA, congratulates Hemant Kumar Ramdowar, head of production at Meaders Feeds in Mauritius, on achieving top honours during this year's feed miller short course. (Photograph: Supplied)

Henry Pienaar, manager at Brennco Feeds in Louis Trichardt, received the second highest mark during the final examination. Here he is shaking hands with Ernst Nef, director of Nef Feed Milling Consulting. (Photograph: Susan Marais)

All 55 participants of this year's AFMA feed miller short course, along with course facilitator Nef, on the far right, and Breytenbach standing second from the left. (Photograph: Susan Marais)

to the advancement of South Africa's feed mill industry. "It fosters industry growth and plays a vital role in ensuring sustainable food security across Africa."

Prinsloo emphasised the invaluable expertise Nef brings to attendees, particularly in mastering the proper pelleting and conditioning of animal feed. "He also highlights the importance of precision in recipe formulation," Prinsloo noted. "Ultimately, quality is at the core of his teachings. It's not just about the machinery used in a feed mill, but also the crucial control aspects surrounding it – something that is of critical importance to Automill."

The course provided a comprehensive breakdown of the various process sections within a compound feed production facility, focussing on the practical aspects of machinery and process technology. This approach enabled students to gain a thorough understanding of the essential components of a compound feed production facility, along with valuable insights into the core production processes that drive quality and efficiency.

Key course topics

- Manufacturing of animal feed.
- Aspiration systems.
- Batch mixing plant.
- Size reduction.
- Mixing.
- Liquid addition.
- Hygienising and compacting.
- Drying and cooling.
- Expansion.

The organising team behind the feed miller short course are, from the left, Bee Oelofsen, marketing and events coordinator at AFMA, Mandy Jansen van Vuuren, AFMA's accountant, Wimpie Groenewald, membership liaison officer at AFMA, Nef, Breytenbach, and Petru Fourie, AFMA's operations manager. (Photograph: Supplied)

Top student Romdowar reflected on the course's impact, noting that it provided valuable insights into the inner workings of a feed mill. Throughout his career, he has worked at every level of a mill, yet there were many small issues he lacked clarity on before attending the course. "The course gave me new perspectives and practical solutions for challenges we've faced in our feed mill," he shared. He is eager to apply these newfound insights to his business.

Henry Pienaar, manager at Brennco Feeds in Louis Trichardt, received the second highest mark during the final examination. Pienaar described the course as a true eye-opener. "Every day, I would walk past equipment and wonder why it was designed a certain way, but I never fully understood its purpose. Now, with this knowledge, I can utilise the machinery much more effectively," he said.

He hopes that the expertise gained will elevate his business, enabling them to produce higher-quality products for their customers.

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The role of feed in food safety

By Elri du Toit, intern, AFMA

Food safety encompasses the proper handling, preparation, and storage of food to prevent foodborne illnesses, which are often caused by harmful bacteria, viruses, parasites, or chemical contaminants entering the human body through contaminated food. While human food safety is widely recognised, the safety of animal feed remains an often overlooked yet essential component of the broader food safety continuum.

Ensuring the safety of animal feed is not only vital for animal health, welfare, and development, but it also directly impacts the safety of food products derived from these animals (Bastianelli and Bas, 2002). Despite becoming a routine part of operations, the critical role of feed safety in safeguarding public health is frequently underestimated. Maintaining feed safety is not only a regulatory obligation but a shared responsibility across the entire value chain.

Entering the conversation

Before the Industrial Revolution, livestock were primarily raised on small family farms, grazing on natural forage and serving as a source of food for the household (Nestel, 1984). However, the rapid urbanisation and population growth triggered by the Industrial Revolution created a significant increase in demand for agricultural and animal products.

This surge in demand gave rise to the so-called 'livestock revolution', which marked a period of rapid advancements in animal agriculture, including the development of intensive production systems and specially formulated diets designed to enhance feed conversion efficiency and accelerate growth rates (Delgado *et al*., 1999).

To produce more animal products in less time, these diets began incorporating a wide range of ingredients – from plant-based products and rendered animal byproducts to antibiotics and organ arsenicals (Sapkota *et al*., 2007). While these innovations improved productivity, they also introduced the potential for contamination with chemical, biological, and other undesirable substances in animal feed, posing a new set of risks to human health.

A notable example that heightened global awareness of feed safety was the detection of the first American case of bovine spongiform encephalopathy (BSE) in a dairy cow (Sapkota *et al*., 2007). This incident underscored the critical link between animal feed and public health, prompting increased scrutiny and regulatory attention from public health authorities.

Feed plays a critical role in ensuring food safety within the farm-to-fork continuum (Sapkota *et al*., 2007). The use of a wide variety of raw materials in animal feed can introduce potential risks to both animal and human health if appropriate risk prevention and control measures are not implemented (Heredia and García, 2018).

For example, the well-known foodborne pathogen *Salmonella* can contaminate animal feed at multiple stages of the feed production process. Without adequate screening, hygiene, and preventive protocols, *Salmonella* can persist in feed, be consumed by animals, and subsequently contaminate animal-derived products such as eggs or meat (Heredia and García, 2018). This creates a direct pathway for the pathogen to reach consumers, posing significant public health risks.

Ensuring food-feed safety

On a global scale, internationally recognised standards – such as those developed by the International Feed Industry Federation (IFIF) and *Codex Alimentarius* – provide a framework that enables feed manufacturers to implement effective quality control systems, reducing the risk of hazardous substances entering the feed supply. To ensure feed safety, manufacturers are encouraged to adopt systems such as hazard analysis and critical control points (HACCP) as well as good manufacturing practices (GMP), which help identify and manage risks across the entire feed production chain.

Table 1 outlines key global frameworks and regulations that support the production of safe animal feed, ultimately

Table 1: Key global regulations and frameworks for the animal feed industry.

Framework/regulation	Region/ country	Issuing body	Key elements	Purpose
Codex Code of Practice on Good Animal Feeding (CAC/RCP 54-2004)	Global	FAO/WHO *Codex Alimentarius*	GMP, HACCP, traceability, approved additives, and contaminant control	Ensure safe feed to protect animal and human health
EU Feed Hygiene Regulation (EC no 183/2005)	European Union	European Commission	HACCP, facility registration, hygiene standards, and banned substances	Feed-to-food safety, contamination prevention
FSMA Animal Food Rule	United States	FDA	CGMP, HARPC, facility registration, preventive controls	Prevent feed contamination and improve food safety
China's Feed and Feed Additives Regulations	China	Ministry of Agriculture and Rural Affairs	Licensing, import controls, banned substances, national standards	Standardise and monitor feed safety
Japan Feed Safety Law	Japan	MAFF	Additive regulation, labelling, contaminant monitoring, and inspections	Ensure feed safety for livestock and consumers
Canadian Feeds Regulations (Feeds Act)	Canada	CFIA	Pre-market approval, labelling, contaminant control, recordkeeping	Regulate the composition and safety of feed
IFIF and GFSI Global Feed Safety Initiatives	Global	IFIF/industry	Feed safety management systems, benchmarking, and training	Harmonise standards and promote safe global feed trade

protecting both animal welfare and human health.

South Africa's animal feed sector operates under strict legislation, primarily governed by the *Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947)*. This *Act* regulates the registration, composition, and evaluation of animal feeds to ensure they meet safety and quality standards. It forms a key component of the broader food safety framework and aligns with national food safety requirements.

The Animal Feed Manufacturers Association (AFMA) contributes to feed and food safety by promoting good manufacturing practices and responsible feed production among its members. Through its Code of Conduct, AFMA encourages compliance with feed safety standards. Members who participate in the Code undergo independent audits every two years, supporting broader industry efforts to enhance feed safety and complement government oversight.

AFMA also facilitates the voluntary submission of *Salmonella* and polychlorinated biphenyl (PCB)/dioxin test results by its members, enabling the identification of annual and quarterly trends. This system allows for early detection of any potential rise in harmful contaminants that may pose risks to animal health, and ultimately human health.

In partnership with The Southern African Grain Laboratory (SAGL), AFMA also supports the mycotoxin monitoring project – now in its tenth year – by encouraging members to submit maize samples for mycotoxin analysis. Through these proactive initiatives, AFMA continues to strengthen feed safety and uphold public health within the food supply chain.

Conclusion

Global demand for animal products is projected to increase by 70% in 2025 (FAO, 2025). This growth will drive a corresponding rise in animal feed production. As a result, feed manufacturers must implement robust protocols to ensure the production of high-quality, safe animal feed – especially when scaling up throughput. Without proper controls, there is an increased risk of compromising feed safety, which can, in turn, pose threats to human health (Sapkota *et al*., 2007).

An additional concern is the impact of climate change, which has led to shifting weather patterns and suboptimal crop storage conditions. These changes can increase the prevalence of feed contaminants such as mycotoxins. To mitigate this risk, feed manufacturers must maintain comprehensive records of their raw material sources. The type, origin, and processing methods of these materials significantly influence the likelihood of contamination.

Feed safety is the foundation of food safety. Every stakeholder in the animal feed and livestock production chains has a responsibility to ensure that feed is safe, traceable, and sustainably produced. By investing in rigorous quality systems, adhering to best practices, and proactively managing emerging risks, we safeguard both animal and human health. Ultimately, safe feed means safe food – a shared benefit that spans the entire farm-to-fork continuum.

For more information, send an email to intern@afma.co.za.

Impact of global trade wars on South Africa's raw grain procurement and market instability

By Dr Lucius Phaleng, trade advisor, AFMA

Trade wars, although often rooted in specific economic or political goals, tend to have consequences that extend far beyond the initial intention. They disrupt global supply chains, raise consumer prices, and can lead to prolonged periods of economic stagnation or even conflict.

Trade restrictions may not only raise consumer prices in the short term but can also negatively affect employment, economic growth, and purchasing power in the long term. Just as trade has generated uneven distribution of welfare gains and losses across sectors, countries, producers, and consumers, the effects of trade wars are also complex.

New trade barriers imposed by the initiator of trade wars will protect or even create jobs in specific industries, but other related downstream sectors will lose due to the higher costs associated with their imported parts and intermediate goods. In addition to creating winners and losers at the domestic level, trade wars will also impact the rest of the countries that are not directly involved in them.

Domestic firms in both the initiating and targeted countries in a trade war will have to quickly adjust to the new tariffs as well as other restrictive measures. Businesses with alternative export destinations that are less dependent on intermediate inputs or raw materials from the targeted market, tend to find it easier to make the necessary adjustments to their supply chains. Regardless, trade wars will always add transaction and adjustment costs to businesses and reduce global aggregate welfare.

If two countries that engage in a trade war carry great weight in the world economy, then the trade war will not only affect the participating countries but also cause turbulence to the global economy and global supply chains. Furthermore, fewer countries may benefit from trade wars as bystanders, as they become alternative suppliers or investment destinations to the targeted country.

Raw grain procurement

Global trade wars significantly impact the animal feed industry by disrupting raw grain procurement, leading to higher costs and potential shortages. Trade tariffs, restrictions, and political instability can increase the price of essential feed ingredients, affecting profitability and the cost of animal products. Most feed ingredients and raw materials are transported by sea from suppliers across the world, and sea freight is under fire due to these wars.

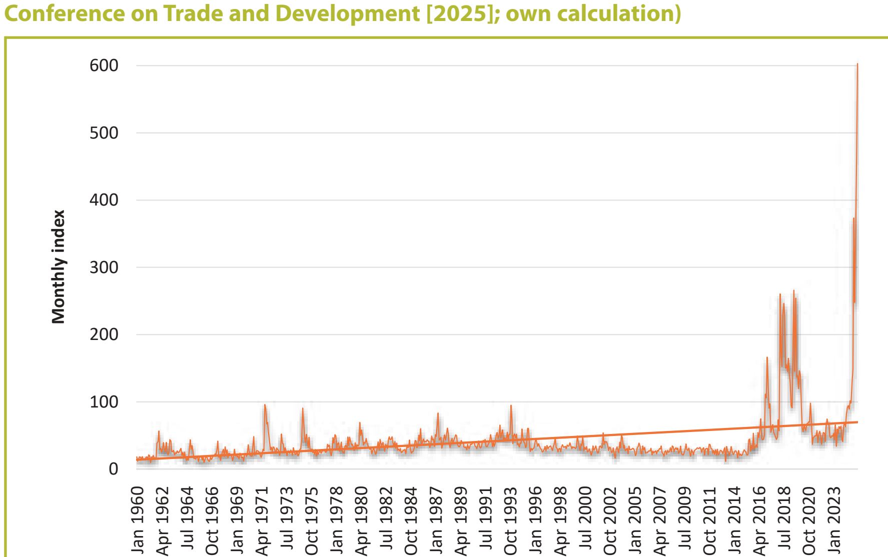
The escalating trade tensions between the United States (US) and China have significantly disrupted global shipping operations, with freight rates expected to surge by 30%. This has broader implications for global trade, potentially leading to increased costs for feed manufacturers that import ingredients and raw materials, and further disrupting trade routes and pricing models due to the imbalance of the global container market.

The trade wars create uncertainty about future trade policies, leading to a rise in the trade policy uncertainty (TPU) index, which negatively affects economic activities in the emerging markets and sectors reliant on international trade. The index reached a record high during the US presidential elections in November last year, and has remained exceptionally high (*Figure 1*) in subsequent months. The previous time the TPU index increased as strongly was during Donald Trump's first presidential term, when trade policy tensions rose between the US and its trading partners.

Feed additive implications

The animal feed industry depends on a wide variety of raw materials, including primary commodities such as yellow maize, soya beans, and other grains. It also utilises byproducts from processing industries, including oilseed meals, flour, germ, molasses, bagasse, and animal meal. Supplements derived from mining, such as

Figure 1: Historic highs in trade policy uncertainty. (Source: United Nations Conference on Trade and Development [2025]; own calculation)



limestone and phosphates, and chemicals such as vitamins and medicines are included in scientifically formulated feeds designed to meet the specific nutritional requirements of different animals and growth stages.

Currently, the industry is self-sufficient, with only minimal reliance on imports of raw materials and feed additives. Nonetheless, it imports various feed additives such as amino acids, enzymes, antioxidants, and growth promoters from international markets to improve feed efficiency and support animal health.

According to Trade Map, Malaysia, China, and Eswatini are the primary suppliers of feed additives (harmonised system code 2309.90) to South Africa, while the US exported approximately 829 tonnes of feed additives. The imported feed additives may be affected by potential uncertainties surrounding additional tariffs and supply chain disruptions. Nevertheless, the industry is encountering increasing challenges stemming from trade wars, which have significantly disrupted various ingredient supply chains and increased trade policy uncertainty.

Such disruptions jeopardise the stability of supply chains and complicate import strategies, thereby potentially affecting the availability and cost of imported feed additives in South Africa sourced from international markets.

Impact on local food security

Global trade conflicts have significant and complex effects on South Africa's raw grain procurement and overall market stability. The rise in trade tensions, marked by higher tariffs, restrictions, and increased policy uncertainty, disturbs international supply chains, raises costs, and threatens the availability of vital raw materials and feed additives crucial for the animal feed industry.

These disruptions increase operational expenses for local producers and pose risks to the country's food security and economic stability. The dynamic relationship between domestic responses and global market changes highlights the importance of strategic diversification for alternative markets.

For more information, email Dr Lucius Phaleng at trade@afma.co.za.

2025 feed outlook:
Trends influencing the global feed industry

By Petru Fourie, AFMA operations manager

The global animal feed industry is adapting to a changing world. In 2024, feed production grew by 1,2%, reaching 1,396 billion metric tonnes (mt), according to the 2025 *Alltech Agri-Food Outlook*. While the growth is modest, it marks a clear recovery from a stagnant 2023 and illustrates the sector's ability to bounce back despite continued challenges such as disease outbreaks, climate shifts, rising costs, and changing consumer habits.

But the numbers only tell part of the story. Behind this recovery is a deeper shift. Feed producers around the world are focussing more on being resilient and responsive, not simply to survive, but to stay competitive. For South Africa's feed industry, the trends in the Alltech report offer both caution and opportunity.

Mixed growth across feed sector

While global feed production in 2024 matched the levels recorded in 2022, growth varied widely between species and regions. Poultry feed remained the largest segment, accounting for 42,7% of total global feed volumes. This was followed by pig feed at 26,4%, dairy at 11,9%, and beef at 9,6% (*Table 1*). While poultry maintained its leading position, growth in this sector was modest. Ongoing outbreaks of highly pathogenic avian influenza (HPAI) continued to affect broiler and layer production. Broiler feed increased by 1,8%, reaching 385,4 million mt, while layer feed grew by 1,4%.

Pet food stood out as the fastest-growing segment, increasing by 4,5%. This growth reflects continued urbanisation, more pet ownership, and a rising demand for premium pet nutrition.

In contrast, pig feed declined by 0,6%, and aquaculture feed contracted by 1,1%. These decreases point to ongoing challenges with disease recovery and market instability. Although total feed production is on the rise again, the strength and stability of different animal protein value chains remain uneven across the sector.

Africa steps forward

Looking at regional performance, Africa and Latin America recorded the strongest growth in global feed production. Africa grew by an impressive 7,2%, while Latin America followed with 3,6%. The Middle East saw a 2,8% increase, and Europe recorded growth of 2,7%. In contrast, feed production in the Asia-Pacific region declined by 0,8% (*Table 2*). This drop was mostly due to a reduction of 6,5 million mt

Table 1: Feed tonnage by sector (2023 vs 2024).

Sector	2024 feed tonnage (million mt)	2023 feed tonnage (million mt)	Growth (million mt)	Growth (%)	% of total feed
Aqua	52,966	53,568	-0,602	-1,1%	3,8%
Beef	134,054	131,627	+2,427	1,8%	9,6%
Dairy	165,500	160,426	+5,074	3,2%	11,9%
Equine	9,630	9,415	+0,215	2,3%	0,7%
Other ruminants	23,636	23,148	+0,488	2,1%	1,7%
Other species*	7,874	8,188	-0,314	-3,8%	0,6%
Pet	37,692	36,068	+1,624	4,5%	2,7%
Pig	369,293	371,406	-2,113	-0,6%	26,4%
Poultry	595,795	585,889	+9,905	1,7%	42,7%
Grand total	**1 396,438**	**1 379,734**	**+16,705**	**1,2%**	**100%**

**The 'other species' category includes minor or specialty livestock (for example rabbits, deer/other cervids, camelids); game birds not included under poultry (for example quail, pheasant); and any exotic or niche species raised on farms or in other managed environments.*

Table 2: Feed tonnage by region (2023 vs 2024).

Region	2024 feed tonnage (million mt)	2023 feed tonnage (million mt)	Growth (million mt)	Growth (%)
Africa	57,787	53,895	+3,893	**7,2%**
Asia-Pacific	533,137	537,251	-4,114	**-0,8%**
Europe	276,761	260,779	+6,982	**2,7%**
Latin America	198,376	191,490	+6,886	**3,6%**
Middle East	37,682	36,657	+1,025	**2,8%**
North America	290,724	288,957	+1,767	**0,6%**
Oceania	10,972	10,706	+0,266	**2,5%**
Grand total	1 396,438	1 379,734	+16,705	**1,2%**

**Figures used in Alltech's Agri-Food Outlook are updated throughout the year as official feed tonnage information becomes available. 2023 data reflects final figures.*

in China's pig feed production, driven by industry restructuring and price pressures.

Africa's momentum is particularly important for South African feed manufacturers. Although the continent still accounts for a smaller share of global feed volumes, it recorded the highest growth rate worldwide in 2024. Some standout figures from Africa include a 32,2% increase in beef feed, a 25,7% increase in dairy feed, and a 9,1% increase in aquaculture feed.

These gains reflect the expansion of commercial livestock systems, increasing demand for animal protein, and greater investment in local food supply chains. For South Africa, this creates a strategic opportunity to serve as a regional hub for feed innovation, training, and input services.

Disease dynamics

The outlook confirms that transboundary animal diseases continue to have a significant impact on global feed production. HPAI affected both broiler and layer feed volumes in 2024, with the most severe effects seen in North America, Europe, and Asia-Pacific. In the United States, HPAI outbreaks led to flock reductions resulting in a 4,2% decline in layer feed production.

Countries are responding differently. In France, authorities adopted a vaccination strategy to help reduce losses. Globally, disease remains the second most reported challenge in feed production, following input cost pressures.

African swine fever (ASF) is still affecting pig sectors in China, Vietnam, and Eastern Europe. Although some countries have started to recover, pig feed production remains very sensitive to biosecurity protocols and policy decisions. The global decline of 0,6% in pig feed may seem minor, but it reflects major regional disruptions and continued caution among producers.

For South African feed manufacturers, the message is clear. Biosecurity is no longer just a compliance matter; it is central to business continuity. Strong on-site hygiene, traceability, and proactive disease prevention are essential to reduce risk and safeguard future operations.

Protein affordability

One of the key takeaways from the Alltech report is the growing influence of consumer affordability on feed demand. In countries facing food price inflation, especially across Asia-Pacific and Latin America, layer feed recorded strong growth as eggs remain one of the most affordable and accessible sources of animal protein.

In contrast, North America experienced a 4,2% decline in layer feed production, primarily due to the effects of HPAI. This pattern highlights an important consideration for feed manufacturers: Protein choices are increasingly shaped by what consumers can afford. Feed formulations must therefore not only take nutritional performance into account, but also price sensitivity and market trends.

South African feed manufacturers face similar challenges, particularly with ongoing volatility in maize and soya bean prices. As inflation continues to pressure livestock and poultry producers, developing cost-effective, value-based feed solutions will be essential.

What the sector should expect

Based on feed tonnage performance and global sentiment, some key trends are expected to influence the feed sector in 2025:

- Poultry will remain the top-performing species, with feed volumes projected to make up between 43 and 45% of global totals.
- Pet food is expected to grow more slowly than in 2024 but will continue to expand in emerging markets.
- The outlook for pig feed remains mixed. While Latin America and Europe are cautiously optimistic, feed manufacturers in Asia-Pacific and Africa face ongoing challenges.
- Dairy animal feed is projected to grow in Asia-Pacific and Africa, driven by increasing demand and more intensive production systems.
- Beef cattle feed volumes are expected to remain stable, but may be affected by drought conditions, especially in North America where ongoing drought conditions are already impacting feed availability and herd sizes.

Most feed manufacturers anticipate stable or improved market conditions for 2025, although this will depend heavily on managing key risks such as disease outbreaks and inflationary pressure.

Conclusion

South Africa's feed industry is operating in a high-stakes environment. With variable raw material cost prices, ongoing disease threats, and shifts in regional demand, the ability to adapt will be essential. Feed manufacturers should focus on tightening biosecurity, developing cost-effective formulations, and exploring potential growth in regional African markets where demand for dairy and beef feed is rising quickly.❖

To access more global data and industry insights, download the full 2025 *Alltech Agri-Food Outlook* at *www.alltech.com/agri-food-outlook*.

The animal science students who attended the outreach at Meadow Feeds in Pietermaritzburg.

Roshan Sookdhew, quality and risk officer at Meadow Feeds KwaZulu-Natal, took the students on a tour of the mill.

AFMA student outreach at the University of Zululand: A day at Meadow Feeds

By Bee Oelofsen, marketing and events co-ordinator, AFMA

On 24 April, the Animal Feed Manufacturers Association (AFMA) had the pleasure of hosting 65 animal science students from the University of Zululand at Meadow Feeds in Pietermaritzburg for an AFMA student outreach event. The goal was clear: to help students bridge the gap between what they've learned in class and real-world industry practices.

Following a safety briefing, the students were divided into two groups. One group started with a comprehensive tour of the feed mill, while the other attended presentations led by the Meadow Feeds team. After lunch, the groups switched activities.

The tour offered an in-depth look at the entire operation, covering the warehouse, laboratory, control room, and production floor. Students gained valuable insight into the transformation of raw materials into safe, high-quality animal feed, as well as the real-world application of food safety, quality control, and pest management practices.

Specialists share their knowledge

During the presentations, Meadow Feeds employees offered valuable insights into their roles within the company. Martina Longmore discussed raw material logistics as well as food safety, and provided an overview of a production manager's daily tasks, while Stephan Gericke outlined the responsibilities of a technical manager. Maxwell Fakude and Clint Lawson explained the role of technical advisors in the field.

Keroosha Amichand shared practical guidance on CV preparation and interview expectations, while Lientjie Mogano emphasised the importance of professional registration after earning a degree.

After the event, the students' feedback was overwhelmingly positive and encouraging. One student remarked: "I learned how raw materials are transformed into a final product and how these products help prevent contamination. These are aspects we don't typically get to see at university." Another said: "Before this outreach, I wasn't aware of the diverse career paths in animal science. Now I am, and I found the guidance incredibly valuable."

AFMA extends its heartfelt gratitude to the entire Meadow Feeds team for sharing their time and expertise. Their dedication ensured that the students were well cared for throughout the event, making a lasting impact on their knowledge and future career prospects.

Boundless opportunities

AFMA's outreach events aim to showcase the diverse opportunities within the animal feed industry. Beyond becoming an animal

Stephan Gericke, technical manager at Meadow Feeds KwaZulu-Natal, and Martina Longmore, senior nutritionist at Meadow Feeds KwaZulu-Natal.

nutritionist, students can explore exciting careers in production, quality control, logistics, technical support, and more. Following this inspiring event, attendees left with a deeper understanding of the industry and renewed enthusiasm for the many ways they can contribute in the future.

For more information, send an email to events@afma.co.za.

Promising prospects:
Careers and opportunities in the feed industry

By Carin Venter

In 2020, the South African animal feed industry employed an estimated 17 000 people. This raises an intriguing question regarding the career landscape in the sector – an essential link in the feed and food chain – and opportunities for employees to grow and advance by transitioning into different roles within the industry.

Marianne van der Laarse, managing director of Agrijob and AgriCAREERConnect, recalls a time when persuading young people to pursue agricultural studies was a significant challenge. "However, emerging innovations and trends have created new career pathways, also in the livestock feed sector. We strongly encourage students to gain practical experience, as it will greatly enhance their job prospects."

Regarding careers in the animal feed sector, Van der Laarse categorises the various roles as follows:

- **Commercial roles** such as technical sales, technical advisors, marketers, key account managers, product development managers, chief executive officers (CEOs), and financial managers.
- **Technical roles** such as nutritionists, technical services, and technical support (not sales-related).
- **Operational posts** such as CEOs or general managers, factory/operations managers, financial managers, millwrights, safety, health, and environmental managers, quality and quality assurance managers, quality control managers, and raw materials controllers.

From *Table 1* it is evident that there is a much greater demand for candidates with commercial experience.

According to Van der Laarse, the agricultural industry is facing a significant shortage of experienced professionals in marketing, trading, and procurement – particularly those with specialised scientific and product knowledge, as well as exceptional interpersonal and communication skills to effectively market and sell products or services within the sector.

"As a result, individuals who hold a BSc in Agriculture, complemented by additional qualifications in commerce, trade, management or industrial engineering, are both rare and highly sought after. This career space sits at the intersection of science and integrated technologies, equipping graduates with a diverse skill set across multiple disciplines and paving the way for a promising and resilient career trajectory."

She advises graduates from all science-related fields, whether specialising in livestock, plants, food, microbiology, environmental science or agricultural economics, to enhance their expertise by upskilling in key interdisciplinary areas. These include commerce, logistics, retail management, import and export, marketing and trading, industrial engineering, enterprise resource planning (ERP), electronic engineering, mechatronics, information technology, data analytics, management, and GIS technology.

Graduate placement space

The Fresh Produce Exporters' Forum (FPEF), in collaboration with Agrijob, provides subsidies for graduates by facilitating their placement with companies. Over the years, this initiative has enabled approximately 70% of graduates involved to secure full-time employment. However, many are later headhunted by companies offering lucrative packages – an opportunity that, while appealing, may not always be beneficial in the long run. "Young professionals who accept these offers could face challenges such as retrenchment, forcing them to seek new employment at lower compensation," says Van der Laarse.

The agricultural sector, including the animal feeds industry, is urgently seeking to employ individuals aged 30 to 48 with strong managerial skills. Van der Laarse notes that most professionals in these roles are older, highlighting the pressing need to train younger candidates for leadership positions.

"We need career-driven men and women across all areas of the industry. It is crucial for companies to invest in young talent, and for management to actively support and empower the next generation to develop managerial expertise. Businesses should make every effort to retain these young professionals.

"An emerging trend in the animal science industry is the increasing participation of women, surpassing that of men. However, there remains significant work to be done in expanding internship opportunities within the sector. While some companies offer their own internship programmes, it would be ideal for them to maintain these initiatives annually.

Table 1: Percentage distribution of job advertisements in the animal feed industry by category, posted on the Agrijob website between April 2022 and May 2025.

Operations feed milling: 11%	Commercial: 54%	Technical: 19%
Factory/operations manager	Technical sales	Nutritionist, technical services
Millwright	Marketing	Technical support – not sales
Safety and health	Key account management	
Environmental manager	Product/development manager	
Quality manager	Senior and financial management	
Quality assurance manager		
Quality control manager		
Raw materials controller		

This is how companies build and retain a strong workforce."

New career opportunities

"Due to a shortage of skilled sales staff, some companies attempt to recruit technical employees to fill these roles. While some are hesitant to make the transition, others embrace the opportunity and successfully step into these positions."

Van der Laarse says a good example is an individual with an animal science qualification or a technical advisory background shifting into a completely different yet rewarding role such as enterprise resource planning (ERP) system management or a managerial position.

"There is significant potential for career advancement," she notes. "Companies should recognise this within their own workforce, as retaining employees by offering growth opportunities is far more beneficial than losing them to competitors through headhunting."

In-service training in the animal feed industry remains limited, primarily catering to students pursuing a national diploma. After having completed the theoretical component of their studies, these students must undertake six to 12 months of practical work as a prerequisite for their qualification. However, there is also a demand for basic, unskilled workers who can be trained on the job. Some of these employees excel in their roles, and companies often seek to retain them as valuable team members.

AgriCAREERConnect visited Stellenbosch University in October last year. Representatives from Meadow Feeds, Alltech, Rijk Zwaan, Koppert, the Fresh Produce Exporters' Forum, Berryworld, the Unlimited Group, Citrus Academy, and Standard Bank attended the event.

"When it comes to tertiary education and the qualifications that companies require, young professionals should think outside the box and explore integrated career paths beyond their core skill set. This forward-thinking approach is becoming increasingly relevant and will continue to shape the future of the industry. For instance, pursuing a degree in animal science, gaining hands-on experience during holidays, and remaining open to diverse career opportunities can significantly enhance their prospects."

For more information, contact Marianne van der Laarse at 082 388 1000 or visit *www.agrijob.co.za.*

AFMA

SAFE FEED FOR SAFE FOOD

Animal Feed Manufacturers Association

EMPOWERING THE FEED INDUSTRY

AFMA's Commitment to Sustainable Growth and Food Security

The Animal Feed Manufacturers Association (AFMA) is the official representative body for the South African feed industry, playing a vital role within the broader agricultural sector. Positioned in the food value chain, AFMA partners with government, regulatory bodies, parastatals, forums, academia, international agencies, and other related stakeholders in the value chain, to drive growth and innovation in the agricultural sector.

VISION

The dynamic animal feed thought leader influencing food security through partnerships with all stakeholders.

STRATEGIC PILLARS

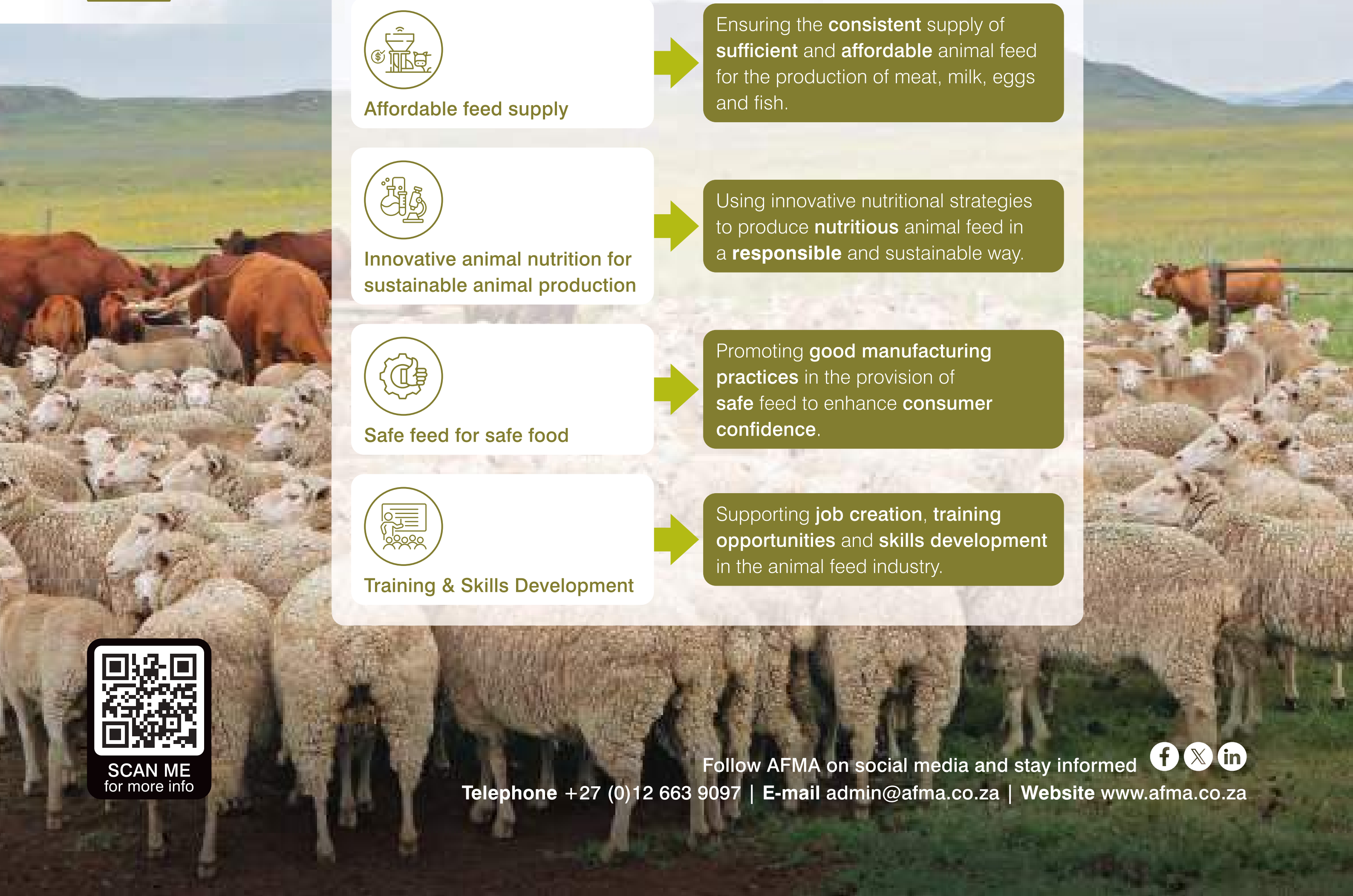
AFMA's activities are guided by four strategic pillars:

Affordable feed supply – Ensuring the **consistent** supply of **sufficient** and **affordable** animal feed for the production of meat, milk, eggs and fish.

Innovative animal nutrition for sustainable animal production – Using innovative nutritional strategies to produce **nutritious** animal feed in a **responsible** and sustainable way.

Safe feed for safe food – Promoting **good manufacturing practices** in the provision of **safe** feed to enhance **consumer confidence**.

Training & Skills Development – Supporting **job creation**, **training opportunities** and **skills development** in the animal feed industry.



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Anina Hunter, AFMA chairperson, with Plaas Media's LiMari Louw, broadcast editor, and Susan Marais, news editor. (Photograph: Supplied)

Petru Fourie, AFMA's operations manager, Siyabonga Mbambo, Feeds Bill consultant, and Bonita Cilliers, AFMA's technical and regulatory advisor.

Committed to producing safe feed

By Susan Marais, Plaas Media

For the past 80 years, the Animal Feed Manufacturers Association (AFMA) and its members have consistently demonstrated their ability to produce safe feed, ensuring safe food for human consumption. However, the time has come to broaden the focus. AFMA is committed to collaborating with government and the private sector to foster an enabling environment in which industry role-players can thrive and long-term solutions to food insecurity can be developed.

Anina Hunter, chairperson of AFMA, shared this vision during its recent media and industry day, attended by journalists, AFMA members, industry partners, and government representatives.

"Between 50 and 60% of Africa's population still lacks reliable access to food, which needs to be addressed urgently. While South Africa's feed milling industry may be a relatively small player on the global stage, it can still play a crucial role in tackling this challenge across the continent."

AFMA's Liesl Breytenbach, executive director, and Dr Lucius Phaleng, trade advisor.

Last year, AFMA members accounted for almost 60% of all commercial feed sold in South Africa. However, electricity supply remains a major concern: "Today, this is the only cost driver that I, as a manufacturer, have no control over. Industry and government must come together to address this challenge."

Feed leads to food

Liesl Breytenbach, executive director of AFMA, highlighted the industry's vital role in the animal protein value chain, serving as the link between grain production and the consumer's plate. She reaffirmed AFMA's dedication to feed and food safety, noting that feed manufacturers must adhere to the AFMA code of conduct before becoming members. "The days of treating the feed chain as separate from the food chain are long gone," she said.

AFMA's trade advisor, Dr Lucius Phaleng, stressed the importance of removing trade related obstacles such as unnecessary tariffs to ensure that feed remains as affordable as possible. A key concern is tariffs on products not manufactured locally. In this regard, AFMA has been engaging with the International Trade Administration Commission (ITAC) of South Africa in the review process of soya meal import duties.

"Previously, we relied more heavily on imported soya meal. To encourage local production and expand crushing capacity, ITAC introduced a 6,6% import tariff which successfully fulfilled its purpose. Now it is time for a reassessment," Dr Phaleng explained.

AFMA aims to introduce a grain supplier declaration document in the future, marking a significant step towards self-regulation. "It would serve as a commitment from all suppliers to the South African feed industry, affirming their adherence to specific standards." He added that such compliance could further strengthen trust within the industry.

Regulations and sustainability

Bonita Cilliers, AFMA's technical and regulatory advisor, discussed the association's ongoing engagement with authorities and international stakeholders to keep the South African feed industry relevant.

One of the biggest challenges, she noted, is achieving synergy between government and industry. The latter is rapidly evolving while regulatory processes often lag.

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

AFMA membership: A layered-cake recipe for industry success

By Wimpie Groenewald, membership liaison officer, AFMA

In the world of feed manufacturing, success is not achieved on one's own. It takes a well-balanced mix of people, products, and processes, all working in harmony. That is where the Animal Feed Manufacturers Association (AFMA) comes in. AFMA brings together the full spectrum of the feed value chain to build a safe, smart, and sustainable network.

Like baking a perfect cake, the feed industry depends on the right combination of core ingredients, tools, and expertise. Each AFMA member plays a vital role in this process, and together we create a resilient, future-ready industry.

Understanding the process

AFMA membership is categorised into three distinct types, namely full, associate, and affiliate. Each membership category represents a critical element in the feed manufacturing value chain, ensuring a comprehensive and interconnected industry structure.

Full members: The cake

Full members are the primary feed manufacturers, the very heart and foundation of the industry. They produce complete and compound feeds that nourish South Africa's livestock. Without them, the value chain would lack its central product. They are the cake itself. These manufacturers are the backbone of AFMA, ensuring that high-quality feed products reach farms across the country.

Associate members: Ingredients

Associate members supply the critical building blocks of animal feed: raw materials, vitamins, minerals, premixes, and speciality additives. These are the quality ingredients that define the nutrition, safety, and performance of the final product. Just as no cake can be baked without flour, sugar, and eggs, no feed can be manufactured without these essential components.

Affiliate members: Tools and expertise

Affiliate members include consultants, equipment providers, logistics companies, and other service partners. They are the tools and the know-how – ensuring that the feed manufacturing process runs efficiently, consistently, and in line with the highest standards. Without these, the ingredients remain unused and the cake unfinished.

The AFMA membership process

AFMA's membership process is designed to ensure that all members contribute meaningfully to the feed value chain while upholding the association's commitment to industry standards and ethical conduct. The structure intentionally brings together essential industry stakeholders – from manufacturers to suppliers and service providers – creating opportunities to connect, collaborate, and contribute to a stronger, more resilient sector.

The membership process involves:

- Identifying the appropriate membership category based on the role in the feed value chain (full, associate, affiliate).
- Completing the membership application, detailing the company's operations, products, and services.
- Undergoing a review process to verify alignment with AFMA's values and industry standards (pre-screening).
- Affiliate members who comply with AFMA's values and industry standards are awarded AFMA membership after the pre-screening process, and after settling their yearly membership fees.
- After the pre-screening phase full and associate members continue with the AFMA code of conduct process by undergoing a code of conduct audit every two years to prove compliance with the code of conduct before membership is awarded/renewed. AFMA membership fees automatically continues during the process.
- Accessing industry insights, training, networking opportunities, and advocacy resources upon successful membership approval.

AFMA membership is automatically renewed and invoiced each year in September. AFMA members who wish not to renew their membership is subject to a notice period. The notice period for affiliate and associate members is three months, while full membership can only be cancelled by a six-month notice period.

Bringing it together

At AFMA, we connect the cake, the ingredients, and the tools to build a robust and resilient feed value chain. By fostering collaboration between manufacturers, suppliers, and service providers, we create a network that thrives on mutual support and shared expertise.

When the right partners come together, excellence is inevitable.

For more information, send an email to Wimpie Groenewald admin@afma.co.za.

Mitigating enteric methane emissions: An overview of methanogenesis, inhibitors, and future prospects

By Xin Xie, Yurong Cao, Qiushuang Li, Qi Li, Xingze Yang, Rong Wang, Xiumin Zhang, Zhiliang Tan, Bo Lin and Min Wang

Ruminant livestock are essential for global food security, as they can convert human-inedible complex carbohydrates into high-value animal proteins such as meat and milk. Methane is a natural product of the anaerobic microbial fermentation in the rumen, and is also a greenhouse gas with a global warming potential over 26 times greater than carbon dioxide (CO_2) and a shorter half-life (Wang *et al*., 2021, 2022).

The atmospheric methane concentration has continuously increased since 1983, and contributes to approximately 30% of global warming (Feng *et al*., 2022). Approximately 30% of global anthropogenic methane emissions originate from livestock production, with 88% coming from enteric fermentation (Food and Agriculture Organization [FAO], 2022). The enteric methane emissions also represent a loss of energy from feed ingested of 2 to 12% of the energy intake (Attwood and McSweeney, 2008).

Most methane is emitted by cattle (77%), followed by buffalo (13%), and other small ruminants (10%) (Gerber and FAO, 2013). As the global population grows with increasing demand for meat and milk, ruminant agriculture will expand with corresponding increases in enteric methane emissions, which can have an impact on climate changes (Wang *et al*., 2024). Rapid and effective mitigation of enteric methane emissions is crucial for carbon reduction to slow global warming, and meet international climate targets proposed by the Paris Agreement (Arndt *et al*., 2022; Clark *et al*., 2020).

In the last decade, ruminant nutrition has made great advances in understanding the factors driving methanogenesis in the rumen and developing methane mitigation strategies. Feeding inhibitors can help optimise rumen function to increase the efficiency of nutrient utilisation and decrease environmental impacts (Kebreab *et al*., 2023).

Although numerous strategies have been proposed, practical implementation on-farm remains challenging (Beauchemin *et al*., 2022). Furthermore, the area of developing inhibitors is evolving at a rapid pace under mitigation pressure, and as such there is a need for continual reviews to guide mechanisms of action, effectiveness, risk, and potential for widespread use of inhibitors in ruminant production systems.

Extent of methane mitigation

The effect of methane reduction presented here was based on studies retrieved from the literature in the last five years from 2020 to 2024. Searches were conducted using the keywords of 'methane' combined with 'dairy', 'beef', 'sheep' and 'goat' from peer-reviewed journal articles available in the Google Scholar online database (*scholar. google.com*) and the Web of Science online database (*webofknowledge.com*).

Preference was only given to studies with *in vivo* measurements of enteric methane emissions, which had clearly defined experimental treatments and controls with multiple replications and at least four animals in continuous design experiments or cross-over studies, among other criteria. We extracted 78 studies that utilised treatments such as lipids, nitrates, tannins, saponins, essential oils, ionophores, macroalgae, small molecule targeted inhibitors, and probiotics.

Lipids

Lipids are known to increase energy density in feed and improve animal productive performance (Bahramkhani-Zaringoli *et al*., 2022; Kazemi-Bonchenari *et al*., 2020). An inhibitory effect on methanogenesis has been observed with the use of lipids, including vegetable oil, animal oil, and certain high-fat by-products (Zhang *et al*., 2021). Medium and long-chain fatty acids have been shown to inhibit and damage cell membranes, thereby resulting in the inhibition of methanogenic activities (i.e. *Methanobrevibacter*) and reduction of methane production (McCauley *et al*., 2020; Yang *et al*., 2024).

Theoretically, unsaturated fatty acids have a stronger methanogenesis inhibition effect due to the additional H_2 sinks as compared to saturated fatty acids. This effect is strengthened as the degree of unsaturation increases (Hristov *et al*., 2013), although the methane reduction through the hydrogenation of fatty acids is limited (Martin *et al*., 2010).

Additionally, oil supplementation can improve the fatty acid profiles in both milk and meat. Thanh *et al*. (2023) reveal that oil markedly increased the levels of health-promoting fatty acids in milk. Supplementing linseed to the feed can achieve a desirable n-6 to n-3 polyunsaturated fatty acids (PUFA) ratio in meat of lambs (Li *et al.*, 2020). The meta-analysis by Arndt *et al.* (2022) shows that the use of oils and fats reduced daily methane emissions by 19%, methane yield by 23%, methane intensity in terms of weight gain by 22%, and methane intensity in terms of milk production by 12% according to the studies from 1964 to 2018.

Recent studies from 2020 to 2024 indicated that lipid supplementation shows average reductions of 24% in daily methane emissions (ranging from -5 to -41%), average reductions of 23% in methane yield (ranging from -9 to -39%), and average reductions of 29% in methane intensity (ranging from -14 to -62%).

Although every increasing 10g/kg total mixed ration (TMR) of dietary fat supplementation decreases methane emissions by 1 to 5%, high-fat supplementation would exert a negative impact on feed intake and feed digestibility of animals (Beauchemin *et al.*, 2020). However, there is a practical implication; dietary methane mitigation without adversely affecting the lactation performance of dairy cows occurs when the dietary starch/NDF ratio is below 0,63 and dietary fat content is between 2,89 and 4,69% (Zhang *et al.*, 2024). El-Zaiat *et al.* (2021) and Yang *et al.* (2009) report that excessive supplementation of seed oil can coat on feed particles with potential toxicity to cellulolytic bacteria, such as *Butyrivibrio fibrisolvens*, *Fibrobacter succinogenes* and *Ruminococcus flavefaciens*.

Excessive supplementation of lipids also reduces milk fat percentage and yield by 7,8 and 6% respectively (Ondarza *et al.*, 2024), with its toxicity depending on the carbon chain length and saturation level of the lipids (Roques *et al.*, 2024). Other factors, such as fatty acid composition, sources of fat, and types of feed ingested, are critical to influence the methane mitigation effects (Yanza *et al.*, 2021b). Long-term studies suggest that feeding diets with whole cottonseed, that are rich in oils, reduce methane yield and maintain milk yield for up to eight weeks, but these effects are not sustained beyond 19 weeks (Muñoz *et al.*, 2021).

Saponins

Saponins are a class of glycosides that are widely distributed in terrestrial plants, and show the function of binding with sterols on the surface of protozoan cell membranes which leads to cell lysis. As a large proportion of methanogens are attached to protozoa, the inhibitory effects of saponins on protozoa can indirectly reduce methane production (Goel *et al.*, 2008). Additionally, saponins can inhibit cellulose-degrading bacteria and cellulose-degrading anaerobic fungi, which are important H_2 producers for methanogenesis (Kholif, 2023).

Saponins can reduce methane production by 14,8%, as demonstrated by *in vitro* studies (Martins *et al.*, 2024). Meta-analysis results indicate that saponins can reduce methane production by 37% *in vivo* (Pepeta *et al.*, 2024). Furthermore, saponin supplementation has a positive effect on nutrient digestion and can also improve antioxidant capability and immune function (Kholif, 2023; Liu *et al.*, 2021). The meta-analysis by Arndt *et al.* (2022) shows that the use of saponin as additives reduced daily methane emissions by 8%, and methane yield by 3%.

Over the past five years, most of the investigations have primarily been conducted *in vitro*, with limited available literatures for *in vivo* researches. Recent studies have indicated that saponin supplementation shows average reductions of 28% (ranging from 4 to 47%) in daily methane emissions. Consequently, there is still a lack of conclusive understanding of the mitigation effect of saponin supplementation *in vivo*, and thus, we did not calculate an average reduction for methane yield and methane intensity.

Dietary saponins level is recommended to be less than 45g/kg TMR on dry matter basis, as higher saponin supplementation can inhibit the activities of cellulose-degrading micro-organisms (Holtshausen *et al.*, 2009; Ridla *et al.*, 2021). Meta-analysis has found that high doses of saponin supplementation decreases feed digestibility (Ridla *et al.*, 2021). The extent of methane mitigation increases with higher doses of saponin-rich sources and reaches a plateau once the saponin content exceeds 500mg/g DM (dry matter; Jayanegara *et al.*, 2014).

The effectiveness of saponins may also depend on their sources, highlighting the importance of selecting appropriate saponins for practical applications (Palangi and Lackner, 2022). *Quillaja saponaria* is recommended for large ruminants as it can enhance productive performance and maintain rumen health (Yanza *et al.*, 2024). As the impact of saponins on rumen microbiota, fermentation, and methane production is complex and multifactorial, further research is needed to determine the benefits and drawbacks of long-term saponin use in animal production.

Essential oils

Essential oils, volatile compounds derived from various plant species, have long been utilised as antibacterial agents due to their bacterial inhibition properties. They indirectly suppress the growth of protozoa, or outcompete with methanogens for H_2 utilisation through unsaturated fatty acids, leading to reductions in methane emissions (Martins *et al.*, 2024; Orzuna-Orzuna *et al.*, 2022; Tseten *et al.*, 2022). Proper essential oil supplementation could enhance propionate production and decrease ammonia-N concentrations in the rumen, without adverse impacts on rumen fermentation (Ugbogu *et al.*, 2019; Zhang *et al.*, 2021).

Metagenomic analysis revealed that supplementing essential oil increases VFA production through enriching bacterial communities of *Bacteroides* sp. and *Succinivibrio* sp. (Lei *et al.*, 2019). Furthermore, essential oil supplementation also increases milk fat yield and the concentration of unsaturated fatty acids in milk (Belanche *et al.*, 2020; El-Essawy *et al.*, 2021). Supplementation of essential oils to beef cattle diets can show other benefits including increasing average daily gain (ADG) and feed efficiency (Orzuna-Orzuna *et al.*, 2022).

The meta-analysis by Arndt *et al.* (2022) shows that the use of essential oils reduced daily methane emissions by 5%, methane yield by 7%, and methane intensity by 4%. Studies from the past five years indicated that essential oil supplementation shows average reductions of 15% in daily methane emissions (ranging from 6 to 32%), average reductions of 18% in methane yield (ranging from 6% to 29%), and average reductions of 26% in methane intensity.

Ionophores

Ionophores have been extensively employed as antimicrobial agents within the dairy, beef, and poultry farming industries. Monensin and lasalocid are

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currently the most extensive, while salinomycin, narasin, maduramicin, and semduramicin are also gaining increasing attention. These groups are capable of binding with both intracellular and extracellular cations, leading to a perturbation in the normal ion concentration.

This interference results in the disruption of transmembrane transport and consequent ion imbalance and damage to the plasma membrane of Gram-positive bacteria, as well as major H_2-producing bacteria and protozoa. By reducing the number of attached protozoa and methanogenic bacteria via the mechanisms aforementioned, ionophores can reduce methane emissions (Ekinci *et al*., 2023).

Additionally, ionophore supplementation may have other benefits, such as increasing the efficiency of milk production in dairy cattle (Horst *et al*., 2024). A recent study indicates that supplementing monensin up to 23 ppm increases milk production, with the optimal dose identified at approximately 16 ppm (Rezaei Ahvanooei *et al*., 2023).

The meta-analysis by Arndt *et al*. (2022) shows that the use of ionophores reduced daily methane emissions by 8%, methane yield by 7%, and methane intensity by 1%. Studies from the past five years indicated that ionophore supplementation shows average reductions of 21% in daily methane emissions (ranging from 8 to 34%), average reductions of 17% in methane yield (ranging from 2 to 34%), and average reductions of 14% in methane intensity (ranging from 11 to 20%).

Macroalgae

Macroalgae has emerged as a research hotspot as an anti-methanogenic feed additive. Seaweed, a type of macroalgae, includes brown, red, and green algae. Halogenated compounds such as chloroform and bromoform in seaweed can inhibit methane synthesis by suppressing MCR activities and inhibiting the growth of *Methanobrevibacter smithii* and *Methanobrevibacter ruminantium*, thus exhibiting significant methanogenesis inhibition potential (Roque *et al*., 2019). Among these, *Asparagopsis taxiformis* and *Asparagopsis armata* are rich in halogenated bioactive compounds, with *Asparagopsis taxiformis* demonstrating the strongest linear effect on methane reduction, reducing methane emissions by over 64% in beef cattle and Jersey cows (Colin *et al*., 2024; Sofyan *et al*., 2022).

Numerous *in vivo* and *in vitro* studies have validated their methane-mitigating effects (Nunes *et al*., 2024). Additionally, brown seaweed polyphenols also play a role in reducing enteric methane emissions and modulating rumen fermentation (Min *et al*., 2021). The meta-analysis demonstrates that increasing concentrations of *Asparagopsis* correspond to a linear reduction in methane mitigation efficacy, without adversely impacting feed intake (Alvarez-Hess *et al*., 2024). It is also shown that red seaweed can increase milk and meat production in cattle, while brown seaweed can increase ADG in cattle (Narvaez-Izquiedo *et al*., 2024). The inclusion of brown algae (*Ascophyllum nodosum*) and green algae (*Chlorophyta*) in feed has also been shown to mitigate methane emissions (Bošnjaković *et al*., 2024; De Bhowmick and Hayes, 2023).

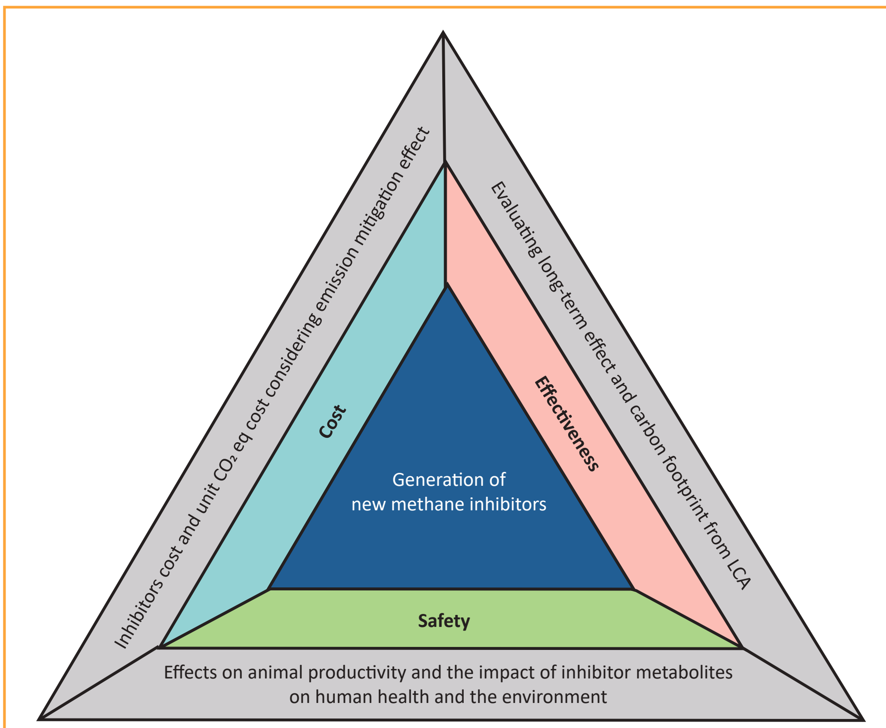
Studies from the past five years indicated that macroalgae supplementation shows average reductions of 44% in daily methane emissions (ranging from 22 to 75%), average reductions of 32% in methane yield (ranging from 16 to 70%), and average reductions of 30% in methane intensity (ranging from 20 to 74%).

Probiotics

Probiotics, widely regarded as safe feed additives, can stimulate bacterial activity, maintain rumen fermentation processes, and improve animal health. For ruminants, bacterial species such as *Bacillus*, *Bifidobacterium*, *Propionibacterium*, lactic acid bacteria, and yeasts (*Saccharomyces cerevisiae*) have shown potential in mitigating methane emissions, but the exact mechanisms remain unclear. The supplementation of live yeast stimulated H_2 utilisation by the acetogenic bacteria, suggesting that yeasts may inhibit methanogenesis by enhancing reductive acetogenesis, which reduces the H_2 available for methanogenesis (Mwenya *et al*., 2004).

The supplementation of probiotics in feed has been shown to increase feed intake, enhance digestibility coefficients, and boost gas production from the feed

Figure 1: Design principles for generating new inhibitors of methanogenesis. Three fundamental principles in the design of inhibitors: safety, cost, and effectiveness. Each principle is represented on a different side of the triangular framework, with specific considerations outlined.

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(Hassan *et al*., 2020). Probiotic yeasts play significant roles in regulating rumen pH, increasing milk yield, and enhancing immune function (Patel *et al*., 2015; Vohra *et al*., 2016). Additionally, studies have shown that probiotic supplementation can significantly increase the ADG in beef cattle (Pittaluga *et al*., 2023).

The meta-analysis by Arndt *et al*. (2022) shows that the use of probiotics reduced daily methane emissions by 1%, methane yield by 2%, and methane intensity by 4%. Studies from the past five years indicated that probiotics supplementation shows an average reduction of 11% in daily methane, average reduction of 11% in methane yield (ranging from -10 to -11%).

New generation of inhibitors

Undoubtedly, the new generation of inhibitors must prioritise safety. Safety is a comprehensive and systematic issue that is not limited to the well-being of ruminants, but also includes the safety of humans and the environment. Some traditional inhibitors have been regarded as impractical in production due to their potential harm to humans and the environment. For instance, the metabolites of halogenated compounds, such as bromoform, are ozone-depleting gases that further damage the ozone layer and exacerbate the greenhouse effect (Glasson *et al*., 2022). Hence, the effects of enteric methane mitigation generated by inhibitors may be offset by the environmental damage caused by their metabolites. Once inhibitors improve ruminant digestion and productive performance, or at least not affect them adversely, farmers could consider utilising them.

It is evident that the design and subsequent use of new synthetic inhibitors also require *in vitro* and *in vivo* experiments to verify whether these inhibitors and their metabolites have adverse effects on ruminants, humans, and the environment, which are crucial factors for the regulatory approval process to evaluate the new generation of methanogenesis inhibitors.

Another design principle for methanogenesis inhibitors is effectiveness, particularly in the long term, where methanogenesis inhibition can still achieve a significant mitigation of methane. Based on previous reviews, many types of inhibitors currently show satisfactory results in reducing methane production in short-term *in vivo* experiments (Króliczewska *et al*., 2023). However, when administered over extended periods, the anti-methanogenesis effect significantly reduced or even disappeared due to the gradual adaptation of rumen methanogens. For example, ionophores can significantly reduce methane production, but the mitigation effect appears to gradually weaken after prolonged feeding (Muñoz *et al*., 2021; Van Gastelen *et al*., 2024).

Moreover, cost-effectiveness is frequently overlooked by ruminant nutritionists during the design of inhibitors. Although the technological mitigation potential of livestock is significant, its achievable potential at reasonable economic costs may be substantially smaller (Herrero *et al*., 2016). As such, maximising methane emission mitigation within a limited budget is a critical issue.

When methanogenesis inhibition strategies do not significantly improve productive performance and feed efficiency, the use of inhibitors implies an increase in feed costs, which may reduce the economic return on production, thus limiting the application of inhibitors (Lean *et al*., 2021). Who will bear the costs of such mitigation strategies is a question worth considering.

Prospects of future inhibitors

As one of the most important food sources of livelihood and economy for humans, animal husbandry is a major contributor to greenhouse methane emissions (Wang *et al*., 2021). To reduce methane production, feed manipulation and the use of various biological or chemical additives can be employed without adversely affecting ruminant productivity.

Although various feeding strategies such as adding oils and fats, using electron receptor additives, and applying small molecule targeted inhibitors have demonstrated significant methane mitigation effects, more experiments are needed to verify whether these additives can still significantly reduce rumen methane production after long term use. Moreover, for grazing and extensive systems, the continuous supplementation of inhibitors or other mitigation strategies is impractical.

To ensure the sustained activity of methanogenesis-inhibiting compounds in the rumen, the combination of inhibitors with slow-release technology should be considered (Roques *et al*., 2024). Additionally, all chemical and biological interventions, which may affect the health of ruminants or consumers, must be managed with caution.

For emerging algal inhibitors, further in-depth studies are necessary to determine their impact on animal health and potential residues in animal-derived products. Additionally, further research is needed to understand the impact of methanogenesis inhibition on rumen microbial communities, fermentation pathways, and H_2 flux, which is critical to developing more accurate and efficient mitigation strategies while not affecting or potentially improving the efficiency of productivity.

Both traditional and new-generation synthetic additives must be established on a foundation of safety, economic viability, and effectiveness. When considering the widespread use of inhibitors, additional factors including consumer acceptance and technical support for producers must also be taken into account (Beauchemin *et al*., 2022). The most important prerequisite condition is to ensure that these additives are safe for animals, consumers and the environment, and are approved by government agencies and accepted by consumers.

Future inhibitors should achieve more precise methane reduction control by targeting methane-producing microbes and metabolic pathways.

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Precision dairy cow nutrition utilising methionine supplementation

EVONIK
Leading Beyond Chemistry

By Ranier van Heerden, ruminant business manager, sub-Saharan Africa, Evonik

Dairy producers are under constant pressure to function more efficiently, especially due to substantial attention being placed on protein and amino acid nutrition. This is primarily due to the negative environmental effects of excessive nitrogen excretion, high costs of protein supplements, and increasing public demand for milk protein.

These negative effects can partially be alleviated by utilising rumen-protected methionine (RPM), a valuable nutritional tool to effectively meet the cow's requirements for absorbed amino acids (AA). Rumen-protected Met reduces the amount of nitrogen excreted into the environment while subsequently increasing cow performance and health.

Dairy cows require specific post-ruminally absorbed AA and not dietary crude protein (CP), whereas rumen microbes require various nitrogen (N) containing compounds such as rumen degradable protein (RDP), peptides, AA, urea, and ammonia. When formulating dairy diets, one of the main goals is to optimise the AA profile and the supply of metabolisable protein (MP) reaching the cow's small intestine – especially for the essential AA Met.

From a biological perspective, improving cow performance, health, and subsequent sustainability through AA balancing is achievable. This can be done by either decreasing dietary CP levels, optimising rumen fermentation and thus microbial protein production, altering the passage of essential AA (EAA) to the small intestine, increasing the efficiency of absorbed AA, and/or modifying the rumen microflora, particularly those involved in peptide degradation and AA deamination.

However, recent research clearly demonstrates that when AA are ignored when formulating, diets tend be more expensive and higher in CP, which has a negative effect on cow performance and reproduction, resulting in more N being excreted into the environment. Balancing for AA continues to be more widely accepted due to the positive impacts seen on lactation performance, reproduction, subsequent lactations, and calf performance (Cardoso, 2021), especially considering Met (Batistel *et al*., 2017).

A tendency to overfeed dietary CP

Both EAA's Met and lysine (Lys) have consistently been identified as the two most limiting AA for lactating dairy cows (Lean *et al*., 2018). However, to rectify these AA limitations, nutritionists often utilise high-quality plant- and/or animal-based protein supplements in a 'shotgun' balancing approach, to improve the level and AA profile of duodenal MP to supply a theoretically optimal Lys:Met ratio.

However, studies in which rumen undegradable protein (RUP) or RDP were increased have yielded variable results, likely due to an oversupply of dietary CP and/or an imbalance of AA. It is important to note that CP can be divided further into various sub-classes based on different digestion kinetics, which include the rate of degradation in the rumen and the rate of passage out of the rumen.

Additionally, rumen microbes require fermentable metabolisable energy (FME) to ferment plant-based fibre to volatile fatty acids (such as acetic, propionic, and butyric acid), supplying up to 60 to 75 % of the cow's daily metabolisable energy (ME) requirements. Proportionally, microbial protein represents 50 to 80% of the total MP flowing to the cow's small intestine.

After the MP reaches the cow's small intestine it is broken down enzymatically to various AA available for absorption by the cow and used for maintenance, growth, gestation, and lactation. Each individual AA is absorbed and utilised for various functions with different efficiencies, and is also influenced by various other factors, such as cow status, level of performance, and diet composition.

Protein and amino acid nutrition

The suggestions and recommendations for protein and AA nutrition are as follows:

Establish an optimal EAA concentration in MP: Formulate diets for the stage of lactation, level of production, cow pregnancy status, and production system (*Table 1*). Low-producing cows (such as those in later lactation) have fewer protein and AA needs than high-producing cows and/or cows in early lactation. Expressed as a percentage of MP on energy bases for Met 1,15 to 1,19g/Mcal ME and Lys 3,10 to 3,20g/Mcal ME.

Optimise rumen function and microbial protein yield: Since it is widely accepted that microbial protein has a superior AA profile (Sok *et al*., 2017), particularly regarding Lys and Met, formulate diets maximising MCP yield. Monitor histidine levels since microbial protein tends to be low, and diets containing grasses and legumes are predominant. It is suggested to keep rumen N over 115% of requirements.

Supplement Mepron® as a source of RPM: Mepron® is the most efficient source of protected Met. It is a mini pellet with a particle size of 1,8 x 3,4mm, containing 85% DL-methionine. With a rumen protection rate of 80% and a digestibility rate of 90%, Mepron® delivers 60% metabolisable Met by using specialised and unique coating technology (ethylcellulose). Mepron® is stable in all mixing and conveying procedures in the feed mill and on-farm, including low-pH diets (such as silages).

Mepron® for ruminants

Methionine supplements are usually divided into two groups, namely lipid matrix or coat-protected products. Lipid sources rely on fat as the carrier of Met

Table 1: Recommended methionine and lysine concentration in metabolisable protein1 (%).

mLys[1] (% MP[3])	mMet[2] (% MP)	Ratio
Yield focussed		
6,90 to 7,10	2,60 to 2,70	2,65 to 2,72
Content focussed		
6,75 to 6,85	2,85 to 2,90	2,35 to 2,40

[1]NDS Professional (CNCPS v6.5/v6.55; [2]mLys: metabolisable lysine; [3]mMet: metabolisable methionine; [3]MP: metabolisable protein.

Table 2: Meta-analysis on different rumen-protected methionine sources[1].

Parameter	Coating type	Mean	P
[2]DMI (kg/d)	Ethylcellulose pH sensitive	-0,01 0,04	NS NS
Milk (kg/d)	Ethylcellulose pH sensitive	0,35 -0,22	<0,001 NS
True milk protein (%)	Ethylcellulose pH sensitive	0,06 0,08	NS NS
True milk protein (g/d)	Ethylcellulose pH sensitive	37 16	NS NS
Milk fat (%)	Ethylcellulose pH sensitive	-0.01 -0.02	NS NS
Milk fat (g/d)	Ethylcellulose pH sensitive	24 -2	NS NS

[1]Adapted from Patton, 2010; [2]DMI: dry matter intake.

and are usually less expensive than coat-protected products – they deliver a lower concentration of Met, and have limited post-ruminal release and absorption. Therefore, nutritionists and producers usually rely on coat-protected products (ethylcellulose and pH-sensitive).

Mepron's action is based on soaking and abrasion, releasing Met slowly; in contrast, pH-sensitive products usually rapidly release Met into the abomasum, causing a marked but short-term spike in blood. Whereas ethylcellulose has slow-release properties and causes no spike, it results in elevated Met blood concentrations over a longer period. Patton *et al*. (2022) reported in a meta-analysis that no correlations were found between high blood spike and higher cow performance. However, *Table 2* shows a study on market-available protected Met products involving both pH-sensitive and ethylcellulose Met in a database of 36 studies.

Cows fed Mepron® (ethylcellulose) produced more milk protein (37 vs 16g) and more fat (24 vs 2g) than those fed with a pH-sensitive product. Cows fed Mepron® also had increased milk production (350g/d) whereas those fed a pH-sensitive product showed a reduction in milk production (-220g/d). Mepron-fed cows showed increased milk protein yield and milk fat yield, as well as total milk production.

Supplementing methionine

Methionine has several functional roles in metabolism that may improve cow performance, aid the cow's transition through the onset of lactation, improve reproduction, and improve calf performance due to carry-over effects:

- Significant improvement in cow performance (milk volume, persistency, and solids) and improved N use efficiency while feeding modern diets, low dietary CP diets, and/or during heat stress (Patton, 2010; Guyader *et al*., 2023; De Oliveira *et al*., 2024).
- Pre-and post-partum supplementation of RPM increases pre-partum dry matter intake (DMI), lactation performance (yield, protein concentration, and energy-corrected milk), reduces negative energy balance and natural pasture-fed beef pre-and post-partum, and increases cow health status (Batistel *et al*., 2018).
- Methionine is a precursor of importance for protein synthesis, enzyme production, antioxidants, and a methyl donor for the synthesis of choline and carnitine, both of which are involved in lipid metabolism (Chandler and White, 2017).
- Supplementation of RPM during the periparturient period and early lactation has shown improved liver function, lower inflammation status, and less oxidation stress by lowering blood fatty acid and β-hydroxybutyrate levels and increasing neutrophil and monocyte function (Batistel *et al*., 2017; Han *et al*., 2018).
- Blood, milk, and liver biomarkers have indicated that at least part of the effect of RPM supplementation on milk production is due to improved immune status and liver function (Vailati-Riboni *et al*., 2017).
- Balancing diets for EAA with RPM enhance the activity of skeletal muscle genes related to the transportation of various nutrients, biological processes that generate energy, tissue protein replenishment, and coordination of antioxidant responses during the periparturient period (Thanh *et al*., 2023).
- Supplementation with RPM supports embryo viability and implementation through higher lipid content, embryo volume, changes in DNA methylation (Bonilla *et al*., 2010), and lower pregnancy losses (Toledo *et al*., 2017).
- The addition of RPM to dairy diets increased the rate of utilisation of some AA and improved the protein efficiency of others (Vailati-Riboni *et al*., 2019)
- Methionine supplementation improves calf performance via foetal programming as a methyl donor (epigenetics and DNA methylation) and the mammalian target of rapamycin (mTOR) regulator (cell growth, activity, and greater nutrient transport from the maternal to foetal circulation through nutrient transporters) (Krog *et al*., 2018; Ma *et al*., 2019).
- Cows that were supplemented with RPM during gestation and the transition period have calves that are heavier at birth and grow better (average daily gain) with improved hindgut health and function (Elolimy *et al*., 2019; Urie *et al*., 2018).

Conclusion

Optimising the quantity and quality of MP (and metabolisable EAA) in dairy diets by implementing modern formulation and nutritional strategies could potentially have significant advantages on cow performance, reproduction, and health status – in addition to subsequent lactations and improved calf health and performance. Thus, it improves the efficiency, sustainability, and profitability of the entire production system.

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Nutrition strategies to control post-weaning diarrhoea of piglets

By Qingsong Tang, Tianyi Lan, Chengyu Zhou, Jingchun Gao, Liuting Wu, Haiyang Wei, Wenxue Li, Zhiru Tang, Wenjie Tang, Hui Diao, Yetong Xu, Xie Peng, Jiaman Pang, Xuan Zhao and Zhihong Sun

Post-weaning diarrhoea (PWD) is one of the greatest sources of economic losses in swine production worldwide. Early weaning of piglets frequently disturbs intestinal morphology and undermines the intestinal barrier function, resulting in diarrhoea, dehydration, retarded growth, and increased mortality rates (Cao *et al*., 2022)

Post-weaning diarrhoea in piglets is closely associated with changes in the nutrient composition and levels of diets, and is accompanied by environmental, psychological, and microbiological changes (Rist *et al*., 2013). These changes usually disrupt the digestive and intestinal functions of the piglets (Souza *et al*., 2011).

No 'magic bullet'

At the same time, early weaning piglets cannot digest solid feed well due to insufficient secretion of digestive enzymes in the incomplete function of the gastrointestinal tract, which is very likely to lead to the damage of intestinal barrier function, including disruption of tight junction proteins, increase in intestinal permeability, and electrolyte imbalance (Ma *et al*., 2021a,b; Wang *et al*., 2016).

In addition, weaning stress often causes low immune function in piglets, and makes the intestine susceptible to attack by pathogens such as enterotoxigenic *Escherichia coli* (ETEC) and the diarrhoea virus, which can easily cause intestinal inflammation and PWD (Lodemann *et al*., 2017). It is difficult for the piglet to dynamically process large amounts of fluid in the intestinal lumen in an organised manner when it is challenged by multiple stresses.

In some large-scale pig farms, the diarrhoea incidence of piglets is as high as 50%, and the mortality rate is 15 to 20%. In the past decades, antibiotic growth promoters and high doses of zinc oxide and copper sulphate have been widely used in piglet diets to control the diarrhoea incidence during the weaning transition.

However, the addition of antibiotics, high doses of zinc oxide and copper sulphate to diets of weaned piglets has been challenged by problems of bacterial resistance and has faced restricted use worldwide (Jensen *et al*., 2016; Pilote *et al*., 2019). So far, we still do not have a single 'magic bullet' to replace antibiotics and high copper and zinc in the diets of weaned piglets.

Diet makes all the difference

Finding alternative ways to reduce PWD in piglets has become a priority for sustainable pig production due to environmental, health, and safety concerns. An important change during the weaning period of piglets is the change in diet, including changes in nutrient composition and levels, and the pathogens, antigenic proteins, and mycotoxins are important factors to be considered that can cause or exacerbate PWD in piglets.

In the last few years, significant progress has been made in the studies towards the mechanism of PWD in piglets as well as the effects of the composition and nutritional properties of dietary ingredients. The modification of dietary composition is one of the important directions to reduce the risk of PWD. The goal of this review, therefore, is to describe the mechanisms of absorption and secretion of intestinal fluids and electrolytes in diarrheic piglets, as well as the pathogenesis of ETEC and diarrheal viruses.

Building on this knowledge, we review the effects and propose mechanisms of CP levels, antigenic proteins, acid-binding capacity (ABC), and deoxynivalenol (DON) in diets on diarrhoea in weaned piglets. Finally, we discuss recent strategies for nutritional regulation from the perspective of diets, and examine the main challenges in the development of therapeutic treatments for diarrhoea in weaned piglets.

Changing composition in diets

Reducing CP levels in diets

Many studies have investigated the degree of reducing dietary CP required to effectively reduce PWD. Studies have shown that reducing dietary CP from 18,5 to 16,5% significantly reduces the diarrhoea incidence in weaned piglets (Marchetti *et al*., 2023).

Ammonia, amines, and hydrogen sulphide in the intestine linearly decreased when dietary CP levels were reduced (21, 20, 19, 18, 17, and 16%), and diarrhoea incidence was significantly reduced in weaned piglets (Kim *et al*., 2023). Under *E. coli* infection, weaned piglets fed diets containing 25,6 and 17,5% CP had diarrhoea incidences of 44,6 and 31,5%, respectively, and in the absence of *E. coli* infection the same piglets had diarrhoea incidences of 19,6 and 8,3%, respectively (Heo *et al*., 2009).

Feeding 19% CP levels (22% CP in the control group) reduced the diarrhoea incidence in weaned piglets under different hygienic conditions (Lee *et al*., 2022). It is evident that reducing dietary CP levels is an effective strategy for controlling the incidence of diarrhoea in weaned piglets, especially in environments with *E. coli* infection and poor sanitation.

It is worth noting that the effect of dietary CP levels on the growth performance of weaned piglets has been a matter of debate among researchers, and lowering it too much tends to limit the growth of piglets and reduce the economic efficiency of farming. The study showed that both average daily gain and gain/feed ratio were significantly reduced by diets with 19 and 16% CP levels (control 22% CP) (Limbach *et al*., 2021).

Low-protein diets

However, it has also been shown that low-protein diets (as low as 16%) improve intestinal barrier function and reduce PWD in weaned piglets, but do not affect growth performance (Kim *et al*., 2023; Marchetti *et al*., 2023). One study showed that a strategy of using a low-protein diet of 17,3% CP for day 5, 7, 10, and 14 after weaning, followed by a switch to a 21,5% CP diet, resulted in a reduction in the piglet diarrhoea incidence without affecting piglet growth performance (Heo *et al*., 2008).

Similarly, feeding a low-protein diet (16,6% CP) at the 6 to 9kg stage, followed by a switch to a standard CP level diet (19,1% CP) at the 9 to 15kg stage, also reduced the diarrhoea incidence in piglets (Lynegaard *et al*., 2021). Adequate protein supply is critical because piglets have a high capacity for rapid growth and protein deposition, and protein intake is highly linearly correlated with ADG.

Summarising recent studies on dietary CP levels for weaned piglets, we can conclude that there exists a regression equation depicting the relationship between dietary CP levels and diarrhoea incidence, represented as $Y = 3{,}532 \times X - 32{,}24$. Notably, for every 2% decrease in dietary CP levels, the diarrhoea incidence is observed to decrease by 7,06%. Therefore, a way to ensure dietary protein supply of weaned piglets, while avoiding excessive protein into the hindgut fermentation, is a key issue in the technology of low-protein diets to reduce diarrhoea.

With the increasing research on technology of low-protein diets, studies have reported that a three to four percentage point reduction in CP levels accompanied by supplementation with crystalline lysine, threonine, tryptophan, methionine, and valine did not have a negative effect on animal performance and nitrogen deposition (Wang *et al*., 2018). It can be seen that reducing the CP level in piglet diets is an effective strategy to reduce PWD in piglets.

Maintaining a well-structured diet that is low in ABC to support good intestinal barrier function and microbial homeostasis during the weaning period of piglets is essential to reduce piglet diarrhoea incidence and improve growth performance.

Therefore, the ABC of feedstuffs can be used as a nutritional constraint for dietary formulation, and reducing the ABC value of complete diets by selecting feedstuffs with lower ABC values and exogenously adding acids are good strategies for improving the intestinal barrier function and control diarrhoea in weaned piglets (Huting *et al*., 2021).

In general, cereals have low ABC values, ranging from 78 to 147 milliequivalent (mEq) H^+/kg for ABC-4 and 135 to 286 mEq H^+/kg for ABC-3, whereas protein feedstuffs have slightly higher ABC values, ranging from -13 to 1 059 mEq H^+/kg for ABC-4 and 823 to 2 100 mEq H^+/kg for ABC-3. Soya bean meal (SBM) is known to be the most common source of protein in swine diets and is usually added at 15 to 30% in weaned piglets, but SBM has a high ABC-4 value (618 mEq H^+/kg) (Stein *et al*., 2008).

Therefore, the use of fermented SBM (ABC-4, 207 mEq H^+/kg) or fermented soya, isolate (ABC-4, -13 mEq H^+/kg) to partially


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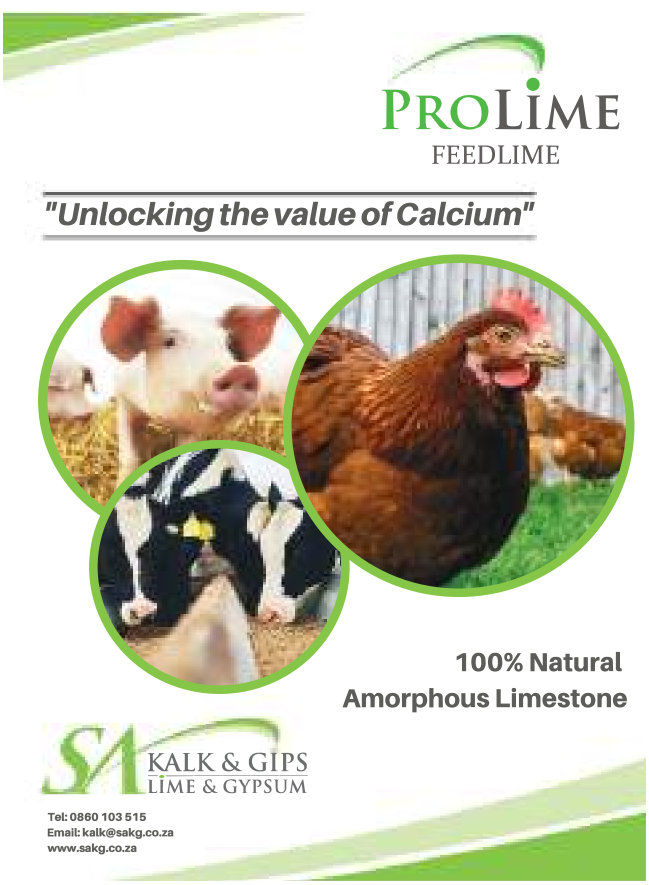
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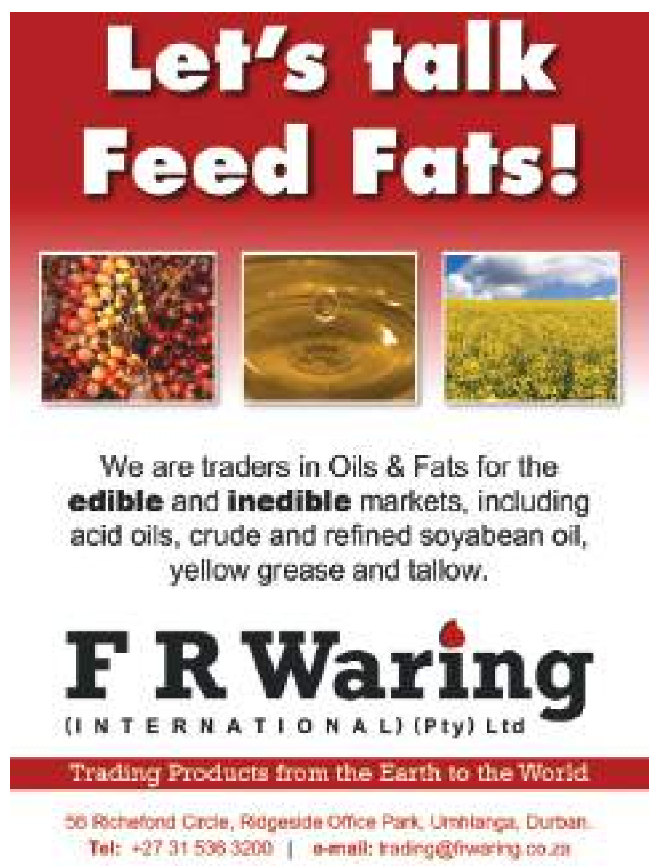
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Table 1: Effect of different CP levels in the diets on diarrhoea incidence of piglets.

Weaning age	IBW, kg	Experimental period	CP levels	Diarrhoea scores or incidence rates	References
20 days old	5,53	14 days of age	16%, 19%, 22%	Diarrhoea scores (1 to 7d): 1,25 for 16% CP, 1,50 for 19% CP, 1,67 for 22% CP Diarrhoea score (8 to 14d): 1,21 for 16% CP, 1,42 for 19% CP, 1,67 for 22% CP (scores: 1 = normal faeces, 2 = moist faeces, 3 = mild diarrhoea, 4 = severe diarrhoea, 5 = watery diarrhoea)	Limbach *et al.* (2021)
21 days old	5,9	1 to 14 days of age	17,5%, 25,6%	Not infected with *Escherichia coli* Diarrhoea incidence (1 to 7d): 9,5% for 17,5% CP Diarrhoea incidence (1 to 14d): 8,3% for 17,5% CP, 19,6% for 25,6% CP Infected with *E. coli* Diarrhoea incidence (1 to 7d): 21,4% for 17,5% CP Diarrhoea incidence (1 to 14d): 31,5% for 17,5% CP, 44,6% for 25,6% CP	Heo *et al.* (2009)
21 days old	5,99	1 to 14 days of age	17%, 19%, 23%	Diarrhoea incidence: 24,6% for 17% CP, 43,65% for 19% CP, 54,9% for 23% CP	Wu *et al.* (2015)
28 days old	7,98	1 to 14 days of age	17%, 30%	Diarrhoea incidence: 13% for 17% CP, 96% for 30% CP	Gao *et al.* (2020)
NA	8,2	1 to 21 days of age	16%, 17%, 18%, 19%, 20%, 21%	Diarrhoea score: 1,4 for 16% CP, 1,58 for 17% CP, 2,12 for 18% CP, 2,48 for 19% CP, 2,62 for 20% CP, 3,23 for 21% CP (scores: 0 = normal faeces, 1 = moist faeces, 2 = mild diarrhoea, 3 = severe and watery diarrhoea)	Kim *et al.* (2023)
NA	10	10 to 20kg of BW	12%, 14%, 16%, 18%, 20%	Diarrhoea incidence: 13,36% for 12% CP, 24,63% for 14% CP, 28,31% for 16% CP, 49,55% for 18% CP, 46,39% for 20% CP	Liu *et al.* (2022a)

NA = not available in the publication; IBW = initial bodyweight; CP = crude protein.

replace the amount of SBM used, as well as the application of low-protein forage techniques are good strategies to reduce the ABC of the diets.

The mineral source was one of the key factors for the high ABC values of the feedstuffs, especially the ABC-4 of calcium carbonate, limestone flour, and zinc oxide were higher than 10 000 mEq H^+/kg. Calcium carbonate and limestone (as a Ca source) have an ABC-4 of 18 384 mEq H^+/kg and 12 932 mEq H^+/kg, respectively, and can therefore be partially replaced with monocalcium phosphate (ABC-4, 1 587 mEq H^+/kg), dicalcium phosphate (ABC-4, 1 348 mEq H^+/kg), or calcium propionate (ABC-4, 9 240 mEq H^+/kg) as a Ca source.

At the same time, the use of high doses of phytase reduces the amount of calcium carbonate and limestone flour used in the diets. High dosage of zinc oxide is widely used to reduce the diarrhoea incidence of weaned piglets because of its strong bacteriostatic property.

However, high dosage of zinc oxide leads to increase in ABC value of diets and bacterial resistance, and can also cause environmental pollution, so the use of zinc oxide in weaned piglets is also being gradually limited (Bonetti *et al.*, 2021). Therefore, using low ABC feedstuffs to replace high ABC feedstuffs, as well as techniques such as low-protein diets and the addition of high doses of phytase can be some of the strategies to reduce dietary ABC (*Table 1*).

Conclusion and perspective

A dynamic imbalance in the absorption and secretion of intestinal fluids is the underlying cause of diarrhoea in piglets. The processes of intestinal luminal fluid absorption and secretion are driven by the active transport of electrolytes (Na^+, Cl^-, HCO_3^-, and K^+) and solutes (glucose, amino acids, fatty acids, etc.) and are closely linked to AQPs and intestinal permeability.

Based on the literature report, excessive levels of CP in the diets, stimulation by antigenic proteins, and DON contamination are important factors contributing to the imbalance of intestinal fluid absorption and secretion. Although various dietary strategies (e.g. CP reduction, ABC reduction, processing, vitamin supplementation, vomitoxin detoxification) have been widely recognised as promising strategies to reduce PWD in piglets, an integrated approach should be taken to control PWD, including nutritional and management-related measures.

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Prebiotics in animal nutrition:
Harnessing agro-industrial waste for improved gut health and performance

By M Christina Ravanal, Carolina A Contador, Wing-Tak Wong, Qile Zhang, Analese Roman-Benn, Kong Shun Ah-Hen, Pillar Ulloa and Hon-Ming Lam

The practice of using antibiotics as feed additives in animal farming, with the purpose of promoting animal growth and balancing gut flora, has been banned to tackle the dissemination of antibiotic-resistant bacteria and their potential food-borne transmission to humans (Haulisah *et al*., 2021).

However, the elimination of antimicrobial growth promoters has been a challenge for the animal nutrition industry, as some adverse consequences have emerged for the production, health, and welfare of animals (Khan *et al*., 2022). Therefore, significant research efforts have been focussed on the development of antibiotic alternatives to maintain or improve animal health and performance.

Health and production stimulator

Modulation of the gut microbiota with feed additives such as prebiotics and probiotics has become a need to maximise productivity and maintain animal health and welfare. Among these, prebiotics are a promising alternative. Their inclusion in livestock and poultry feed has shown the capability to improve host health and productivity through the selective stimulation of beneficial gut microbiota (Solís-Cruz *et al*., 2019). In this regard, agro-industrial waste plays a role as a source of feed ingredients in animal nutrition (Pinotti *et al*., 2020).

In particular, agro-industrial waste is often rich in carbohydrates and fibre, which are considered prebiotics that can promote the proliferation of beneficial microbes in the large intestine. Agro-industrial waste from fruits (such as mango peels, citrus peels, apple pomace) and vegetables (such as garlic straw, potato processing waste, onion skins) have been explored to produce prebiotics (Rahmani *et al*., 2017) that are employed as feed supplements.

The micro-organisms commonly used as probiotics belong to various bacterial species, with *Bifidobacterium*, *Lactobacillus*, *Streptococcus*, *Bacillus*, and *Enterococcus* commonly used (Kim *et al*., 2020). Over the years, numerous scientific studies have demonstrated the high potential of probiotics to provide health benefits on livestock, leading to a significant increase in research on probiotics in animal feeding (Di Gioia and Biavati, 2018).

The positive effects of prebiotics on health are associated to their capability to modify the gut microflora by selectively stimulating the growth and/or activity of beneficial bacteria (probiotics), such as *Firmicutes*, and *Bacteroidetes*, which produce beneficial metabolites (Uyeno *et al*., 2015; Yin *et al*., 2018). Other phyla have specific niches that differ based on the animal species. This can help to control pathogenic bacteria in livestock species, promoting overall health (Azad *et al*., 2020).

Studies have shown that prebiotics, when employed as feed additives in animal nutrition, can lead to significant population proliferation of probiotic bacteria such as *Bifidobacterium* and *Lactobacillus*. Supplementing generally healthy calves with a prebiotic has revealed to have a positive but not significant effect on the microbial community that is relatively stable in these animals (Heinrichs *et al*., 2009).

Recent findings have shown the potential use of prebiotics as alternatives to antibiotics to enhance animal growth and health without eventual risks to human wellness and the ecosystem (Chiesa *et al*., 2017; Pan *et al*., 2019). Studies examining the effects of prebiotics on animal health frequently yield inconsistent results due to the high specificity of individual compounds, variations in dosages, and differences in the timing of the application.

The agriculture industry produces diverse types of wastes, including stems, stalks, leaves, seeds, straw, husks, peels, sugar cane bagasse, and pulp from fruits, cereals, or legumes, among others (Sadh *et al*., 2018). Various nutrients derived from these wastes, including pectins, cellulose, hemicellulose, and xylans, can support the development of different intestinal micro-organisms. In this regard, this review highlights recent findings of prebiotics derived from agro-industrial waste and their effects on animal health.

Types of prebiotics

Prebiotics can be classified into several categories based on their development and regulatory status. Inulin, fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), and lactulose are generally classified as well-established prebiotics. Xylo-oligosaccharides (XOS) and isomalto oligosaccharides (IMO) among others are classified as 'emerging' prebiotics (Cardoso *et al*., 2021). Inulin, XOS, cereal fibre, lacticol, FOS, and GOS are among the most common prebiotics used in animal nutrition (Crittenden and Playne, 2008).

Inulin

Inulin is a linear polymer with β-glycosidic bonds (2→1) derived from D-fructose, having usually terminal glucose units with β (2→1) linkage. Inulin has degree of polymerisation of up to 60. It is classified as a fructan and is synthesised by a range of plants. Inulin is a storage carbohydrate present in many plant species (Davani-Davari *et al*., 2019).

Fructo-oligosaccharides

FOS are categorised as a type of inulin-derived oligosaccharides, specifically fructans, consisting of 2 to 60 D-fructose units connected by β-(2,1) linkages. They are naturally existing short-chain carbohydrates with a D glucosyl ending (Apolinário *et al*., 2014). FOS at an administration dose of 4g/kg feed (Xu *et al*., 2003) have been found to promote the growth of probiotic bacteria in male broilers. However, FOS administered at concentrations of 0,5, 1 and 2% had no effect on the growth and productivity of turkeys (Juśkiewicz *et al*., 2006).

Galacto-oligosaccharides

GOS are galactose-containing oligosaccharides that exhibit diverse variations in chain length, branching, and glycosyl linkages in their chemical structures. Based on the source of β-galactosidase, when lactose acts as the sole substrate, the galactose released during the enzymatic hydrolysis of lactose can be transferred to another lactose molecule via β (1→6), β (1→4) or β (1→3) glycosidic linkage to the galactose moiety (Mei *et al*., 2022). A novel GOS mixture (Tzortzis *et al*., 2005) has been shown to promote the growth of *Bifidobacterium* and *Lactobacillus* in pigs.

Lactulose

Lactulose is an artificial disaccharide produced from lactose through the action of β-galactosidase or epimerase. It is composed of fructose and galactose. Lactulose has low absorption rates in the gastrointestinal tract (GIT), and the cells lining the intestinal tract lack digestive enzymes for its hydrolysis (Chu *et al*., 2022).

Xylo-oligosaccharides

XOS are oligomers of sugar consisting of β-D-xylopyranosyl (xylose) units connected via β (1→4)-xylosidic linkages (Santibáñez *et al*., 2020). XOS are isolated from xylan-containing lignocellulosic materials, such as crop residues, wood, and herbaceous biomass, known to have prebiotic effects. XOS can also be generated by the addition of exogenous enzymes, such as xylanase, to the lignocellulosic residues (Baker *et al*., 2021).

Isomalto-oligosaccharides

IMO are glucose oligomers that exhibit α-D-(1,6)-linkages, occurring as isomaltose, isomaltotriose, isomaltotetraose, isomaltopentaose, and other oligosaccharides with higher branching. IMO are derived from starch through the action of enzymes belonging to various glycosyl hydrolase families. The enzymes involved in the production of IMO exhibit transferase, hydrolytic or branching activity, leading to a mixture of α-linked gluco-oligomers with varying types of glycosidic linkages and degrees of polymerisation (2-10) (Logtenberg *et al*., 2021).

Polydextrose

Polydextrose is a highly branched glucose polymer with random linkages, characterised by an average polymerisation degree of 12, with a range from 2 to 120. The molecule encompasses all possible combinations of α- and β-linked 1→2, 1→3, 1→4, and 1→6 glycosidic linkages, although the 1→6 (both α and β) linkages are the most common. Polydextrose undergoes partial fermentation in the large intestine, favouring increases in the amount of faecal volume, reduction in transit time, and the softening of faecal material, along with a decrease in faecal pH (Do Carmo *et al*., 2016).

Gluco-oligosaccharides

Gluco-oligosaccharides (GlcOS) refer to the oligosaccharides consisting of exclusively D-glucose units, exhibiting diverse degrees of polymerisation and glycosidic linkages. The α-gluco-oligosaccharides (α-GlcOS) are hydrolysates of starch (α-[1→4] glucan), while β-gluco-oligosaccharides (β-GlcOS) are hydrolysates of (1,3)(1,4)-β-D-glucan. Both provide a valuable prebiotic source that promotes the selective proliferation of probiotic bacteria (Zeng *et al*., 2023).

Prebiotics' effects on gut health

The GIT harbours a vast array of live micro-organisms collectively referred to as gut microbiota, which play crucial roles in both health and disease (Ursell *et al*., 2012). Nowadays, the prohibition of the utilisation of antibiotics as growth promoters has posed a challenge in animal nutrition, resulting in the search for alternative strategies to manage and prevent the colonisation of pathogenic bacteria.

The alteration of the gut microbiota using novel feed additives (such as probiotics and prebiotics) with host-protective functions to promote animal health is a buzzword in the fields of animal feeding (Gaggìa *et al*., 203 2010; Markowiak and Śliżewska, 2018). A healthy gut microbiota has numerous important functions in animal health, including aiding in modulating the gastrointestinal environment, strengthening the immune system, and inhibiting the proliferation of pathogenic bacteria (Anadón *et al*., 2019; Markowiak and Śliżewska, 2018).

Prebiotic interactions

Prebiotics are short-chain carbohydrates that are resistant to digestion by enzymatic methods but selectively enhance the activity of certain probiotic bacteria in the gut (Anadón *et al*., 2019; Sarkar, 2007). These carbohydrates include disaccharides, oligosaccharides, polysaccharides, resistant starch, and some sugar polyols, and have a low level of polymerisation and a linear shape (Al-Sheraji *et al*., 2013). They are non-digestible as they have glycosidic bonds that are resistant to digestion, allowing them to be selectively fermented by bacteria in the gut.

Effects of prebiotics

Monogastric animals have one simple, single-chambered stomach of which horses, poultry and pigs are the most popular agricultural species (Ojha *et al*., 2019). Scientific evidence shows that prebiotics have been used in animal feed for poultry and pigs since the 1990s; with the majority of such research being in poultry (Di Gioia and Biavati, 2018). The prebiotics most commonly used in monogastric animals are FOS, MOS, GOS and inulin; with FOS being more widely investigated than GOS (Park *et al*., 2013; Rehman *et al*., 2009).

According to Solis-Cruz *et al*. (2019), bacteria such as *Lactobacillus* spp. and *Bifidobacterium* spp. that form a part of the intestinal microbiota in poultry, confer positive effects on the intestinal physiology and are beneficial to their health. These beneficial bacteria have reportedly increased when chickens were fed diets supplemented with prebiotics –

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Table 1: The effects of feeding prebiotics on animal nutrition and health in monogastric animals.

Prebiotics	Animal	Dosage	Duration	Effects	References
TOS	Pigs	35g/kg	42 days	Increased the count of stool *Bifidobacterium* and *Lactobacillus*.	Smiricky-Tjardes *et al*. (2003)
FOS	Broiler chickens	4g/kg	49 days	Increased daily growth and growth of *Bifidobacterium* and *Lactobacillus*. Inhibited the growth of *Escherichia coli* in gastrointestinal tract.	Xu *et al*. (2003)
FOS	Male turkeys	2%	56 days	A reduction of the intestinal pH.	Juśkiewicz *et al*. (2006)
FOS	Weaned piglets	0,6%	7 days	Increased *Bifidobacteria*, *Lactobacillus* in jejunum and IFN-γ. Decreased proteobacteria in the jejunum and ileum. Decreased IL-4 and IL-10.	Chang *et al*. (2018)
scFOS	Adult pigs	10g/d	28 days	Increased Bacteroidetes, *Prevotella*, *Bacteroidales*, *Ruminococcaceae*.	Le Bourgot *et al*. (2017)
AIOS	Pigs	100mg/kg	14 days	Increased villus height, villus height-to crypt depth ratio and goblet cells.	Wan *et al*. (2018)
FOS	*Salmonella* challenged laying hens	0,5 and 1%	3 weeks	Increased IL-1β, IL-18, and IFN-γ. Decreased *Salmonella*.	Adhikari *et al*. (2018)
GOS	Kuroiler chickens	3,5mg/ embryo	12th day of incubation until hatched	Reduced severity of intestinal lesions and oocyst excretion induced by natural infection with *Eimeria*, with positive effects on the chicken's productive traits.	Angwech *et al*. (2019)
MOS+MP	Broiler chickens (Ross 308)	100g/t of diet	35 days	Jejunal villus length and positive changes in microbial population and higher level of calcium in blood. Increased serum concentration of calcium.	Karimian and Rezaeipour (2020)
***Saccharo myces* derived prebiotics**	Broiler chickens	50 and 100g/t	42 days	Decreased *Camphylobacter*.	Froebel *et al*. (2019)
XOS	Pigs	100 to 500g/t	70 days	Decreased proteobacteria, *Citrobacter*. Increased Firmicutes, *Lactobacillus* and SCFAs.	Pan *et al*. (2019)
XOS	Weaned piglets	0,01%		Weaned Increased *Streptococcus*, *Turicibacter*, ZO-1. Decreased *Lactobacillus*, IFN-γ.	Yin *et al*. (2019)

TOS = trans-galactooligosaccharides; FOS = fructo-oligosaccharides; scFOS = short-chain fructo-oligosaccharides; AIOS = alginate oligosaccharide; GOS = galacto-oligosaccharides; MOS = mannan-oligosaccharides; MP = microbial phytase; XOS = xylo-oligosaccharides; IFN = interferon; IL = interleukin; SCFAs = short-chain fatty acids; ZO = zonula occludens.

they fermented and metabolised the prebiotics, thus increasing their activity.

Studies by Totton *et al*. (2012) and Park *et al*. (2013) found that prebiotics regulated the intestinal microbiota of chickens by selectively stimulating the beneficial bacteria and inhibiting the unwanted bacteria such as *Salmonella* which resulted in an increase of their stool volume. Prebiotics, including FOS and MOS, were found to increase bodyweight in poultry along with the quantities of beneficial bacteria such as *Lactobacillus* and *Bifidobacterium* spp., while decreasing the quantities of pathogenic bacteria such as *Escherichia coli*, *Salmonella* and *Clostridium perfringens* (Chambers and Gong, 2011; Lee *et al*., 2012; Stanley *et al*., 2014).

Angwech *et al*. (2019) reported that *in ovo* delivered prebiotics (3,5mg/embryo on the 12th day of incubation) diminished the severity of intestinal lesions and oocyst excretion-induced infections by *Eimeria* (parasites capable of causing the disease coccidiosis) in Kuroiler chickens. The chickens were protected from coccidia for the first 56 days of their lives which worked in synergy with an anticoccidial drug to manage the 390 disease post-infection. This resulted in positive effects on the performance of the birds and the quality of their meat.

On the other hand, Wan *et al*. (2018) found that pigs supplemented with AIOS at 100mg/kg for two weeks exhibited increased villus height, villus height-to-crypt depth ratio and goblet cell counts. Similar examples are cited in *Table 1*.

Improving performance

Recently, novel precision biotics (PB) have being actively researched for their ability to improve growth performance and control nitrogen emissions (Jacquier *et al*., 2022; Walsh *et al*., 2021). This novel class of nutritional feed ingredients function as microbiome metabolic modulators (Jacquier *et al*., 2022; Walsh *et al*., 2021).

The mechanism of action of PB is through the modulation of metabolic pathway abundance, rather than the modulation of bacterial taxa or overall gut microbial profiles, which differentiates them from existing microbiome-targeting technologies (Bortoluzzi *et al*., 2023). This targeted modulation promotes beneficial outcomes for both the animal and the environment.

Several studies have focussed on the impact of a glycan-based PB in the poultry industry. Walsh *et al*. (2021) and Jacquier *et al*. (2022) have reported the effects of supplementation of this mixture in broiler chickens. Walsh *et al*. (2021) evaluated, through meta-analysis, the effects of two structurally distinct, precision glycan microbiome metabolic modulators (MMMs) on the performance of broiler chickens. MMM 1 and MMM2 increased final bodyweight compared to the negative control by 43 and 48g/bird, respectively. The different structure of MMMs had an impact on size and performance effects in broiler chickens.

Metagenomic analysis confirmed an increase in the abundance of genes belonging to the acrylate pathway, involved in propionate production (fatty acid biosynthesis) in response to both MMMs. Arginine-N-succinyl transferase genes, involved in arginine catabolism, were also upregulated in response to MMM2 (Walsh *et al*., 2021).

Jacquier *et al*. (2022) conducted a two-part experiment to examine the effects of PB. In the first trial, they tested the main effects of PB dose (0, 250 and 500g/t) and xylanase supplementation (0 or 100g/t) in boiler chickens. No significant interaction was detected between PB and xylanase on performance. However, supplementation with PB at 250 and 500g/t improved feed conversion ratio by seven and 11 points compared to diets without glycans.

Additionally, Bortoluzzi *et al*. (2023) tested the mixture of glycan-based PB to modulate the utilisation of proteins and improve the growth performance of broiler chickens. It was observed that supplementation with 3% of PB in the diets had a positive impact on performance, with improved bodyweight gain and the corrected feed conversion ratio (cFCR). The functional microbiome analysis revealed that PB shifted the microbiome pathways toward a beneficial increase in protein utilisation, and desirable pathways related to nitrogen utilisation, resulting in improved growth performance (Bortoluzzi *et al*., 2023).

Polygastric animals

The stomachs of ruminants consist of four compartments: the rumen, reticulum, omasum and the abomasum; with each chamber performing different processes (Stover *et al*., 2016). Prebiotics effectively alter the activity and composition of the microbiome in the ruminant's GIT because they are substrates that enhance the presence of certain beneficial ruminal micro-organisms.

However, because ruminants are capable of catabolising most of the common prebiotic compounds, using prebiotics to promote growth in the ruminant industry has been limited (Bąkowski and Kiczorowska, 2020). Additionally, several nondigestible oligosaccharides naturally found in cell walls of plants are included in ruminant feeds, possibly making the implementation of prebiotics in ruminants unnecessary (Anadón *et al*., 2019; Di Gioia and Biavati, 2018).

Nonetheless, using prebiotics in pre-weaned ruminants (given that they are fed a low roughage diet) have been found to increase their growth, diminish the chances and severity of diarrhoea and respiratory diseases while aiding in the formation of a desirable intestinal flora, which can improve their performance as they age (Ghosh and Mehla, 2012; Roodposhti and Dabiri, 2012; Uyeno *et al*., 2015).

Prebiotics such as galactosyl lactose, cello-oligosaccharides, MOS, and yeast cell wall extracts are used in pre-weaned calves. It is believed that MOS block the colonisation of pathogens in the digestive tract, while FOS, along with spray-dried bovine serum, reduced the occurrence of enteric disease in calves due to the ability of this sugar to block the adhesion of *Escherichia coli* and *Salmonella* to the intestinal epithelium.

It was reported that adding galactosyl-lactose (GL) to milk replacer positively impacted the growth and general health of dairy calves. While further investigation is necessary, research has shown that supplementation with MOS, FOS and GL may serve to improve the growth performance of calves in both pre- and post-weaning stages (Bhat and Shaheen, 2017; Uyeno *et al*., 2015).

Agro-industrial residues

Prebiotics can be produced from agro-industrial waste through enzymatic technologies, fermentation, and acid hydrolysis (Bamigbade *et al*., 2022; Gonçalves *et al*., 2023; Patel and Shukla, 2017). Enzymatic hydrolysis uses specific enzymes to gently break down carbohydrates into prebiotic-like oligosaccharides, preserving functionality (Radenkovs *et al*., 2018).

Fermentation uses micro-organisms to metabolise waste carbohydrates into prebiotic such as FOS or GOS (Gonçalves *et al*., 2023; Patel *et al*., 2020; Patel and Shukla, 2017). Acid hydrolysis employs acids to break down carbohydrates into prebiotics (Bamigbade *et al*., 2022), breaking glycosidic bonds and releasing monosaccharides or smaller oligosaccharides, but it requires careful handling due to its corrosive nature. The treatment conditions depend on the type of waste being processed.

The two main industrial methods used for producing prebiotics are 1) natural extraction or hydrolysis from plant or milk sources, and 2) chemical synthesis pathways using enzymatic or isomerisation reactions (Al-Sheraji *et al*., 2013). However, natural sources have limited prebiotic content, so most commercial prebiotics are chemically synthesised from raw materials such as lactose and sucrose (Davani-Davari *et al*., 2019).

Conclusions

With the ban on antimicrobial growth promoters, the utilisation of prebiotics derived from agro-industrial residues has emerged as a promising and safe alternative for maintaining animal health and well-being through optimal nutrition. These agro-industrial residues, which may be detrimental to human health and the environment, can be repurposed as valuable resources for prebiotic production.

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Effects of inclusion of black soldier fly larvae on growth performance, relative organ weight, and meat quality of broiler chickens

By HN Lee, KH Yum, GL Yeom, YB Kim, JY Park, S Park, G Park, Y Choi, J Choi, and JH Kim

The global population is anticipated to increase to about 9,2 billion people by the year 2050 (Ndotono *et al.*, 2022). Meat consumption is steadily increasing as the population grows. The world population is expected to increase by 11% between 2021 and 2030, and global meat consumption is expected to increase by 14% in 2030 compared to that of about ten years ago (Farchi *et al.*, 2017; Godfray *et al.*, 2018; OECD/FAO, 2023).

With the increasing human population, demand for meat consumption is also increasing, subsequently increasing demand for protein sources (Affedzie-Obresi *et al.*, 2020). Additionally, increasing demand for protein sources has led to competition for resources (Schiavone *et al.*, 2017a). In addition, food and feed supplies are unstable due to conflict, natural climate cycles, anthropogenic climate changes, livestock production, and health crises (GNAFC, 2022).

Protein is an essential feed ingredient and one of the most expensive components required for livestock feed (Beski *et al.*, 2015). However, prices of protein ingredients such as soya bean and fish meals are increasing (Kim *et al.*, 2021a) due to several factors, including a lack of land for production, global cost fluctuations, human consumption of grains, and other constraints (Onsongo *et al.*, 2018). Accordingly, insects are attracting attention as an alternative new source of protein (Kim *et al.*, 2021a).

Insects as feed components

Among various insects, black soldier fly larvae (*Hermetia illucens*; BSFL) have emerged as one of the promising insects that can be used as feed components (Khan *et al.*, 2018; Heita *et al.*, 2023). The reason is because BSFL can rapidly consume large quantities of organic waste such as spoiled feed, food, and manure. Moreover, BSFL can convert low-quality organic waste into high-quality proteins and fat (Dörper *et al.*, 2021). Thus, treating organic waste with BSFL is a promising technology that can reduce and recycle food waste responsible for unsanitary conditions encountered in urban areas, into useful products (Dzepe *et al.*, 2021).

The BSFL contains high levels of protein, fat, amino acids, and fatty acids that are favourable for poultry nutrition (Veldkamp and Bosch, 2015). In particular, BSFL contains high levels of saturated fatty acids (SFAs), including lauric acid and myristic acid (Li *et al.*, 2016; Ushakova *et al.*, 2016; Beneatha *et al.*, 2020). Medium-chain fatty acids (MCFAs), such as lauric acid, have been reported to exert antibacterial effects in broiler chickens (Papule *et al.*, 2021). In addition, lauric and myristic acids have been shown to improve growth performance and meat quality (Zeitz *et al.*, 2015).

Previous studies have shown that dietary supplementation with 3 to 20% BSFL had no adverse effects on broiler chickens (Choi *et al.*, 2013; Herawati and Permata, 2023). However, limited research has been conducted on the effects of including full-fat BSFL powder at levels below 3% in broiler diets. For this reason, increasing concentrations of dietary BSFL are expected to improve growth performance, meat quality, and antibacterial effects.

Table 1: Effects of increasing inclusion levels of black soldier fly larvae (BSFL) in diets on relative organ weight of broiler chickens.[1]

	Inclusion levels of BSFL in diets, %				P-value		
Items[2]	**0**	**1**	**2**	**SEM**	**T**	**L**	**Q**
Liver, %	2,30	2,41	2,44	0,093	0,582	0,329	0,757
Spleen, %	0,13	0,08	0,10	0,016	0,133	0,204	0,110
Kidney, %	0,53	0,47	0,61	0,049	0,172	0,275	0,121
Bursa of Fabricius, %	0,22	0,21	0,18	0,019	0,272	0,116	0,862
Thymus, %	0,36	0,46	0,34	0,037	0,092	0,632	0,035

Abbreviation: T = overall effects of treatments; L = linear effects of increasing inclusion levels of BSFL in diets; Q = quadratic effects of increasing inclusion levels of BSFL in diets. [1]Data is least squares means of five observations per treatment. [2]The relative organ weight was expressed as a percentage of BW.

However, data regarding the use of full-fat BSFL powder in broiler diets remains limited. Moreover, no studies have investigated the effects of full-fat BSFL powder at inclusion levels below 3% in broiler diets. Therefore, the objective of this experiment was to investigate the effects of dietary full-fat BSFL supplementation on the growth performance and health of broiler chickens. Specifically, this study examined the effects of two inclusion levels (i.e., 1 and 2%) of full-fat BSFL on growth performance, relative organ weight, and meat quality in broiler chickens.

Growth performance

Increasing inclusion levels of BSFL in diets did not significantly affect BW, BWG, or FI of broiler chickens. Birds fed diets containing 0, 1, and 2% BSFL did not show differences in BW, BWG, or FI at zero to three weeks or four to five weeks. In the overall period, the FE of birds fed diets containing 1% BSFL was greater (P < 0,05) than the FE of birds fed diets containing 2% BSFL. However, BW, BWG, and FI were not influenced by increasing inclusion levels of BSFL in diets.

Relative organ weight

Relative thymus weight exhibited a quadratic relationship (P < 0,05) with increasing concentrations of BSFL in diets (*Table 1*). However, birds fed diets containing 0, 1, and 2% BSFL did not show differences in relative organ weights (liver, spleen, kidney, and bursa of Fabricius).

Breast meat quality

For meat colour, values for a* and b* were decreased (linear, P < 0,05) when the BSFL inclusion level was increased in diets. The shear force decreased (quadratic, P < 0,05) when the BSFL inclusion level was increased in diets. The thiobarbituric acid reactive substances (TBARS) (days) were decreased (quadratic, P < 0,05) with increasing concentrations of BSFL in diets. Increasing concentrations of BSFL in diets decreased (linear and quadratic, P < 0,01) meat colour of sensory evaluation.

The wetness was increased (linear, P < 0,01) as BSFL concentrations were increased in diets. Broiler chickens fed diets containing 2% BSFL had less (P < 0,05) b* value for meat colour than those fed diets containing 0% and 1% BSFL. The TBARS (5 d) value for birds fed diets containing 2% BSFL was less (P < 0,05) than for those fed diets containing 1% BSFL. Birds fed diets containing 1 and 2% BSFL had greater (P < 0,05) meat colour in sensory evaluation than those fed diets containing 0% BSFL.

The wetness in sensory evaluation for 2% BSFL was greater (P < 0,05) than those for 0 and 1% BSFL. Increasing inclusion levels of BSFL in diets had no significant effects on melanin concentrations in breast meat. In addition, melanin concentrations in breast meat showed no significant differences between basal diet and BSFL-supplemented diets.

Table 2: Effects of increasing inclusion levels of BSFL in diets on faecal index of broiler chickens.[1]

	Inclusion levels of BSFL in diets, %				P-value		
Items	**0**	**1**	**2**	**SEM**	**T**	**L**	**Q**
Moisture, %	72,3	76,1	74,7	2,22	0, 485	0,454	0,351
pH	6,6	6,2	6,2	0,22	0,302	0,227	0,332

T = overall effects of treatments; L = linear effects of increasing inclusion levels of BSFL in diets. [1]Data is least squares means of five observations per treatment.

Liver characteristics

Liver colour, liver haemorrhage, and fatty liver score were not affected by increasing inclusion levels of BSFL in diets. Additional supplementation of BSFL in diets did not affect fatty liver incidence compared with a basal diet. Increasing inclusion levels of BSFL in diets had no significant effects on MDA or TAC in breast meat of broiler chickens. Additional supplementation of BSFL in diets did not affect antioxidant capacity in the liver.

Fatty acid concentrations

Increasing inclusion levels of BSFL in diets increased (linear, P < 0,01) myristic acid concentrations in breast meat. Eicosapentaenoic acid (EPA) concentrations in breast meat were also increased (linear, P < 0,05) as BSFL concentrations of diets were increased. Broiler chickens fed diets containing 2% BSFL had greater (P < 0,05) myristic acid concentrations in breast meat than those fed diets containing 0 and 1% BSFL. However, dietary supplementation of BSFL had no significant effects on fatty acids except for myristic acid and EPA.

Faecal index

Faecal index was not significantly affected by increasing levels of BSFL in the diet (*Table 2*). Additional supplementation of BSFL in diets did not affect faecal index incidence compared with a basal diet.

Breast meat quality

Colour, fat content, flavour, texture, and price of meat are important factors influencing consumers' purchasing decisions (West *et al*., 2001; Brunsø *et al*., 2005). Among these, meat colour is a key characteristic of fresh meat (Verbeke *et al*., 2005), as it serves as an indicator of both spoilage and wholesomeness (Mancini, 2009). Previous studies have reported that consumers prefer a red colour in meat (Carpenter *et al*., 2001). However, our study indicated that increasing concentrations of BSFL in diets linearly decreased a* and b* values of breast meat. Therefore, dietary supplementation of BSFL in broiler diets may influence consumer purchasing behaviour by altering meat colour.

Increasing concentrations of BSFL in diets linearly decreased a* values of breast meat in broiler chickens. This result was different from the study of Schiavone *et al*. (2019) who reported that dietary supplementation of BSFL defatted meal increased a* values of breast meat in broiler chickens. Adding BSFL to diets may lead to an accumulation of insect meal pigments in intramuscular fat, which may affect a* values of breast meat (Schiavone *et al*., 2019). This result may be associated with differences in the accumulation of pigments in intramuscular fat due to the form of BSFL. In addition, this study used BSFL having a


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thick red or brown colour. Therefore, BSFL colour affected a* values of breast meat in broiler chickens.

On the other hand, increasing concentrations of BSFL in diets linearly decreased b* values of breast meat in our experiment. This result was similar to findings of Schiavone *et al*. (2019) who reported that increasing concentrations of dietary BSFL defatted meal linearly decreased b* values of breast meat in broiler chickens.

To meet energy and nutrient requirements, dietary maize gluten meal concentrations were found to be decreased when inclusion levels of BSFL in diets were increased. In general, maize gluten meal is utilised as a dietary xanthophyll with yellow pigments (Livingston *et al*., 1969). In our experiment, two additional diets were formulated with increasing concentrations of BSFL in diets, which decreased maize gluten meal concentrations in diets. The decrease of maize gluten meal concentrations in diets may have decreased b* values of breast meat in broiler chickens.

This study showed that increasing BSFL supplementation in diets had a quadratic association with TBARS of breast meat in broiler chickens. Furthermore, birds fed diets containing 2% BSFL had fewer TBARS values than those fed diets containing 1% BSFL. This result was similar to findings of previous experiments. Murawska *et al*. (2021) reported that feeding diets with supplementing BSFL meal to broiler chickens increased TBARS values. The reason for this result may be associated with lower polyunsaturated fatty acids (PUFAs) in meat, which would be more susceptible to oxidation (Murawska *et al*., 2021). However, our study did not show a difference in PUFAs concentration among breast meat samples of broiler chickens.

In our experiment, BSFL contained a high amount of MCFAs such as lauric acid (35,75%). The MCFAs have been reported to have antimicrobial effects in mammals and birds (Zentek *et al*., 2011). In addition, MCFAs have functions in digestion, absorption, transportation, and metabolism (Bach and Babayan, 1982; Caspary, 1992). For this reason, MCFAs can cause oxidation during energy production processes such as digestion, absorption, transportation, and metabolism (Seaton *et al*., 1986). Thus, lauric acid concentrations in diets may affect TBARS values of breast meat in broiler chickens.

Liver characteristics

Increasing concentrations of BSFL in diets had no effect on liver colour, haemorrhagic score, or fatty liver score in broiler chickens. The BSFL having higher concentrations of SFAs generally can cause accumulation of triglycerides in the liver, which can increase the development of fatty liver. However, the current study showed that increasing inclusion levels of BSFL in diets had no significant effects on fatty liver incidence.

The MDA and TAC are indicators of oxidative stress and antioxidant activity, reflecting the overall antioxidant status of the body (Valle *et al*., 2015; Kim *et al*., 2020b; Chen *et al*., 2022). In the present study, dietary BSFL supplementation did not affect hepatic MDA levels, suggesting no impact on liver antioxidant capacity in broiler chickens. This finding contrasts with the results of Ognik *et al*. (2020), who reported that dietary supplementation of 0, 5, 10, and 15% full-fat BSFL meals tended to increase MDA levels in young turkeys.

On the other hand, Chen *et al*. (2022) observed that no significant changes in serum MDA when 25, 50, 75, and 100% of soya bean oil was replaced with BSFL oil in broiler diets. Kim *et al*. (2020b) also reported that dietary supplementation of BSFL oil had no effect on serum MDA levels of broiler chickens.

Previous studies have reported that SFAs exhibit greater oxidative stability than unsaturated fatty acids (UFAs; Cosgrove *et al*., 1987; Mottram, 1998). Therefore, the high SFAs content in BSFL may have contributed to the lack of significant effects on antioxidant capacity in our study. Additionally, tallow was used as a fat source in the diets of this study. Tallow is known to contain a higher proportion of SFAs compared to UFAs, similar to BSFL (Kierończyk *et al*., 2023). Thus, the similarity in fatty acid profiles between tallow and BSFL may have minimised any additional effects of BSFL supplementation on liver antioxidant capacity.

Fatty acid concentration

We observed that increasing concentrations of BSFL in diets linearly increased myristic acid and EPA concentrations in breast meat of broiler chickens. Moreover, myristic acid concentrations of breast meat were increased in broiler chickens fed diets containing 2% BSFL.

Kierończyk *et al*. (2022) reported that increasing inclusion levels of BSFL in diets increased myristic acid and EPA concentrations in turkey breast meat. Consistent with previous studies, these results indicated that changing dietary BSFL concentrations can affect fatty acid compositions of breast meat in broiler chickens (Schiavone *et al*., 2017b; De Souza Vilela *et al*., 2021). However, our study revealed no significant differences in fatty acids except for myristic acid and EPA concentrations in breast meat. This result is likely to be a consequence of changed fatty acid compositions of BSFL fat according to rearing substrate and age of BSFL (Schiavone *et al*., 2017b).

Conclusions

This study demonstrated that BSFL can be effectively utilised as a feed ingredient for broiler chickens. Dietary supplementation of 1% BSFL resulted in greater improvements in growth performance, immune organ development, and meat quality compared to 2% supplementation. No adverse effects on antioxidant capacity were observed following BSFL supplementation. Therefore, supplementation of 1% BSFL in diets is recommended to enhance both performance and health in broiler chickens.

However, data on the amino acid composition of breast meat and antioxidant capacity in the liver remain limited. Thus, further research is warranted to elucidate the effects of BSFL on hepatic antioxidant capacity and the amino acid profile of breast meat in broiler chickens.

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Short communication:
Can vitamin D be supplied from the large intestine?

By David Fraser, Sydney School of Veterinary Science, University of Sydney, Australia

The conventional approach to vitamin D is that it is a micronutrient, one of four fat-soluble vitamins, along with vitamins A, E, and K. Dietary vitamin D is absorbed in the small intestine by a passive mechanism in association with dietary fatty acids (Reboul, 2022; Yang *et al*., 2022; Li and Tso, 2003). If the diet is low in fat or if there is a defect in the digestion of fat and absorption of dietary fatty acids, then vitamin D along with the other fat-soluble vitamins, fail to enter the small intestine mucosal cells for subsequent transport in blood in lipoprotein or chylomicron lipid. If these conditions persist then fat-soluble vitamin deficiency could develop.

However, vitamin D status in populations around the world is largely determined by the formation of vitamin D_3 in skin by the photochemical action of solar ultraviolet radiation on 7-dehydrocholesterol (Engelsen, 2010). Nevertheless, public health policies promote the concept that vitamin D deficiency is to be prevented by the intake of diets supplemented with oral vitamin D (Giustina *et al*., 2024).

Different forms

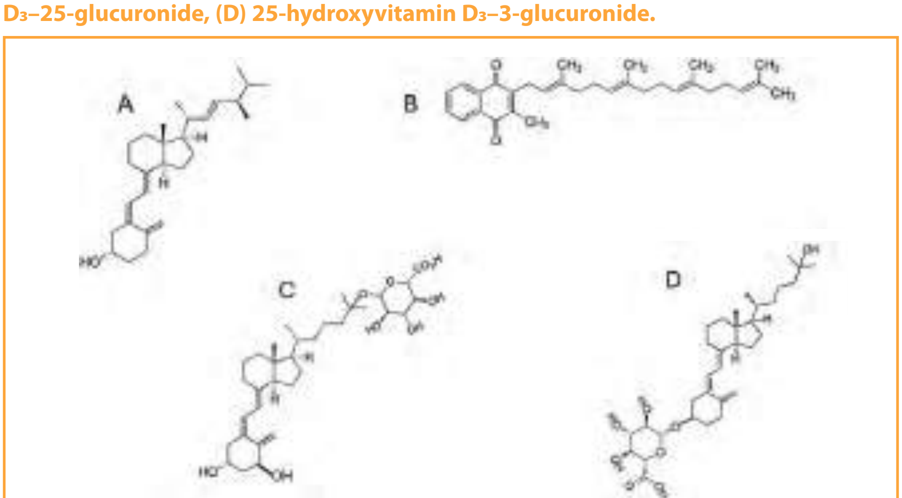
Although vitamin D_3 (cholecalciferol) produced in skin is the natural form of vitamin D for humans and many other terrestrial animals, vitamin D for dietary supplementation is often vitamin D_2 (ergocalciferol), because of the ease of its commercial production by ultraviolet irradiation of ergosterol from yeast (Paliu *et al*., 2024). Furthermore, for humans (Tripkovic *et al*., 2012) but not all terrestrial mammals (Hunt *et al*., 1967), the biological activity of vitamin D_2 is comparable, although not identical to that of vitamin D_3 (Durrant *et al*., 2022).

Surprisingly, some animals such as horses (Azarpeykan *et al*., 2022) and elephants (Childs-Sanford *et al*., 2024) seem unable to produce vitamin D_3 in their skin and circulating 25-hydroxyvitamin D [25(OH)D] is derived from vitamin D_2. The assumption is that the source of this vitamin D_2 is from endophytic fungi exposed to sunlight on the herbivorous diet these animals are eating. Some of the ergosterol in these fungi would thus be converted to vitamin D_2 by solar UV radiation (Jäpelt *et al*., 2011).

As well as oral input, it is now apparent that vitamin D_2 is also being produced metabolically in the alimentary tract by anaerobic micro-organisms with no exposure to ultraviolet light (Chaves *et al*., 2024). This vitamin D_2 production is occurring in the fermentation chamber of the rumen of ruminant animals, such as sheep and cattle. Metabolic production in this forestomach allows the vitamin D_2 to be absorbed when the feed mass is digested in the small intestine and contributes to the vitamin D_2 and 25(OH) D_2 found in ruminant meat (Dunlop *et al*., 2021).

In monogastric animals such as mice, microbial fermentation occurs in the colon and caecum, after food has already been processed in the small intestine. Microbial production of vitamin D_2 has now also been demonstrated in the colon of mice (Chaves *et al*., 2024), so the question needs to be asked: Is vitamin D_2 which is being generated in the large intestine of monogastric animals, including humans, able to be absorbed from that site, and will it then function either locally in the colon mucosa or systemically in the whole body?

Figure 1: Molecular structures: (A) vitamin D_2 (ergocalciferol) (MW 396,63 kDa), (B) vitamin K_2 (menaquinone-4; MK4) (MW 444,65 kDa), (C) 1,25-dihydroxyvitamin D_3–25-glucuronide, (D) 25-hydroxyvitamin D_3–3-glucuronide.



DNA of vitamin D

The vitamin D endocrine function, performed by 1,25-dihydroxyvitamin D [$1,25(OH)_2D$], regulates gene expression in many cell types throughout the body. The activity of $1,25(OH)_2D$ has a particular role in the large intestine in maintaining the mucosal cell barrier against bacterial invasion and acting on the immune cells to inhibit inflammation (Sun and Zhang, 2022). These functions are protective against inflammatory bowel disease and colon cancer (Meeker *et al*., 2016). However, the mucosa of the large intestine has the special feature of a complete capability to convert the parent vitamin D molecule to the hormone 1,25(OH)$_2$D, for its local autocrine or paracrine action in the mucosa.

The human colon mucosal cells (Vantieghem *et al*., 2006) contain the two vitamin D 25-hydroxylases, CYP27A1 and CYP2R1, which would in theory convert vitamin D, delivered to the mucosa in the circulating blood, to 25(OH)D. This could then be converted to 1,25(OH)$_2$D by the 1alpha-hydroxylase, CYP27B1, also present in these cells (Lagishetty *et al*., 2010; Cross *et al*., 2011), for its subsequent local regulatory functions in the colon mucosa. The maintenance of good vitamin D status, with serum concentrations of 25(OH)D > 50 nmol/L, thus would enable adequate local 1,25(OH)$_2$D production to perform its protective roles in the large intestinal mucosa (Meeker *et al*., 2016).

The absorptive functions of the large intestine mucosa include the uptake of water, electrolytes, and microbially produced short chain fatty acids (Kunzelmann and Mall, 2002). But, compared to the wide range of absorptive functions of the small intestine mucosa, the absorption capacity for organic molecules by the colon mucosa is limited. This can be seen from studies on the bacterial production of vitamin K$_2$ (menaquinone) in the lumen of the large intestine. This lipophilic molecule is an essential component of the bacterial electron transport system particularly in Gram-positive bacteria, as well as having a role in animal physiology as an enzyme co-factor in the production of blood-clotting proteins (Kurosu and Begari, 2010).

The chemical structure of vitamin K$_2$ consists of a 2-methyl-1,4-naphthoquinone with a side chain of variable numbers of five carbon isoprene units. The shortest side chain has four isoprene units and is known as menaquinone-4 or MK-4, while the longest side chain has 13 such units. In human faeces the total vitamin K$_2$ concentration is as high as 34,5 nmol/g dry matter with MK-4 being about 1,4 nmol/g dry matter (0,6 µg/g dry matter) (Karl *et al*., 2017). Compared with the concentration of vitamin D$_2$ in mouse colon contents of 0,04 µg/g dry matter (Chaves *et al*., 2024), the concentration of MK-4 is 15 times greater.

How much MK-4 then gets absorbed across the colon mucosa? Studies with radioactively labelled vitamin K presented into the lumen of the colon in rats indicated that very little was absorbed, and the absorbability declined even further as the number of side-chain isoprene units increased (Ichihashi *et al*., 1992; Groenen-van Dooren *et al*., 1995). Even though colonic bacteria are producing quantities of vitamin K$_2$ in amounts that would more than meet the needs of this micronutrient in human physiology, very little is available because of its very limited absorption across the colon mucosa.

Role of the large intestine

How then would even smaller quantities of vitamin D$_2$ being generated by microbial metabolism in the large intestine have any chance of contributing to vitamin D status of a human or other terrestrial mammals? An ingenious method of testing the possible uptake of vitamin D and its metabolites by the large intestinal mucosa has been to provide oral intakes of these molecules which have been linked to glucuronic acid.

When 1,25(OH)$_2$D$_3$ was conjugated with glucuronic acid through the 25-hydroxy group and given orally to rats it passed along the length of the small intestine without any absorption because uptake into mucosal cells was prevented by the conjugated glucuronic acid.

On arrival in the large intestine, bacterial glucuronidase released 1,25(OH)$_2$D$_3$ (Goff *et al*., 2012). This hormonal form of vitamin D was presumably absorbed by the colon mucosal cells because there was a resultant upregulation of the vitamin D 24-hydroxylase gene (CYP24) in those cells (Goff *et al*., 2012; Koszewski *et al*., 2012). Likewise, when the 3β-glucuronide of 25(OH)D$_3$ passed into the lumen of the mouse colon, 25(OH)D$_3$ was released by cleavage of the glucuronide ligand and there was a consequent increase in mRNA for the CYP24 enzyme (Reynolds *et al*., 2020).

Although these experimental results are good indications that the colon mucosa is able to absorb 25(OH)D$_3$ and 1,25(OH)$_2$D$_3$ they do not conclusively indicate that the more lipophilic parent vitamin D$_2$ would also be absorbed. The 25-hydroxylated vitamin D metabolite has long been postulated to be delivered to the large intestine naturally as a glucuronide conjugate, which is generated in the liver and excreted in bile into the duodenum. It has been suggested that this output of 25(OH)D-glucuronide was part of an enterohepatic circulation of 25(OH)D (Arnaud *et al*., 1975). The output of such glucuronides in bile, along with a range of other polar catabolites of vitamin D, has long been known following injection of radioactively labelled vitamin D (Bell and Kodicek, 1969).

However, when 7 µg ^{14}C-labelled vitamin D$_3$ was injected intravenously into humans with bile duct cannulations, most of the radioactive substances excreted in bile were polar metabolites and only about 4% of the radioactivity was in the form of 25(OH)D$_3$ or its glucuronide conjugate (Clements *et al*., 1984). Such experiments present the liver with a bolus input of vitamin D, as indeed does oral intake of vitamin D in food or supplements.

In contrast, when vitamin D$_3$ is formed by ultraviolet radiation in skin it trickles very slowly into the circulation and likewise enters the liver at the same rate as its metabolite 25(OH)D$_3$ is being released back into blood (Fraser, 2022). Hence 25(OH)D glucuronide would only be delivered to the colon from the relatively unphysiological supply of vitamin D from oral ingestion.

Conclusion

The microbial generation of vitamin D$_2$ in the large intestine, while having the capacity to meet total body vitamin D requirements, could be of greatest benefit in supplying vitamin D for the local production and endocrine role of 1,25(OH)$_2$D in the immune system of the large intestine itself.

On the other hand, for the many nocturnal animal species that are never exposed to the sun and obtain negligible amounts of vitamin D from their diets, the microbial production of vitamin D$_2$ in their large intestine could be the means by which they maintain adequate vitamin D status.

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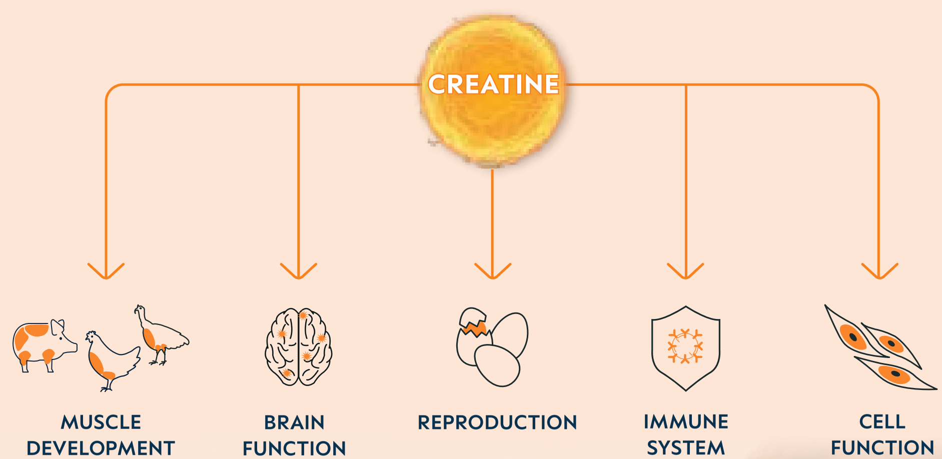

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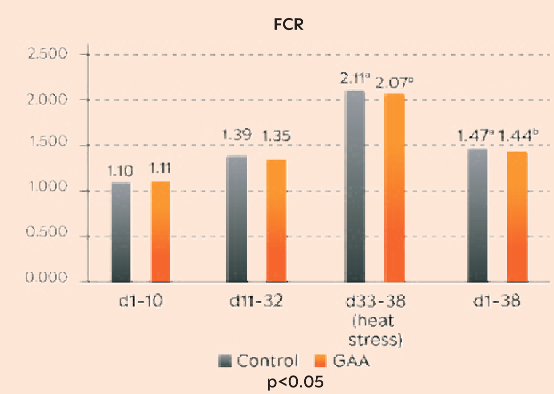

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AFMA INTERVARSITY WRITER'S CUP 2025: WINNER ROUND 3 / LITERATURE REVIEW

The effects of limestone variability on nutrient metabolism and performance in laying hens

By Anri Pienaar, University of Pretoria

Plant-based poultry diets are naturally deficient in calcium (Ca), an essential macromineral for various biological functions (Saunders-Blades *et al*., 2009). This necessitates dietary supplementation with a concentrated Ca source, typically limestone, which, in layer diets, contributes more than 90% of the total dietary Ca (David *et al*., 2023a).

Despite its widespread use, limestone's chemical and physical properties influence its bioavailability, affecting Ca and phosphorus (P) metabolism in poultry. These variations result from differences in geological origin, particle size, and mineral content, impacting nutrient availability (Gilani *et al*., 2022). Understanding how these factors influence nutrient availability is vital for optimising bone mineralisation, production performance, eggshell quality, and animal welfare.

This is particularly relevant for laying hens, which require approximately 2,2g of Ca per day to sustain egg production (Bain *et al*., 2016). Between 1990 and 2010, egg production per hen increased by about 2,5 eggs annually. Moreover, laying cycles have been extended from the conventional 68 to 75 weeks to up to 100 weeks, aiming for a target of 500 eggs per hen housed – a goal now considered attainable by breeding companies (Arulnathan *et al*., 2024).

Despite these advancements, hens are often culled before reaching 100 weeks due to declining eggshell quality and increased incidence of osteoporosis (Bain *et al*., 2016; Fathi *et al*., 2019). Extending the laying period without moulting may be feasible if egg production and eggshell quality are maintained. One potential strategy involves supplementing diets with coarse limestone, which has been shown to limit excessive medullary bone resorption and sustain Ca availability, thereby supporting consistent eggshell formation (Aldridge *et al*., 2022).

This review examines current research on limestone variability, its effects on nutrient metabolism, particularly Ca, and the resulting implications for laying hen productivity.

Calcium metabolism in laying hens

Efficient nutrient utilisation in laying hens is essential from economic, environmental, and welfare perspectives (Abbasi *et al*., 2019). Calcium is critical for skeletal health, acid-base balance, enzymatic activity, and eggshell formation, where it is deposited as calcium carbonate ($CaCO_3$) (Erol Tunç and Cufadar, 2014; Hervo *et al*., 2022).

Calcium and P metabolism are interdependent, requiring efficient regulation to maintain a homeostatic Ca:P ratio of 9:1 to 13:1 in laying hens (Cordeiro *et al*., 2017; Gilani *et al*., 2022). Plasma Ca and P concentrations are regulated through feedback mechanisms involving the parathyroid hormone (PTH), vitamin D_3, and calcitonin (CT), acting via receptors in the small intestine, bones, and kidneys (Proszkowiec-Weglarz and Angel, 2013).

During eggshell calcification, Ca ions are transported to the shell gland, reducing circulating blood ionised Ca (iCa) levels. This triggers PTH secretion, stimulating medullary bone resorption and vitamin D_3 production in the kidney, enhancing Ca absorption and resorption from the small intestine and kidney, respectively (Sinclair-Black *et al*., 2023). Vitamin D_3 modulates Ca and P homeostasis by regulating transport molecule expression (Bikle, 2014).

At the onset of egg production, Ca requirements increase significantly to support eggshell formation (Bain *et al*., 2016). During the light period (about 16 hours), 60 to 70% of the required Ca is supplied through dietary intake, either directly to the shell gland or stored in the medullary bone. However, about one-third of the required Ca is derived from medullary bone resorption during the dark period when dietary Ca supply is limited (Kerschnitzki *et al*., 2014).

Hens mobilise Ca from the medullary bone – a specialised, labile bone type formed at the onset of sexual maturity. This process is driven by rising oestrogen levels, which shift osteoblast activity from structural bone formation to medullary bone development. The medullary bone

Table 1: The adverse effects of excess Ca on nutrient digestibility in laying hens (adapted from David *et al*., 2023).

Effect	Cause	Reference
↓ Ileal digestibility and retention of P	Formation of insoluble Ca-phytate complexes	Abdollahi *et al*., 2016
↓ Phytate-P hydrolysis	Inhibit efficacy of both endogenous and exogenous phytase	Akter *et al*., 2016
↓ Ca retention and bone Ca		Gautier *et al*., 2017
↓ Ileal Ca digestibility		David *et al*., 2022
↓ Availability of Ca, Mg, Mn, Zn, and Fe	Increased pH facilitates the formation of insoluble cation-phytate chelates	Mutucumarana *et al*., 2014
↓ Protein digestibility and N retention	Inactivation of pepsin by pepsinogen at high pH	Akter *et al*., 2016
↓ Fat digestibility and metabolisable energy	Indigestible Ca soap formation	Tancharoenrat and Ravindran, 2014

undergoes continuous cycles of formation and resorption, tightly synchronised with daily eggshell calcification (Kim *et al*., 2012; Kerschnitzki *et al*., 2014). However, peak eggshell formation occurs during the dark period. Consequently, iCa levels in the blood decline, triggering medullary bone resorption to maintain adequate Ca supply for shell formation (Hervo *et al*., 2023).

While P plays a minor role in eggshell formation, it is closely associated with Ca in the skeletal hydroxyapatite matrix (Li *et al*., 2018). During bone resorption, Ca and P are simultaneously released into the bloodstream, with Ca used for eggshell formation and P excreted as uric acid (Manangi *et al*., 2018). Maintaining an optimal Ca:P ratio is crucial for skeletal integrity and minimising P excretion into the environment (Dijkslag *et al*., 2021).

Limestone characteristics

Limestone, the primary inorganic Ca source in laying hen diets, consists mainly of $CaCO_3$, but may contain calcium oxide, aragonite, and dolomite. In poultry nutrition, calcitic limestone (mainly $CaCO_3$) is preferred over dolomitic limestone, which contains both $CaCO_3$ and magnesium carbonate. Magnesium competes with Ca for absorption, potentially reducing Ca availability by occupying absorption sites or forming insoluble complexes with Ca (David *et al*., 2023b).

Unlike broilers, laying hens consume mash-form diets, allowing them to self-regulate their limestone intake based on Ca needs. Fine limestone particles (GMD < 400µm) are commonly used in pelleted broiler diets for pellet integrity (Gilani *et al*., 2022), while laying hens benefit from a combination of fine and coarse limestone particles (Pacheco *et al*., 2022). Hervo *et al*. (2022) confirmed that coarse limestone particles were retained in the gizzard longer than fine particles, with mean retention times of 345 and 64 minutes, respectively. Limestone solubility is directly influenced by particle size, with finer particles exhibiting greater solubility and facilitating more rapid Ca release for intestinal absorption (Xavier *et al*., 2015).

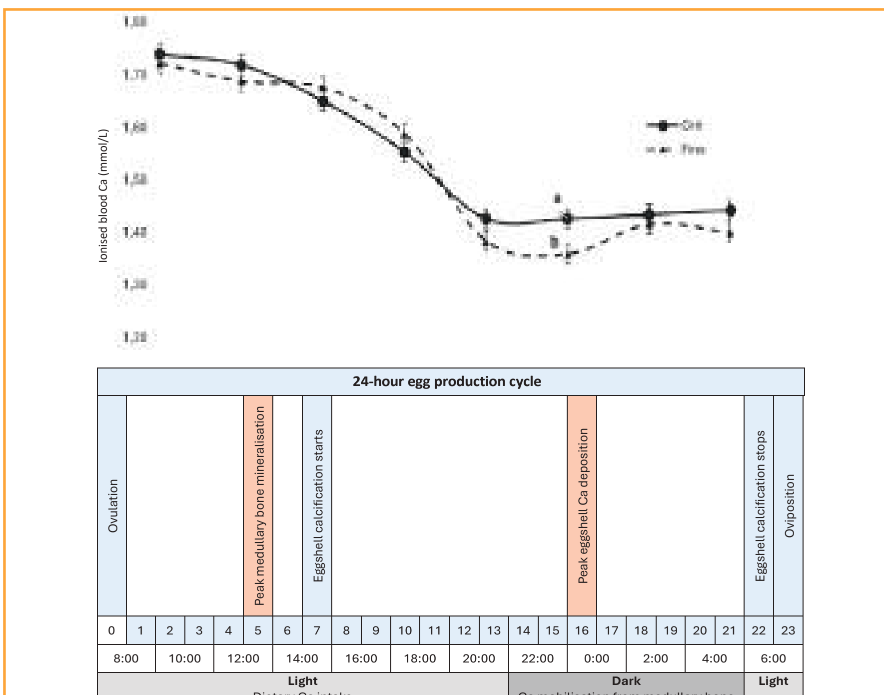
Impact of limestone variability

Although coarse limestone particles have lower solubility, prolonged retention in the gizzard improves Ca availability over time, maintaining stable blood iCa levels throughout eggshell calcification (Waters *et al*., 2024). Additionally, coarse limestone particles stimulate increased H^+/K^+-ATPase activity in the proventriculus by 11%, enhancing hydrochloric acid secretion and reducing gizzard pH and promoting limestone solubilisation (Hervo *et al*., 2024).

Formulating diets with limestone from different sources poses a challenge due to its variability in particle size and solubility (Pacheco *et al*., 2022). This variation affects hen health, productivity, and eggshell quality (Guo and Kim, 2012), as an excess or deficiency in Ca supply influences Ca-P metabolism and absorption, phytase efficacy, and micromineral availability, as shown in *Table 1* (Pacheco *et al*., 2022; Sinclair-Black *et al*., 2023).

As a result of the high Ca requirement in laying hens, impaired Ca and P absorption might have an adverse effect on eggshell quality and medullary bone replenishment, since bone development relies heavily

Figure 1: Limestone particle size influences blood iCa levels in hens, with Ca demand varying depending on the stage of egg formation (adapted from Sinclair-Black *et al*., 2023).



on hydroxyapatite deposition, with approximately 99% of body Ca and 80% of P stored in the skeleton (Veum, 2010). Eggshell integrity is essential for product quality and resistance to breakage or microbial contamination (Bain *et al*., 2013).

Calcium availability is further impaired by the presence of phytate in cereal grains, as 60 to 70% of P is stored as phytic acid. This form is poorly bioavailable to laying hens and prone to chelation with cations such as Ca^{2+}, Zn^{2+}, Mg^{2+}, and Fe^{2+} in the alkaline environment (pH > 5) of the small intestine (Dersjant-Li *et al*., 2018). To enhance P absorption, phytase enzymes are added to diets, hydrolysing phytate-cation complexes and increasing the availability of P and associated cations (Gilani *et al*., 2022).

Moreover, as hens age, intestinal Ca absorption capacity declines. Dietary Ca or P imbalances adversely affect bone homeostasis, leading to osteoporosis and cage layer fatigue, particularly in older hens, and thus reducing eggshell quality, increasing breakage, and compromising welfare (Alfonso-Carrillo *et al*., 2021; Benavides-Reyes *et al*., 2021). Therefore, continuous assessment of limestone quality is key to formulating diets with optimal dietary Ca levels (Gilani *et al*., 2022).

Practical strategies, such as offering coarser limestone particles in the afternoon or providing two hours of light at night to allow feeding, have been implemented to mitigate issues associated with excessive or deficient dietary Ca, as illustrated in *Figure 1*. Aldridge *et al*. (2022) and Alfonso-Carrillo *et al*. (2021) reported that these strategies improved eggshell quality, reduced Ca mobilisation from the bones, and minimised plasma P fluctuations, reducing osteoporosis incidence and excess P excretion.

Conclusion

Limestone variability plays a significant role in nutrient metabolism and performance in laying hens. Factors such as particle size, solubility, and mineral composition influence Ca availability, bone integrity, and eggshell quality. The extended retention of coarse limestone particles in the digestive tract supports more consistent Ca release during critical phases of eggshell formation.

Selecting limestone sources based on these attributes is essential for improving nutrient utilisation, production efficiency, and bird welfare. Prioritising limestone quality in diet formulation is a key strategy for enhancing hen longevity and ensuring sustainable egg production.

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AFMA INTERVARSITY WRITER'S CUP 2025: WINNER ROUND 3 / OWN RESEARCH

The potential of *Allium sativum* to alleviate the impact of cryptosporidiosis on dairy calf growth

By L van Deventer and L Steyn, Stellenbosch University

Cryptosporidium species are parasitic protozoans causing diarrhoea in a variety of hosts and can be found on various farms worldwide (Xiao, 2010; Ryan *et al*., 2014; Widmer *et al*., 2020; Ebiyo and Haile, 2022). Cryptosporidiosis leads to high morbidity and mortality rates in calves (Singh *et al*., 2006) due to severe dehydration and malnutrition (Moore and Zeman, 1991).

Neonatal calves experiencing diarrhoea have reduced starter feed intakes (Gibbons, 2020), contributing to reduced growth rates and carcass quality (Pardon *et al*., 2013), as well as an increased risk of mortality (Gulliksen *et al*., 2009). In heifer calves, cryptosporidiosis negatively affects age at first calving and future milk production due to reduced weight gains during the rearing period (Waltner-Toews *et al*., 1986; Svensson and Hultgren, 2008). Currently, there is no known cure for cryptosporidiosis.

Background

Given the limitations of current treatments, medicinal plants are gaining attention as alternatives to antiparasitic drugs. Various studies have investigated the effects of garlic compounds on the management of cryptosporidiosis in animals such as mice and water buffalo calves. Reported benefits include the elimination or reduction of oocyst excretion (Wahba, 2003; Gaafar, 2012; Farid *et al*., 2022), improved immune function (El Shenawy *et al*., 2008) and interference with the physiological processes of the parasite (Masamha *et al*., 2010).

Exploring plant-based alternatives such as garlic could potentially alleviate the impact of cryptosporidiosis on calf growth and productivity, reducing economic losses and decreasing the use of antibiotics in treating infected calves. Limited research is available on the use of garlic as an alternative treatment for the prevention and management of cryptosporidiosis-infected neonatal dairy heifer calves. Therefore, the aim of the study was to evaluate the effectiveness of garlic extract inclusion in alleviating the impact of cryptosporidiosis on starter feed intake and weight gain in dairy heifer calves.

Materials and methods

The trial was conducted at Oudewagendrift Farm in Worcester in the Western Cape of South Africa.

Layout and animal husbandry

Forty-five Holstein heifer calves, naturally infected with *Cryptosporidium* species, were randomly assigned to one of three treatments (n = 15). Calves were assumed to be naturally infected due to the confirmed presence of *Cryptosporidium* species on the farm. The three treatments were as follows: control (CON), garlic extract (1g/calf/day) in the milk replacer (G1), and garlic extract (2g/calf/day) in the milk replacer (G2).

All calves received their assigned treatment from five days of age until weaning, with inclusion levels remaining consistent throughout the trial. The garlic extract was a commercially available powdered product, derived from garlic powder and oil. Its main components included diallyl sulphide, diallyl disulphide, diallyl trisulphide, and ajoene molecules.

Milk feedings occurred twice daily at 07:00 and 15:00, with a total of 4ℓ/day. Calves were fed a commercial milk replacer and had *ad libitum* access to calf-starter pellets and fresh drinking water from five to 70 days of age. The general health of each calf was observed daily. Any calves experiencing clinical disease were treated accordingly, and treatment records were maintained for electrolyte therapy, antimicrobials, and anti-inflammatory drug administration.

Colostrum quality and passive immune transfer were assessed using a Brix refractometer. Calves were weighed at birth and then weekly for the duration of the trial. Milk replacer intake (g DM/day) was recorded during morning and afternoon feedings, and starter feed refusals were recorded twice weekly.

Results and discussion

Starter feed intake, weight, and growth parameters are presented in *Table 1*. No differences were observed among treatment groups for total feed intake (P = 0,541), average daily feed intake (P = 0,541), or average weekly feed intake (P = 0,541). This corresponds with other studies where garlic inclusion did not

Table 1: Starter feed intake (kg), weight, and growth parameters (mean ± SE) of pre-weaned Holstein heifer calves that received milk replacer with different inclusions of garlic extract (n = 15).

Parameter[1]	Treatment[2]			P-value
	CON	G1	G2	
Starter feed intake				
Total intake	46,049 ± 14,249	43,129 ± 9,616	47,845 ± 10,640	0,541
Average daily intake	0,658 ± 0,204	0,616 ± 0,137	0,683 ± 0,152	0,541
Average weekly intake	4,605 ± 1,425	4,313 ± 0,962	4,785 ± 1,064	0,541
Weight and growth				
Birthweight (kg)	32,227[ab] ± 4,423	30,727[b] ± 4,910	34,867[a] ± 4,870	0,064
Weaning weight (kg)	75,300 ± 9,203	73,393 ± 7,078	78,827 ± 6,306	0,154
Weight gain (kg)	43,073 ± 6,280	42,667 ± 5,050	43,960 ± 5,728	0,818
ADG (kg/day)	0,615 ± 0,090	0,610 ± 0,072	0,628 ± 0,082	0,818
FCR	1,054 ± 0,253	1,005 ± 0,157	1,082 ± 0,168	0,568

[1]ADG – average daily gain, FCR – feed conversion ratio. [2]Treatment: CON (control), G1 (garlic extract inclusion (1g/calf/day) in milk replacer), G2 (garlic extract inclusion [2g/calf/day] in milk replacer).

affect the total and daily feed intakes of calves (Kekana *et al*., 2020; Jagota *et al*., 2021; Özkaya *et al*., 2023), goats (Ikyume *et al*., 2017) or lambs (Khalelisizadeh *et al*., 2011). Various other studies have observed an increase in dry matter intake of calves (Ahmed *et al*., 2009; Ghosh *et al*., 2011; Hassan and Abdel-Raheem, 2013; Mishra *et al*., 2020; Lad *et al*., 2022).

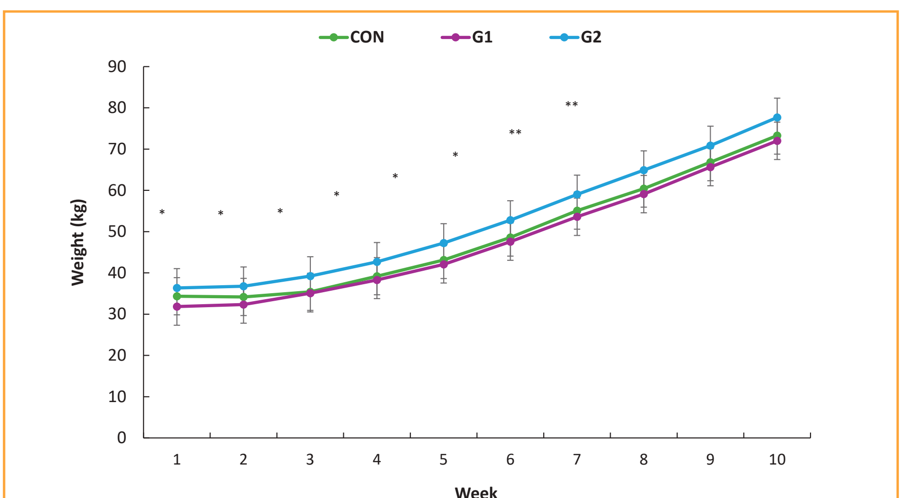
Calves in the G2 treatment group tended to have a higher birthweight than calves in the G1 treatment group (P = 0,064), but both were similar to calves in the CON group. Weaning weight (P = 0,154), weight gain (P = 0,818), average daily gain (ADG) (P = 0,818), and feed conversion ratio (FCR) (P = 0,568) did not differ among treatments.

The differences observed in weight gain (*Figure 1*) during the first two weeks between the calves in the G1 treatment group and calves in the G2 treatment group could be attributed to the differences in birthweight. Throughout the trial, calves in the G2 treatment group maintained higher weights than calves in the G1 and CON groups; however, all groups reached similar weights by the point of weaning. The findings are consistent with previous research where calves in different treatment groups reached similar final bodyweights (Kekana *et al*., 2020).

Garlic extract inclusion did not result in increased weaning weight, ADG, or overall weight gain. This could be due to similar starter feed intakes between groups. However, most calves doubled their birthweight by weaning, meeting the standard goal for dairy calves (Soberon *et al*., 2012).

The results align with previous studies where the inclusion of garlic powder in the milk did not have a significant effect on total live weight gain, daily live weight gain, weaning weight, or ADG (Kekana *et al*., 2020; Özkaya *et al*., 2023). In contrast, studies investigating the effect of garlic powder mixed with calf starters observed a significant increase in the live weight gains of calves (Ghosh *et al*., 2011; Mishra *et al*., 2020; Lad *et al*., 2022).

Figure 1: Average weekly bodyweights of Holstein heifer calves receiving one of three treatments (CON, G1, G2) from five days of age until weaning at ten weeks of age (n = 15).



*Significant differences are indicated by * (P < 0,05) and tendencies by ** (0,05 ≤ P < 0,10).*

Conclusion

No effect was found with the inclusion of garlic extract on the total feed intake, average daily and weekly feed intake, or FCR in calves. As a result, no overall growth performance benefits were observed, and all treatment groups reached similar weights by the end of the trial. The inclusion levels used in this study (1g and 2g garlic/calf/day) may have been insufficient, as previous studies reported improved growth with higher dosages.

Since limited research is available on the inclusion of garlic extract in calf diets, further studies are needed to determine whether higher inclusion levels could enhance growth performance in dairy heifer calves infected with cryptosporidiosis.

Lisa van Deventer.

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Tips to survive the CCMA process

By Tiaan Botes, legal advisor, LWO Employers Organisation

The Commission for Conciliation, Mediation and Arbitration (CCMA) in South Africa plays a critical role in resolving workplace disputes fairly and efficiently. Navigating the CCMA process can be daunting without proper preparation.

The following are key tips to help employers approach their CCMA cases with confidence.

Understand the CCMA process

The CCMA handles labour disputes related to unfair dismissals, unfair labour practices, and other workplace issues. These processes typically start with conciliation where parties attempt to resolve the matter through more informal discussions facilitated by a commissioner. If unresolved, the case usually then proceeds to arbitration, a more formal process where the commissioner will hear the matter on record and make a binding decision.

Some cases may also be dealt with as a so-called 'con-arb' process, which is when conciliation and arbitration is heard on the same day. Should the matter not be resolved at conciliation, it will be arbitrated immediately thereafter.

Employers should familiarise themselves with these stages to avoid surprises. Knowing the process empowers them to present their case clearly and stay focussed.

Prepare thoroughly

Preparation is the key to success at a CCMA hearing. Employers must gather all relevant documentation, such as employment contracts, payslips, warning letters, and email and other correspondence, to support their case.

Evidence should be organised and relevant to the dispute at hand. For employers this generally means proving that any disciplinary actions or dismissals followed fair procedures and were appropriate to the case. Employers should focus on demonstrating how they fairly and reasonably treated the employee under the given circumstances.

Properly preparing beforehand can also help the employer and/or the employer's representatives to remain calm and articulate themselves well during the hearing.

Follow fair procedures

For employers, adhering to fair labour practices before a dispute reaches the CCMA is crucial. Ensure that disciplinary hearings are conducted properly, with clear communication and documented steps. The employer will benefit from showing they acted reasonably and in good faith.

The CCMA will scrutinise whether the employer followed labour legislation, such as the codes of good practice contained in the *Labour Relations Act, 1995 (Act 66 of 1995)* as amended.

Seek professional advice

For employers, professional guidance ensures compliance with legal requirements. Labour law is complex, and missteps (which can occur easily) can weaken your case. Consulting with and obtaining expert representation for your business at the CCMA can provide clarity on your rights and obligations.

Stay calm and professional

CCMA hearings can be emotionally charged, but maintaining composure is essential. Present your case factually, avoiding emotional outbursts or personal attacks. Commissioners value clear, concise arguments backed by witnesses and evidence. Practicing active listening during the hearing also shows respect for the process and can help you respond to the other party's claims effectively.

Know the possible outcomes

Understanding potential outcomes prepares you for what lies ahead. During conciliation, a settlement may be reached, avoiding further proceedings. In arbitration, the commissioner may rule in favour of reinstatement, re-employment, compensation, or no action, depending on the evidence. Being realistic about these possibilities helps you set clear goals for the process.

Facing a CCMA case doesn't have to be overwhelming. By understanding the process, preparing thoroughly, following fair procedures, seeking expert advice and staying professional, you can navigate the CCMA with confidence.

It is important that employers deal with issues in the workplace as quickly and effectively as possible, while taking care to act objectively and consistently. Employers should be proactive and ensure that employment contracts, the disciplinary code, procedures and policies are in place and that this documentation complies with applicable labour law.

The LWO Employers Organisation assists employers to comply with labour law, and to use it to their advantage to protect their business. As a registered employers' organisation with the Department of Employment and Labour, the LWO has the right to represent members at the Commission for Conciliation, Mediation and Arbitration (CCMA). Take note that this article is not legal advice – consult one of our legal advisors about any specific legal problem or matter. For more information, email Tiaan Botes at tiaan@lwo.co.za, info@lwo.co.za, or visit *www.lwo.co.za*.

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ONLINE MAGAZINE:	*www.afma.co.za; www.agriorbit.com; digimags.agriorbit.com*
PRINT DISTRIBUTION:	National & international postal database
INDEXED FOR RESEARCH:	*www.sabinet.co.za* (paid subscription)
READERSHIP:	Minimum 7 500
LSM:	8-10
FREQUENCY:	Quarterly
LANGUAGE:	English

ENQUIRIES

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TARGET AUDIENCE: All members of feed industry bodies (AFMA and others) • Universities, agricultural colleges, technicons • Research institutions Relevant government departments • Producer and industry organisations • Co-operatives • Other media • Raw material suppliers • Clients of AFMA members

ADVERTISING

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PAYMENT TERMS:
Existing clients – strictly 30 days after invoice date.
New clients – 14 days prior to placement.
Rates exclude package discounts, VAT and agency commission.

ADVERTISING PACKAGES

- » One-year pre-planned booking.
- » Added value: Editorial and interviews.
- » 12 easy monthly instalments.
- » Guaranteed coverage in news pages.
- » Advertisements in Plaas Media's other magazines.

As a supplier of animal feed and feed ingredients in South Africa, advertisers who book advertisements in *AFMA Matrix* automatically declare that their product advertisement complies with the provisions of *Act 36 of 1947* and have been approved by the Registrar in the format submitted. Further details included on booking sheets.

ADVERTISEMENTS

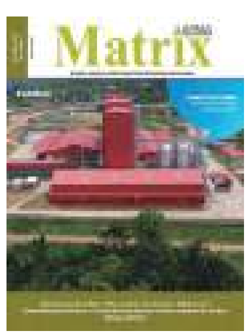
Front cover (logo and photograph)	R28 652	Full page	R15 488
Double-page spread	R28 159	Half page (landscape)	R9 293
Back cover	R27 878	Half page (portrait)	R9 293
Premium page (IFC,P1)	R23 231	Third page	R8 260
Premium page (IBC)	R18 585	Quarter page (portrait)	R7 744
Right-hand full page	R18 585	Banner/strip ad (fifth page landscape)	R6 195

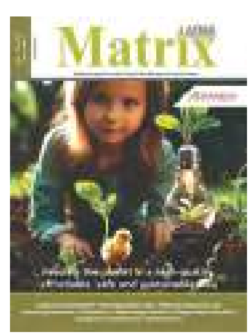
2025 DEADLINES

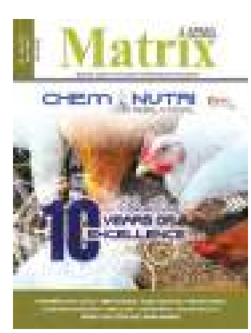
Technical article submissions • Advertorials • Ready advertisements (PDF/Jpeg/TIFF)

JANUARY 2025	APRIL 2025	JULY 2025	OCTOBER 2025	JANUARY 2026
4 November 2024	19 February 2025	19 May 2025	18 August 2025	10 November 2025
20 November 2024	10 March 2025	6 June 2025	8 September 2025	25 November 2025
27 November 2024	17 March 2025	12 June 2025	15 September 2025	8 December 2025

Feed industry • Processing • Milling • Mixing • Formulation • Science • Research • News







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