Jan - Mar 2025
Vol 34 No 1
ISSN 2308-0647

Matrix

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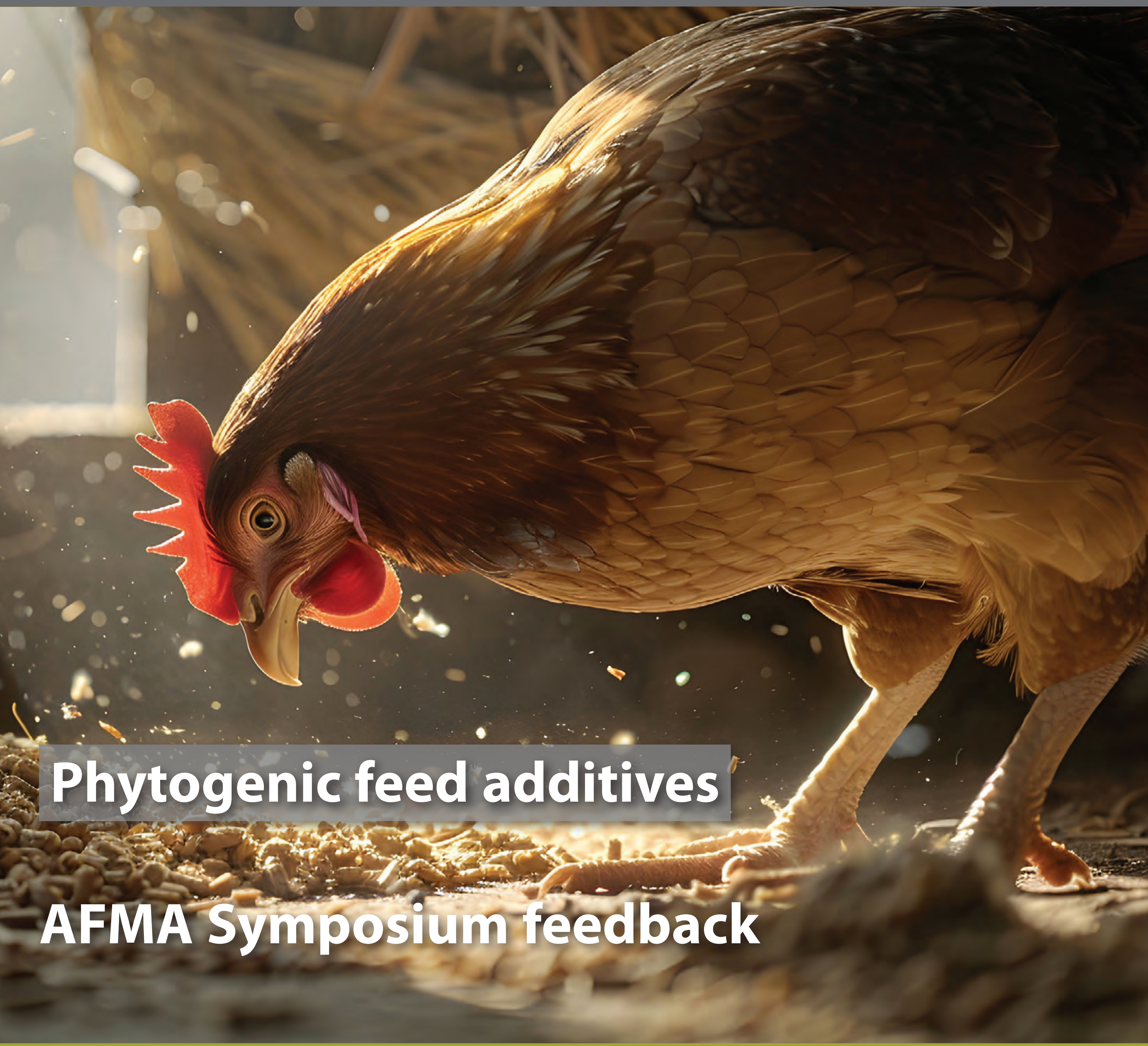
SAFE FEED FOR SAFE FOOD
Animal Feed Manufacturers Association

Quarterly magazine of the Animal Feed Manufacturers Association



Meat consumption trends • AFMA Code of Conduct • Mycotoxin contamination
Antimicrobial resistance • Inorganic phosphorus • Dry matter intake variation
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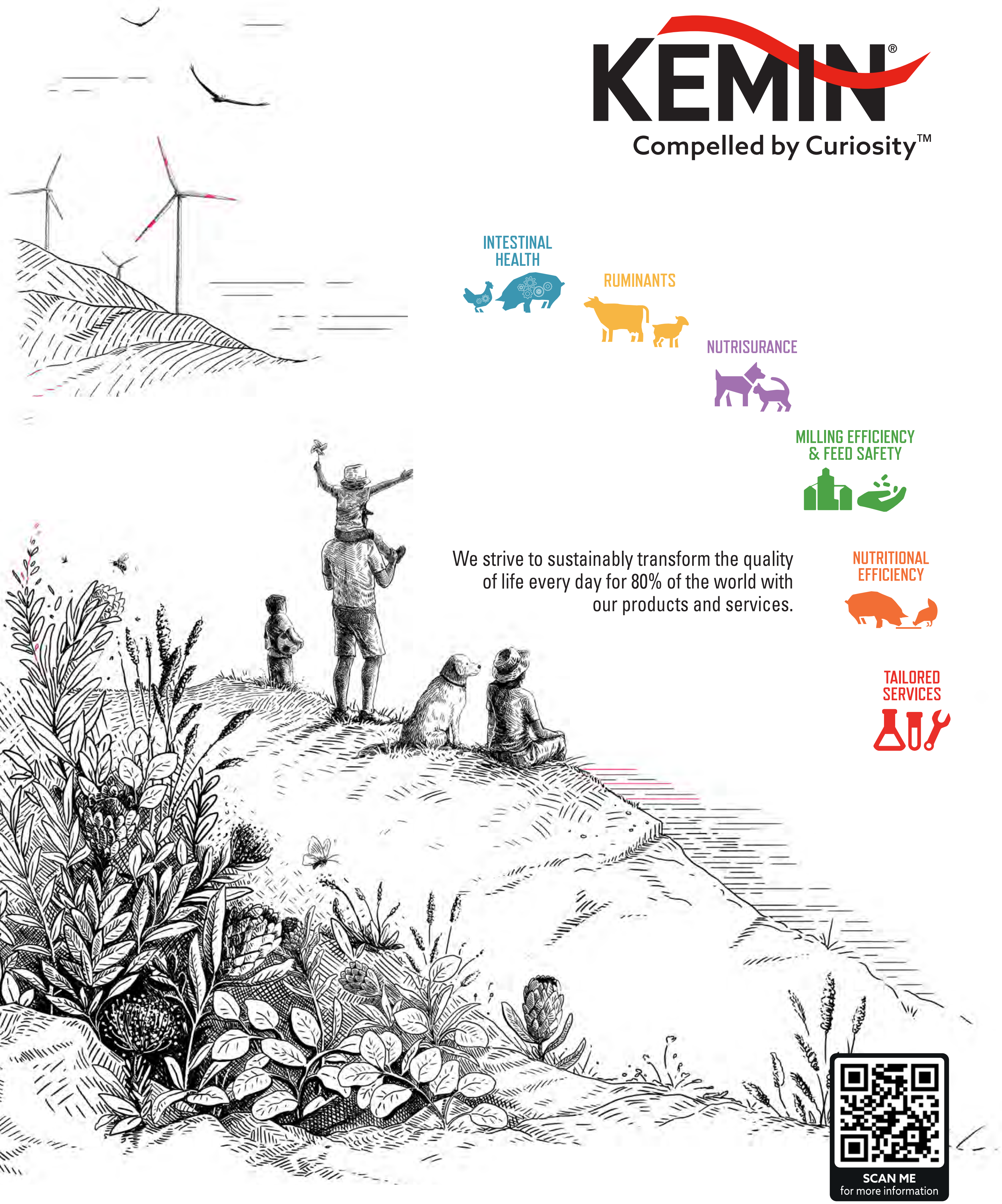
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A thought leader in animal feed

By Liesl Breytenbach, executive director, AFMA

At the start of any new year it is natural to embrace the possibility of opportunities. It is a time to relook, rethink, replan, or just reinforce. The Animal Feed Manufacturers Association (AFMA) had a thorough relook at itself in 2019, the board of directors had a rethink, and AFMA's vision was established as being a thought leader in animal feed.

Little did we know what the next five years would bring. Covid-19 changed the way we live, do business and communicate, and forced us to re-evaluate what is important, critical, and essential. The uninterrupted provision of safe, nutritious, and affordable food was soon labelled as essential, and the animal feed sector found itself to be an integral essential service.

Almost five years later, and we have learned to adapt to a community that demands flexibility and choice by connecting virtually on many levels. The concepts of master plans, value chains, and roundtables have since become part of the South African agricultural strategy for growth. Industry role-players have all navigated towards a next-level structure of collaboration, dialogue, and information flow.

On local ground

South African agriculture was the only sector to record impressive growth rates since the pandemic in 2020, showcasing its potential to pull the economy through times of crisis. During this time, the Agriculture and Agro-Processing Master Plan (AAMP) was drafted and the then Department of Agriculture, Land Reform and Rural Development (DALRRD), together with other industry partners, co-signed the AAMP in May 2022.

Disruptions in global commodity supply chains following the 2022 Russian-Ukrainian conflict, overall concerns regarding the stability of commodity markets and prices, and a drop in disposable income in the majority of G20 countries all contributed towards a decline in broader economic activity and emphasised the need to implement the initiatives of the AAMP in South Africa.

Towards the end of 2024, South Africa had the highest unemployment rate on the continent (32,1%), underscoring the critical need for intervention and solutions. The AAMP partners, of which AFMA is one, is wholly committed to finding solutions and have adopted the concept of commodity value chain round tables (VCRT) from Canada for the implementation of commodity strategies that will benefit the sector. The Grains VCRT was established and created a platform where fragmented relations between government, industry, business, and labour can be managed and moulded towards a true partnership.

This journey will continue and will initially not be a smooth one. The animal feed sector should practice patience, while remaining resilient and focussed on working together to find solutions. Naturally, the success of this initiative can only be confirmed through monitoring, evaluation and diligent reporting, a function and responsibility bestowed upon the National Agriculture Marketing Council (NAMC).

In thought and deed

Besides wars, climate, and other worldwide crises contributing to higher food prices and increasing pressure on value chain stakeholders and consumers, South Africans also had to contend with limited basic electricity and increasing water supply problems, which ignited the resurgence of the old Afrikaans saying, *'n boer maak 'n plan*. Part of this plan is to diversify our agricultural export markets to manage the risk and sustain a growing agricultural sector.

Not only is AFMA's vision to be a thought leader in animal feed, but also to focus on influencing food security and making a lasting impact on the health and wellbeing of the population. The need for a balanced diet that includes animal protein is now more important than ever, and the animal feed sector can play an important role in the provision of affordable food. Initiatives such as VAT-free bone-in chicken and even offal will go a long way in addressing this dire need, but must be implemented effectively and controlled rigorously to avoid unintended consequences and the misuse of good intentions.

Having established strong networks throughout the grains and livestock value chains, AFMA is ideally suited to drive progress across various agricultural value chains. We will drive our strategy based on four pillars:

- Ensuring the consistent supply of sufficient and affordable animal feed for the production of meat, milk, eggs, and fish.
- Using innovative nutritional strategies to produce nutritious animal feed in a responsible and sustainable way.
- Promoting good manufacturing practices in the provision of safe feed to enhance consumer confidence.
- Supporting job creation, training opportunities and skills development in the animal feed industry.

The members of AFMA are at the core of this strategy and 2025 is a great year to make a difference amid growing optimism regarding the government of national unity, improved electricity supply, better-priced input costs, easing in fuel prices, and the prospect of La Niña-induced rainfall in the 2024/25 summer season. Fuelled by positivity, we remain grounded and acknowledge the hard work ahead.

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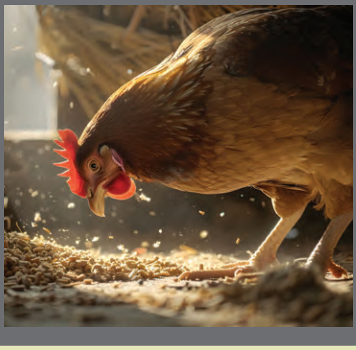

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Published on behalf of AFMA
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NEWS & VIEWS

Important dates on the AFMA calendar

31 March to 11 April 2025
Feed Miller Short Course

6 August 2025
AFMA Golf Day

Iranians produce single-cell protein from methanol

Iranian company Kimia Life has developed a technology for manufacturing single-cell protein from petroleum raw materials. The new product could become a game-changer for the oil-rich country, where the feed industry has long suffered from a feedstuff shortage.

The company is running two pilot projects, converting flare gas to single-cell protein at Abadan Oil Refining Company and processing methanol into the same product at Fanavaran Petrochemical Company's capacities. Kimia Life's CEO, Mr Pourkazem, expressed confidence that the developed technology could significantly boost Iranian food independence and said: "We produce feedstuffs suitable for livestock, poultry and fish by using hydrocarbon resources."

Both methanol and flare gas are available in Iran in abundant quantities, he said. Processing them in animal feed is also a sustainable practice since both substances are considered pollutants. The company has sent first batches of obtained feed protein to livestock companies and got generally positive reactions. – *All About Feed*

IFIF, FAO strengthen collaboration

The International Feed Industry Federation (IFIF) and the Food and Agriculture Organization (FAO) of the United Nations held their 23rd annual meeting recently, reaffirming their partnership on critical issues to advance safe, nutritious and sustainable feed and food production.

The meeting was officially opened by Thanawat Tiensin, assistant director-general and director of the animal production and health division at FAO, alongside IFIF chairperson Ruud Tijssens. Welcoming IFIF delegates representing more than 80% of global compound feed production, they reiterated their commitment to tackling challenges in the feed and food chain through a strengthened collaboration.

Several key topics were discussed, underscoring IFIF and FAO's collaborative efforts for sustainable livestock sector transformation:

- The role of animal feed in sustainable livestock sector transformation.
- *Codex Alimentarius* and feed safety standards.
- Reducing the use of antimicrobials and advancing animal health: FAO's RENOFARM initiative, aimed at minimising antimicrobial needs on farms, and innovative feed practices to reduce antimicrobial use were discussed.
- Global feed standards convergence.
- Emerging food production technologies.
- Development of the feed sector in East Africa.
- Environmental sustainability initiatives. – *Feed Strategy*

Ukraine seeks approval to export to China

Ukraine is hoping to get Beijing's approval to supply peas, poultry meat, animal feed and some other products to the Chinese market, citing the Ukrainian state food safety authority. Ukraine is a major producer of grain, vegetable oils, and other agricultural goods which dominate the country's exports.

Vadym Chaikovskyi, chief state phytosanitary inspector, said in a statement that the process had reached the stage of finalising domestic approval in Ukraine. Ukraine already exports maize, soya beans, barley, vegetable oil and sunflower meal to China.

In the 2023/24 July/June season, Ukraine exported 4,83 million metric tonnes of maize and 702 000 tonnes of barley to China, said Ukrainian traders' union UGA. – *The Pig Site*

Drop in UK feed prices continues

Pig feed prices in the United Kingdom (UK) continue to fall. This is driven by a decline in wheat prices which are down 25% since the second quarter of 2022. Yet prices remain 15% above the same quarter in 2019, demonstrating the overall effect of agricultural inflation which has seen farm input prices increase by 44% between December 2019 and May 2024.

The decline in the weighted feed price has been driven mostly by the reduction in wheat cost; wheat made up 48% of UK pig rations in August 2024. This falling feed cost has been a main contributor to positive net margins over the past 18 months, sitting at £19/head for the third quarter of 2024. – *AHDB*

SA insect-based feed producer expands

Maltento, a leading producer of insect-based animal feed solutions in South Africa, has expanded into the European Union (EU) and UK markets. Maltento achieved its EU export certification three years ago and now, with increased production capacity, is expanding its global footprint by supplying its premium, high-protein ingredients to pet food companies across the UK and EU.

Maltento's golden whole-dried larvae, produced at its state-of-the-art insect production facility in Cape Town, leverages the biotechnology of the black soldier fly to produce golden-dried larvae that contain 45% protein and 27% fat." – *Pet Food Industry*

Animal additives market: US$46 billion by 2029

According to Arizton's latest research report, the global animal feed additives market is growing at a compound annual growth rate of 3,02% from 2023 to 2029.

Livestock farming significantly contributes to environmental issues, including greenhouse gas emissions and resource consumption. To mitigate these impacts, feed additives such as enzymes, probiotics, and methanogenesis inhibitors are increasingly being used to reduce methane emissions in cattle and enhance nutrient absorption, reducing waste.

Natural and plant-based additives, including phytogenics, probiotics, and essential oils, are gaining traction as alternatives to traditional synthetic options. These additives support animal health naturally while aligning with sustainability goals and the growing consumer preference for natural products.

The global rise in meat consumption, driven by population growth, higher incomes, and changing diets, especially in emerging markets such as China, India, and Brazil, has fuelled demand for feed additives that improve animal health and growth rates. This trend has made livestock farming more efficient and productive, with poultry and swine remaining dominant due to their rapid growth cycles and high feed-to-meat conversion efficiency. – *www.barchart.com*

Green light for German feed project

6-R, a project funded by the Federal Ministry of Food and Agriculture (BMEL) in Germany, has demonstrated the positive effects of high rye content in compound feed concepts for pigs. Now the BMEL has given the green light for another research project: FUETURE will evaluate the benefits of resource-efficient animal feed in poultry farming.

Growing regional animal feed and using rye, which requires less fertiliser and water than other cereals and tends to be very healthy: Resource-efficient animal feed and innovative compound feed concepts can make a significant contribution to more sustainable agriculture and food production and have a positive effect on animal welfare. 6-R (1) has already provided valid data supporting these aspects in the context of hog feeding. The initiators are now hoping to see the same results for broilers within the scope of the FUETURE research project.

KWS had already been involved in 6-R as an industry partner. The FUETURE project that has now been approved was initiated jointly by KWS, the University of Veterinary Medicine Hannover Foundation (TiHo) and other partners. It will investigate the resource-efficient use of animal feed in poultry farming. In the case of pig feeding, this has already been achieved based on scientific data from the 6-R project.

The results show that feeding pigs a diet with a high rye content both promotes animal health and significantly reduces CO_2 emissions from livestock farming. If you look at the areas of feed cultivation, livestock farming and slaughter, around 60% of pork's harmful CO_2 emissions come from feeding. Feeding pigs a rye-rich diet can reduce CO_2 emissions by around 20 to 30% up until slaughter. – *KWS*

Animal feed from moringa leaves

To help ruminant farmers counter the high cost of imported feed, Universiti Teknologi Malaysia (UTM) has created pellets from moringa leaves. UTM science faculty bioscience department senior lecturer, Dr Mira Panadi, said she created the MoringaPro Pellet from locally sourced raw materials. "The production uses moringa leaves, which are a main source of protein, enriched with vitamins A, C and E, as well as important minerals such as calcium, iron and potassium.

"This innovative formulation supports livestock health with better results than conventional feed. The product is not only rich in nutrients, but in pellet form, it is more effective and safer than feeding the leaves directly to animals," she said.

Dr Panadi said the product was patented through the Malaysian Intellectual Property Corporation (MyIPO) to protect its formulation and production process. It also won a gold medal at the UTM Industrial Art and Technology Exhibition (Inatex). – *The Star*

World Without Cows released

The official trailer for *World Without Cows*, a documentary examining the multifaceted effects of cattle on economies, ecosystems, and nutrition, has been released. Filmed over three years across 40 global locations, the film challenges prevailing narratives surrounding cattle farming.

The recently unveiled trailer for *World Without Cows* presents a thought-provoking exploration of the critical roles cattle play in our world. This documentary, led by journalists Michelle Michael and Brandon Whitworth, investigates the cultural, economic, and environmental significance of cattle, posing the challenging question: "Are we better off in a world without cows?"

The filmmakers also address the misconceptions about cattle's role in climate change. Dr John Lynch, a climatologist from the University of Oxford, remarked, "Cows are not the biggest contributor to climate change. That's still fossil fuels." This perspective is echoed by Dr Frank Mitloehner, who insists that while animal agriculture must work towards reducing its environmental impact, it is essential not to overstate cattle's contribution to emissions. – *Feed Planet* ❖

Feeding the demand:
Trends in meat consumption

By Petru Fourie, operations manager, AFMA

South Africa's meat consumption trends reflect changing consumer behaviours influenced by economic conditions, health considerations, and cultural shifts. In recent decades, the demand for more affordable protein sources such as poultry has surged, while per capita consumption of beef and mutton decreased.

For feed manufacturers, understanding these patterns is essential for aligning feed production strategies with market demands. Remaining informed of these trends is crucial in meeting evolving demands and being able to adapt to potential shifts in consumer behaviour across the different meat categories.

Meat production vs consumption

Figure 1 illustrates the production versus consumption trends for meat (beef, mutton, goat, pork, poultry) in South Africa. Since around 2000, both meat production and consumption have significantly increased, driven largely by rising consumer demand for animal protein. Poultry has been the major contributor to this growth, given its affordability and relatively shorter production cycle compared to other meats such as beef.

South Africa is not self-sufficient in terms of meat production, which is why the country has been a net importer of poultry since early 2000. Since around 2010, consumption has consistently outpaced production, reflecting a reliance on imports to meet local demand. In the case of beef, mutton and pork, the supply-demand gap has remained narrower, but poultry consistently relies more on imports.

The expansion of the livestock and poultry sector in South Africa has been integral to the development of the animal feed industry. This trend emphasises the importance for feed manufacturers to stay attuned to consumer demand, ensuring sustainable meat production levels and reducing reliance on imports.

Per capita meat consumption

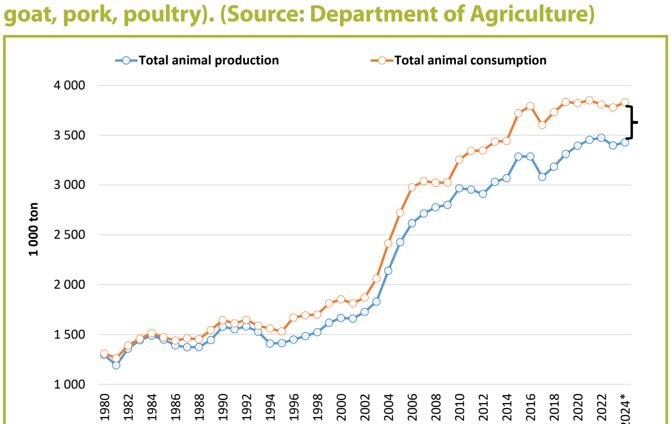
Figure 2 illustrates South Africa's per capita meat consumption (including beef, mutton, goat, pork, poultry) from 1980 to 2024. The trend reflects shifts in consumer preferences and broader economic influences on meat consumption patterns. These shifts transformed the South African meat industry.

From 1980 to the early 2000s total per capita meat consumption per year remained relatively steady, fluctuating between 40 to 45kg per person. However, after 2003 there was a sharp increase, with consumption jumping dramatically by approximately 40% over five years, reaching roughly 61,5kg per capita. This significant surge was primarily driven by increased poultry consumption, as chicken became an increasingly affordable and popular protein source compared to more expensive red meats such as beef and mutton.

However, after peaking in the early 2010s, total meat consumption appears to have stabilised, suggesting that per capita intake has reached a plateau as consumer purchasing power and dietary preferences continue to evolve.

When analysing per capita meat consumption by specific meat types, several significant trends become apparent. *Figure 3* shows the per capita consumption patterns of various products

Figure 1: Total meat production vs consumption (beef, mutton, goat, pork, poultry). (Source: Department of Agriculture)



*2024 figures are preliminary estimates.

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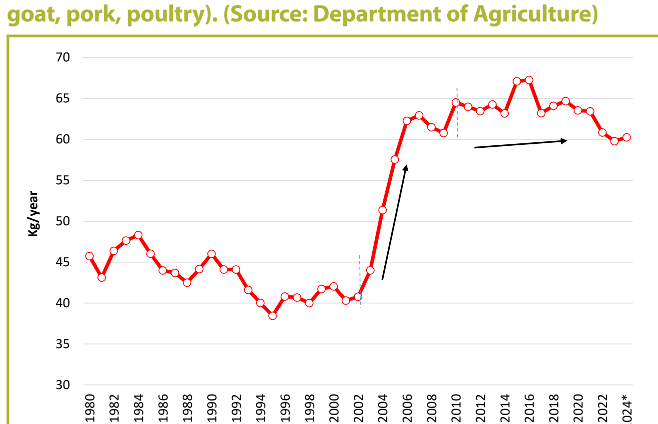
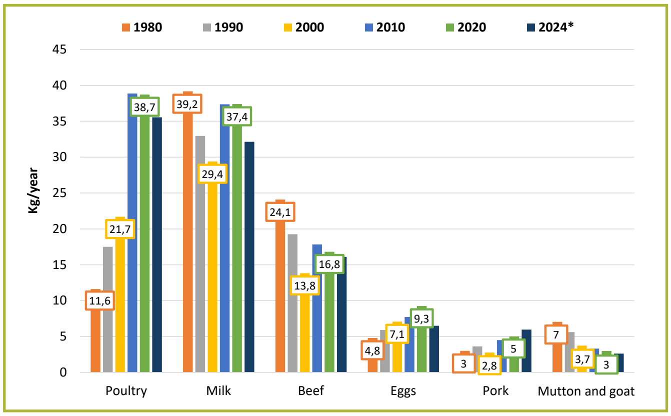


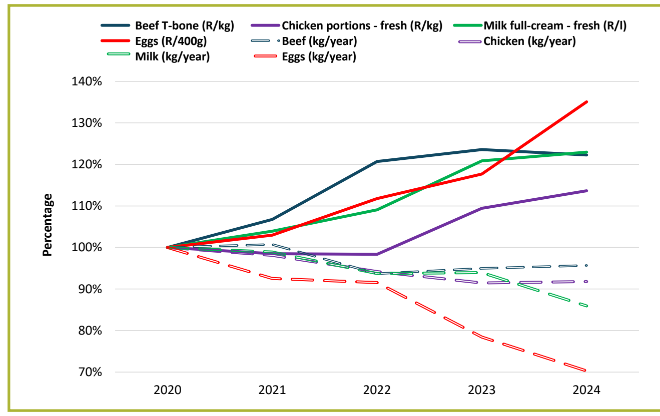
*2024 figures are preliminary estimates.

Figure 3: Per capita consumption of meat, milk, eggs, and poultry in South Africa. (Source: Department of Agriculture)



2024 figures are preliminary estimates.

Figure 4: Index: Price of beef, poultry, milk, eggs vs per capita consumption. (Source: Department of Agriculture, Statistics SA)



2024 figures are preliminary estimates.

in South Africa from 1980 to 2024, including meat, milk and eggs.

Poultry consumption has shown significant growth, especially from 2000 onwards. Poultry per capita consumption almost doubled from 11,6kg/capita/year in 1980 to 21,7kg/capita/year in 2000, largely at the expense of red meat consumption (beef, mutton, goat), while pork consumption remained relatively stable at 3kg/capita/year during this time period.

From 2000 to 2020, similar meat consumption composition changes were observed: chicken consumption increased further to 38,7kg/capita/year, contributing 60% of the total South African meat consumption in 2020. In contrast, the proportion of beef in the meat consumption composition decreased from 33% in 2000 to 26% in 2020. Mutton and goat per capita consumption decreased from 3,7kg/capita/year in 2000 to 3kg/capita/year in 2020, while pork consumption slightly increased to 5kg/capita/year in 2020.

Price vs per capita consumption

Examining the per capita consumption trends for milk, eggs, beef and poultry from 2020 to 2024 (*Figure 3*) reveals a notable decline across all these products. To understand the potential reasons for this decrease, the following section explores the impact of price changes on consumer demand. By comparing the prices of these key products with their per capita consumption, we can identify whether rising costs have influenced purchasing behaviour.

An index was compiled with 2020 as the base year to compare the prices of key products with their per capita consumption, providing a clearer analysis of the impact of price changes on consumption. The data presented in *Figure 4* reflects a significant trend: the price of key protein sources – eggs, chicken, beef, and milk – has steadily increased from 2020 to 2024. However, per capita consumption of these items has declined over the same period. For instance, the price index for eggs and chicken portions shows an upward trajectory, while their per capita consumption (measured in kg/year) decreases.

This pattern suggests that rising prices may be contributing to reduced consumer intake as households adjust their purchasing habits in response to affordability constraints.

A similar trend can be observed with beef and milk. The T-bone beef price index increased, while beef consumption per capita decreased, indicating that higher beef costs might be limiting access to this protein source. For milk, despite its importance in daily nutrition, rising prices are paralleled by a reduction in per capita consumption. Overall, this trend of increasing prices coupled with declining consumption highlights a concerning pattern where inflation in food prices may be affecting the ability of South African consumers to maintain consistent protein intake.

Conclusion

The consumption trends in South Africa indicate a strong consistent demand for affordable protein sources, particularly poultry, which is expected to remain the primary focus for feed manufacturers. Rising prices across all meat categories impacted consumer purchasing power, placing more pressure on affordability and amplifying the demand for poultry. This aligns with the growing preference for pork and eggs, while demand for red meats such as beef and mutton continues to decline.

Going forward, closely monitoring changes in consumer behaviour that may affect future consumption patterns is crucial. As South Africa's reliance on poultry imports underscores a supply gap, the animal feed manufacturers will continue to support and strengthen local production initiatives that could help reduce dependency on imports. In this dynamic environment, feed manufacturers have a pivotal role in supporting the livestock and poultry industry's resilience by addressing affordability challenges to maintain steady protein intake levels for all South Africans.

For more information, email the author at petru@afma.co.za or visit *www.afma.co.za*.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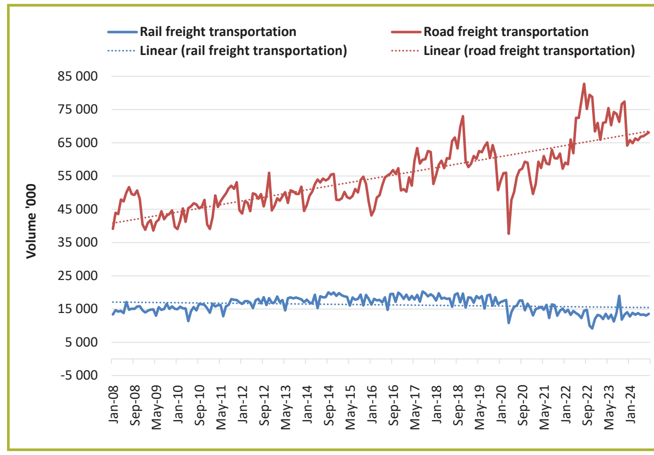
Animal feed ingredient procurement: Transitioning from road to rail

By Lucius Phaleng, AFMA trade advisor

The feed industry is increasingly in need of sustainable and efficient supply chain solutions. A key transition from road to rail transport of raw materials for animal feed is critical for the progression of the local sector. Such a shift will present substantial economic, environmental, and operational benefits.

Historically, South Africa was dependent on rail as a primary transport mode. However, in the last few decades, the reliability of its freight rail network has markedly declined, posing challenges to the competitiveness of the animal feed industry. Notably, volumes transported via rail have declined to their lowest level since 1993. In light of deteriorated rail infrastructure, many producers have turned to road transportation to get their goods and services from point A to point B (*Figure 1*).

Figure 1: Total freight payload ('000 tons) – actual values. (Source: Statistics South Africa)



Transitioning back to rail transport can yield significant cost savings compared to road transport, particularly in respect of longer distances. For animal feed manufacturers who procure raw materials from remote suppliers, rail transportation will offer a more economical solution for moving large quantities of ingredients such as yellow maize and oilcakes. Not only will this enhance the market competitiveness of local feed products but it will also allow for the stabilisation or reduction of prices for livestock producers.

The current situation

According to Statistics South Africa, the volume of goods transported via rail increased from 156,1 million tons in 2022 to 160,3 million tons in 2023. Concurrently, road transport experienced a 1,2% growth, rising from 852,6 to 862,5 million tons during the same period.

The logistics sector plays a crucial role in the South African economy, as trucks are responsible for transporting 80% of the country's goods. Notably, the payload in road freight saw an increase of 1,6%, while heavy traffic on the N3 highway augmented by 5,5% each month. Despite the importance of the logistics sector, the South African economy faces significant challenges due to its increasing reliance on road freight. This dependency has intensified in recent years, leading to higher costs for the economy, as road freight transportation in inherently more expensive than rail. This reliance is also causing a burden on road maintenance budgets.

Costs associated with road transport in South Africa range from approximately R0,50 to R1,50/ton-km, influenced by factors such as cargo type, route, and specific logistic needs. The costs incurred due to high road maintenance costs, fuel expenditure, and toll fees contributes to the overall expenses of road transportation. In contrast, rail freight rates are considerably more economical, typically falling between R0,15 and R0,75/ton-km, making rail a more cost-effective alternative for transporting bulk shipments over long distances.

Potential advantages of rail

The advantages of rail transport stems from economies of scale, characterised by reduced fuel costs and less frequent maintenance compared to road freight. Nonetheless, transitioning from road to rail necessitates thorough planning and adjustments in infrastructure, particularly as numerous animal feed manufacturing facilities are situated in areas without direct rail access.

The shift to rail transport has the potential to significantly enhance supply chain resilience. Unlike road freight, rail is less susceptible to issues such as driver shortages and road traffic regulatory constraints, both of which have increasingly hindered road logistics in recent years. Furthermore, the impact of extreme weather events, exacerbated by climate change, tends to affect road transport more than rail. Think of the storms that struck Durban and its surrounding areas in April 2022. Roads were rendered impassable, bridges were destroyed and the movement of goods disrupted. More recently we saw the Van Reenen Pass closed due to heavy snow, causing delays of up to three days in the movement of goods on that road.

As feed manufacturers seek to optimise costs, the rationale for rail transport is likely to strengthen. Although challenges persist, the long-term benefits associated with rail transport can ultimately outweigh the initial cost and logistical complexity of getting it back on track. However, successful implementation depends on co-ordinated efforts that encompass investment in infrastructure, supportive policy frameworks, and synergetic partnerships with logistics suppliers such as Transnet.

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

AFMA Code of Conduct: Purpose and modernisation

By Wimpie Groenewald, membership liaison officer, AFMA

The Animal Feed Manufacturers Association (AFMA)'s Code of Conduct provides essential guidelines to promote ethical, safe, and sustainable practices in the animal feed industry. This code reflects AFMA's commitment to advancing product quality, consumer confidence, and environmental stewardship while supporting industry innovation and regulatory compliance.

The code sets a benchmark for responsible conduct among AFMA full and associate members and aligns the sector with broader food safety and sustainability goals.

Purpose of the code of conduct

The AFMA Code of Conduct serves as a foundational guide for responsible feed manufacturing. It is not a certification nor does it replace any quality certifications or standards such as ISO 22000. The following sections highlight the core principles of the code, reinforcing AFMA's commitment to integrity and consumer trust.

***Ensuring quality and safety standards*:** A cornerstone of the AFMA Code of Conduct is its emphasis on quality and safety standards in feed production. AFMA members adhere to regulations and best practices designed to ensure the safety of animal feed, thereby protecting both animal health and human food safety. The code requires feed manufacturers to control hazards and prevent contaminants, ensuring that the final product is safe for livestock and humans.

***Promoting ethical business practices*:** The AFMA Code of Conduct underscores the importance of ethical business behaviour, advocating for honesty, transparency, and fairness. This includes maintaining accurate advertising and clear labelling to prevent misleading consumers. By promoting these principles, AFMA supports fair competition and builds trust with the public and industry partners.

***Advocating for animal welfare*:** Animal welfare is integral to AFMA's mission. The code reflects this commitment by promoting the manufacture of balanced, nutrient-rich feeds that support animal health and well-being. By emphasising proper nutrition, the code encourages feed manufacturers to meet ethical standards that enhance farm animal welfare.

***Sustainability*:** AFMA is committed to sustainable feed production, urging members to adopt practices that reduce waste and conserve resources across the food chain.

***Building consumer confidence*:** The AFMA Code of Conduct symbolises quality and reliability. By adhering to the code, AFMA members reinforce public trust in the safety and integrity of animal feed products, supporting the stability of the agri-food sector. The AFMA quality logo, displayed by members who meet the code standards, is recognised as a mark of safe and ethically produced feed.

***Feed safety – a prerequisite for food safety*:** The AFMA Code of Conduct recognises that feed safety is crucial for food safety. Contaminants in animal feed can pose risks to both animal and human health, making it essential to maintain strict safety protocols throughout the production chain. By aligning feed manufacturing with integrated food safety systems, AFMA contributes to a safer food supply and supports public health.

***Co-operation in the agri-food value chain*:** The code encourages collaboration among all stakeholders in the agri-food chain to ensure the safety and quality of animal feed. Each participant in the value chain, from raw material suppliers to final product distributors, shares responsibility for maintaining high standards and controlling hazards. This co-operation fosters transparency and instils confidence among consumers who depend on a safe food supply.

Modernisation of the code

In 2017, AFMA embarked on a significant modernisation of its code of conduct to address evolving industry needs and regulatory requirements. This revision introduced updates to the compliance protocol, audit processes, and membership procedures, making the code more effective and accessible for members. The Covid pandemic effectively halted the first phase of the revised code's implementation.

The modernisation was driven by two primary factors:

- **Enhanced audit options:** Members requested multiple independent assessment bodies to conduct facility audits, improving accessibility and flexibility.
- **Preparation for regulatory changes:** The anticipated *Feeds and Pet Food Bill (X-2019)* requires licensing for feed manufacturing facilities. The revised code supports compliance with this regulation and enhances feed safety management.

Key changes

The following aspects will be addressed in the modernised code of conduct, with implementation planned in stages:

- A documented manual guiding compliance with the code.
- An online membership application with unique membership numbers for approved facilities.
- Audit checklists tailored for different types of facilities, including warehouses.
- A continuous assessment cycle that includes self-assessment by internal quality teams and independent biennial audits.
- Biosecurity measures: Recent disease outbreaks such as African swine fever and highly pathogenic avian influenza have made biosecurity more critical than ever. The revised code mandates a documented biosecurity management system for all AFMA-approved feed manufacturers, focussing on people and vehicle movement to limit the spread of pathogens. This system includes incident management procedures to address potential disease outbreaks.

Looking ahead

AFMA's phased implementation of the revised code of conduct protocol is already underway, with audit renewals that resumed after the pandemic delays.

The following progress has been made with the implementation of the modernised AFMA Code of Conduct, with the resources available:

- An online membership application with unique membership numbers for approved facilities to manage the audit process and membership procedures was adopted.
- Audit checklists tailored for different types of facilities were developed and are currently being reviewed and updated before implementation.
- Benchmarking the current audit scope, process, and performance of the assessment body: Before considering new assessment bodies, it was necessary to benchmark the effectiveness of the current audit scope, processes, and performance. A code of conduct survey was conducted among AFMA full and associate members to establish a benchmark for future reference.

This modernisation strengthens AFMA's self-regulation framework and establishes the organisation as a leader in feed safety and regulatory compliance, being the only voluntary organisation with a mandatory industry standard required for AFMA membership. By adopting this updated code, AFMA members show their dedication to delivering safe, high-quality feed responsibly and sustainably.

The AFMA Code of Conduct, with its emphasis on biosecurity, consumer safety, and ethical practices, lays a strong foundation for feed safety, food security, and industry accountability. Through its continuous evolution, the code ensures that AFMA members remain at the forefront of safe and responsible feed production, contributing to a trustworthy and resilient agri-food value chain.

For more information, contact AFMA at admin@afma.co.za or 012 663 9097.

AFMA Symposium 2024:
Tackling challenges and confronting uncertainty

By Susan Marais, Plaas Media

Animal feed experts are not afraid to explore the unknown and confront the challenges brought on by uncertainty head-on. This was a key takeaway from the Animal Feed Manufacturers Association's (AFMA) annual symposium held at the CSIR International Convention Centre in Pretoria in October last year.

The first session focussed on innovative solutions for success in disruptive times. From left to right are Dr Burak Sarpel Ruperez, technical sales manager for EMEA at Perstorp Animal Nutrition, Theo Venter, professor of practice at the University of Johannesburg, Chantelle Fryer, AFMA's technical programme committee chairperson and session facilitator, and Dr David Bravo, chief science officer at Nutreco.

Policy to plate

Theo Venter, professor of practice at the University of Johannesburg, noted that the two main stakeholders in South Africa's government of national unity (the African National Congress [ANC] and Democratic Alliance [DA]) would strive to make it work for the time being. However, the real test will come in 2026 with local elections, in 2027 when the ANC elects its new leaders, and in 2029 during the next national election.

Dr Burak Sarpel Ruperez, a veterinarian and technical sales manager for EMEA at Perstorp Animal Nutrition, emphasised that the feed production chain should adopt a holistic approach to contamination, rather than focussing on isolated points. "The movement of products creates a major risk for contamination," he said.

The second session focussed on nutritional innovations for optimised performance. The speakers were, from left to right, Manu De Laet, phytogenic poultry technical lead at Cargill in Belgium, Gay Boomgaard, AFMA technical committee chairperson and session facilitator, and Natasha Snyman, COO of Chemuniqué.

He also highlighted often-overlooked contamination sources such as dust and rats. "Dust is a major source of *Salmonella* contamination in feed mills," he explained, adding that *Salmonella* particles can survive on dust for over 300 days. "For every one to two rats seen during the day, there are at least 400 to 1 000 more on the premises."

Dr David Bravo, chief science officer at Nutreco in Switzerland, spoke of the power of plants to combat the complexities the animal production sector is currently struggling with. In the past humanity viewed the world as a clockwork universe, where everything was predictable and fit like the gears of a clock. However, over time it has become evident that contemporary problems, such as illnesses, are not linear but extremely complex. "A decade ago, we didn't have problems such as inflammation in salmon, but today this ails nearly all salmon. Modern human diseases (e.g. Crohn's disease, diabetes, multiple sclerosis) are the same."

Therefore, Dr Bravo said the complex nature of plants is ideal to help resolve these issues. "Animals evolved from plants, and they've adapted to obtain from plants what they need." This ability is the reason why Dr Bravo believes modern technology may enable industry to find complex solutions for the complex health issues the animal sector faces.

Nutritional innovation

Natasha Snyman, COO of Chemuniqué, said when deciding on the correct feed additives you need to analyse your business goals. What is important for your business? The environment? Animal health? Growth or feed conversion rate?

Once you've decided on your goal, Snyman said you can select an additive that works to meet this goal. "If growth is a priority, choose an additive that focusses on rapid weight gain. For health, select an additive that enhances the well-being of animals." She added that the costs and benefits should also be weighed against each other.

Manu De Laet, phytogenic poultry technical lead at Cargill in Belgium, discussed the use of modelling to determine the nutritional matrix values of plant-derived feed additives, such as herbs, spices, and essential oils. De Laet's research demonstrated that the correct additives could lead to significant cost savings.

Animal health and feed safety

Dr Lysiane Duniere, a research scientist at Lallemand Animal Nutrition in France, highlighted the relationship between a cow's rumen and mammary gland through microbial and cellular linkages. She explained that strong interconnections exist between digestive microbiota, the immune system, and host metabolism. While this interconnectedness could be found all along the gastrointestinal tract, it was not limited to that region.

Dysbiosis in the rumen's microbiome, caused by dietary changes or stress, can negatively impact on the hosts' organs and tissue. This, in turn, could have serious consequences for the health and performance of the animal.

Dr Duniere emphasised the importance of maintaining gut microbiota balance, starting in the rumen. While probiotics can be applied strategically, they should

The symposium's third session focussed on animal health and feed safety. It was facilitated by Michel Bradford, swine and poultry product manager at De Heus, on the far left. The speakers were, from left to right, Caitlyn de Vos, ruminant development manager at Vitam International, Dr Lysiane Duniere, research scientist at Lallemand Animal Nutrition in France, and Peter Surai, a professor at Vitagene and Health Research Centre in Scotland.

This year, AFMA's student award for the Intervarsity Writer's Cup was awarded to Mighael van Schalkwyk (middle) of Stellenbosch University. He worked under the mentorship of Dr Brink van Zyl, on the left, chairperson of the Department of Animal Science at Stellenbosch University. Liesl Breytenbach, CEO of AFMA, handed over the award.

In the middle is Jamie Fourie of the University of Pretoria. She was honoured as the Koos van der Merwe/ AFMA Student of the Year for 2024 for her research into determining the acid-binding capacity of various limestone sources and the subsequent impact on proximal gastrointestinal tract pH, calcium and phosphorous digestibility in broilers. The two runners-up were Ramokone Mokonyama of North West University on the left, and Anri Pienaar of the University of Pretoria, right.

be part of a holistic disease management approach.

Importance of organic selenium

Peter Surai, a professor at Vitagene and Health Research Centre in Scotland, discussed the important role of organic selenium in animal nutrition. This trace mineral helps regulate various physiological functions. Organic selenium, in the form of selenomethionine (SeMet), builds reserves in the body, which can be utilised during stress to improve antioxidant defences. However, pure SeMet as a commercial source has low stability and can lose its biological activity during feed pelleting and storage.

In cows, selenium improves immunity and stress resistance, ensuring selenium-rich milk production. In calves, it enhances immunity, gut health, growth and development, and meat quality. In pigs, organic selenium improves boar semen quality and increases selenium transfer via the placenta in sows, enhancing colostrum and milk selenium concentrations. Consequently, organic selenium inclusion leads to selenium-rich meat production.

Mycotoxin decontamination

Caitlyn de Vos, ruminant development manager at Vitam International in South Africa, discussed approaches to mycotoxin decontamination for safer animal feed. She noted the challenge of distinguishing between marketing claims and actual science, highlighting effective methods for managing mycotoxins.

While active carbon is an efficient toxin binder, it can negatively affect nutrient availability. De Vos recommended producers avoid it in feed. "Clays are a good aflatoxin absorbent but inefficient for other mycotoxins due to limited surface availability," she said. "Yeast cell walls are effective in binding flexible mycotoxins such as zearalenone and ochratoxins."

Bio-transforming agents, specifically enzymes, were another efficient solution investigated by De Vos. She found that enzymes could convert mycotoxins into non-toxic metabolites. However, their effectiveness is limited to specific conditions, not always achievable *in vivo*. De Vos concluded her talk by stating: "Currently, modified smectite with algae extracts has demonstrated the ability to bind a wide spectrum of toxins, as proven in dynamic and toxicokinetic tests."

The future of feed milling

Dr Tom Verleyen, director at Kemin Industries, discussed the future of feed milling. He projected that digitalisation and new sensor technology would soon be integrated into these facilities to boost productivity efficiency.

"The feed milling landscape is changing. In the past, every small town had a feed mill, which produced between 20 000 and 50 000 tonnes of feed per year. Today, a single large facility, producing over a million tonnes of feed per year, seems to be the norm." He emphasised the importance of embracing new developments and trends. "What got us here won't get us there."

The inclusion of new developments and trends such as digitalisation, the Internet of Things (IoT) and big data were necessary for industry role-players to be part of Industry 4.0. "Industry 4.0 refers to the Fourth Industrial Revolution, where everything is connected through a Wi-Fi system," Dr Verleyen said, adding that the aim is to improve productivity, quality, and safety.

Industry 4.0 has become the new standard for production processes and includes automation, connectivity, cloud computing, the IoT, big data, and system integration. "It also offers new opportunities, which is why many digital start-ups are currently operating in the agricultural industry," Dr Verleyen noted, highlighting that the agricultural sector often lags other sectors in adopting new technologies.

Despite this, several digitalisation initiatives are underway in the agricultural value chain. For example, 3D cameras are used to predict broilers' bodyweight, eliminating the need for producers to physically catch and weigh chickens.

In feed mills, sensors, data dashboards, and the transformation of data into information and knowledge, and improved efficiency will help accelerate change. Artificial intelligence (AI) will only speed up this process even further.

Dr Verleyen highlighted the role of technology in monitoring bulk tanks, including:

The AFMA Student Research Expo Award for 2024 was awarded to Anel van der Merwe of Stellenbosch University. With her is Liesl Breytenbach, CEO of AFMA.

- **Critical warnings and alerts:** Automatically sends emails or text messages to alert preselected users based on the tank's configuration and role-based access.
- **Geo-mapping:** Bulk tanks are displayed on mapping software to assist in dispatching trucks.
- **Tank status at a glance:** Visualise a tank's key performance indicators.
- **Reporting:** Data can be stored for three years.

Variable feed moisture is one of the biggest issues in feed mills, and Dr Verleyen believes sensors could help determine moisture levels in real-time. Additionally, the feed mill of the future will also be able to improve its carbon footprint of feed production and processing by up to 45%, equivalent to 9,65kg CO_2 per million tonnes of feed produced.

"We need to keep in mind that there are fantastic opportunities available, which all start with data and the installation of the right sensor technology." He added that this is why the right partnerships are needed. "This is a business journey. Working with the right partners is crucial if you want to succeed."

For more information, visit AFMA's website at *www.afmasymposium.co.za*.

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Astral posts top financials as Schutte leaves helm

By Susan Marais, Plaas Media

Integrated poultry producer, Astral Foods, has been able to return to profitable waters, increasing its operating profit by 281% from an operating loss of R621 million in 2023 to a profit of R1 125 million for the year ending September 2024. The poor performance in 2023 was primarily due to load shedding and bird flu.

The company also increased its revenue by 6% to R20,5 billion, boosted headline earnings per share by 245% to 1 920 cents, and cleared the R1 billion debt incurred the previous year. This turnaround culminated in a final dividend of 520 cents per share being declared.

Chris Schutte, Astral's retiring CEO after 16 years, attributed the success to their 'Re-set, Re-focus and Re-start' campaign (Project 3R), which helped the group return to profitability after the worst year in its history. "Leading Astral has been a privilege, and I am grateful to leave the company in a healthy financial position, creating a platform for future growth. I am confident that our well-established and highly experienced executive management team, recognised as the best in the industry, will continue to drive Astral's success. I would like to congratulate Gary Arnold on his appointment as my successor and wish him and the management team all the best."

Chris Schutte (left), outgoing CEO of Astral Foods, and Gary Arnold (right), who will be at the helm officially from 1 February 2025.

Poultry division

Despite economic pressures on households, Astral's poultry division saw a 7,7% revenue increase to R17,1 billion (2023: R15,8 billion). With reduced load shedding, more consumers have been cooking at home, leading to increased poultry meat sales at the retail level.

Overall sales volumes increased by 4,6%, representing 21 449 tonnes, driven by an increase in fresh and fast-food restaurant (QSR) sales. The poultry division's operating profit increased by 142% to R580 million, compared to a loss of R1 380 million in 2023. The operating profit margin increased to 3,4% from -8,7% the previous year.

Non-feed costs in the division reduced year-on-year, positively impacted by the reduced cost of load shedding (R151 million, R410 million lower than the previous year) and costs related to water supply interruptions (R14 million, R17 million lower than 2023). Profitability also benefitted from an insurance recovery of R198 million related to the 2023 highly pathogenic avian influenza claim in the broiler breeding operations.

Feed division

Lower internal feed sales were the main driver behind the 15,2% revenue decline for the feed division, falling to R9,8 billion this year from R11,6 billion in 2023, Schutte explained during a media briefing. He noted that reduced raw material costs also contributed to this decline. "We need to keep in mind that this year's lower performance is being compared to a record-high year. Overall, this division still performed very well compared to Astral's overall history," Schutte said.

Usually, broilers are slaughtered at 33 days, but last year, load shedding forced the company to feed birds for up to 50 days, resulting in a higher feed conversion ratio. However, another reason for lower feed sales was Astral's ability to capitalise on good genetic potential, thereby lowering their feed conversion ratio. Consequently, the feed division's operating profit decreased by 28,3% to R545 million, down from R759 million in 2023.

New product developments

While Astral is refocussing its market strategy, it is also in the process of launching several new products within the next year. The idea for tinned chicken originated from a media outlet twisting Schutte's words earlier this year. However, the report gained such traction that Astral decided to investigate the possibility of creating this product. They are still conducting market research but hope to have Goldi chicken breast fillet in gravy on supermarket shelves by March 2025. "This is pure breast meat in a gravy sauce that can be eaten with a variety of starches. We will position it between corned beef and tinned pilchards."

Frans van Heerden, Astral's commercial poultry managing director, stated that they are also preparing to launch new value-added crumbed products before the beginning of December. These products will be similar to the crumbed, southern fried chicken found in restaurants but don't have to be deep fried. "It is a product that can be popped into the air fryer and therefore it will be healthier." Additionally, the company is working on market innovation in packaging to ensure the best price for consumers, Van Heerden added.

Visit *www.astralfoods.com* for more information.

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Bühler Western Cape celebrates innovation

Bühler has marked another milestone in its dedication to regional support with the expansion of its Cape Town Service Centre. At the annual Customer Day in November last year, Bühler showcased the facility's new features and highlighted its commitment to service excellence, local innovation, and sustainability.

The day featured an interactive setting where Bühler introduced customers to its latest technology advancements. Among these innovations is the temperature vibration monitoring for roller mills, which Bühler is set to launch to improve equipment monitoring.

Boosting productivity

The new technology, designed to reduce unplanned downtime, promises increased productivity for Bühler's clients in the milling and food processing sectors. "We have already introduced this technology to some of our larger customers, and we are excited to provide additional exposure and share its benefits with more customers," says Marc Barris, technical advisor for Bühler Southern Africa.

In addition, Bühler Cape Town recently achieved ISO 9001 certification, underscoring the rigorous quality standards across its facilities. Barris highlights the significance of this certification: "Standardising service across all our locations is crucial, and achieving this certification reinforces the quality that our customers can expect, no matter where they are."

Bühler's global sustainability objectives include developing a pathway to achieve a 60% reduction of greenhouse gas emissions in its operations by 2030. It is committed to having solutions ready to multiply by 2025 that reduce energy, waste and water by 50% in the value chains of its customers. It proactively collaborates with suppliers to reduce climate impacts throughout the value chain.

In line with these objectives, the Western Cape Service Station has implemented a solar initiative, which allows the facility to operate almost entirely off the grid during the year. "For the last year, we have operated independently from the grid, reinforcing our commitment to reducing environmental impact while ensuring reliable service."

The expansion of the Western Cape Service Station, alongside new technologies and green initiatives, highlights Bühler's proactive approach to supporting local industries with high-quality, sustainable solutions.

"We are excited to share these advancements with our customers and to reinforce Bühler's long-standing commitment to innovation and sustainability. This Customer Day is not only a chance for existing customers to explore Bühler's expanded offerings, but also an open invitation for new customers to discover the full range of services we bring to the Western Cape region and beyond," concludes Austin.❖

For more information, visit *www.buhlergroup.com.*

Voermol donates to Semonkong outreach

The Semonkong Hospital Trust is a faith-based, interdenominational organisation that has been hosting an annual week-long veterinary outreach in Semonkong, Lesotho, since 2006. In 2024, this week took place from 22 to 28 September, and Voermol decided to throw their weight behind the effort by donating a R10 000 voucher that could be used towards any Voermol product.

Making a difference

According to Solitha Kruger, a veterinary student at Onderstepoort and a member of the Trust's small-stock committee, the biggest challenge the people of Semonkong face is a lack of knowledge, coupled with a vastly different cultural approach to animal husbandry. A major aspect of the outreach is convincing residents of the value of good animal husbandry practices.

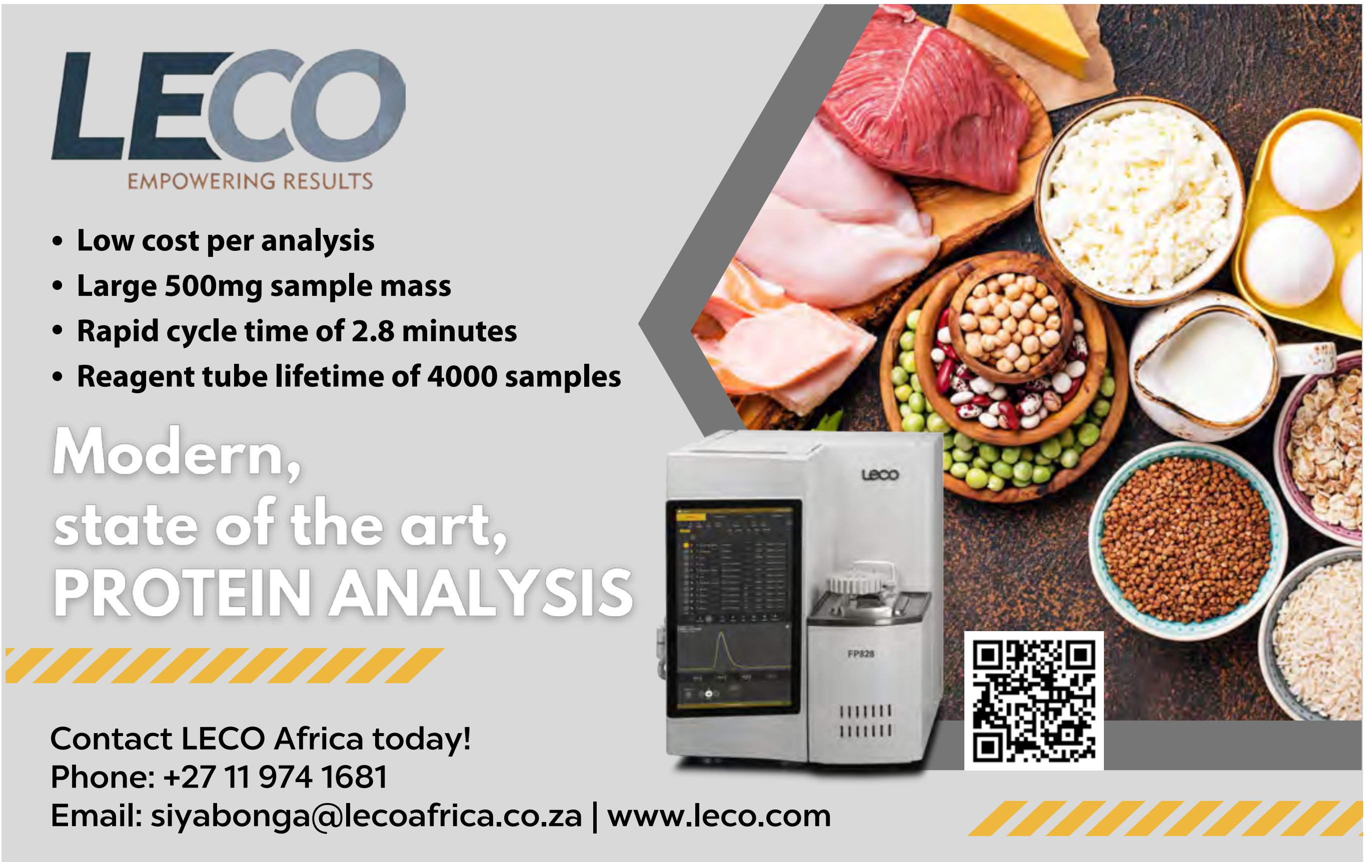
"Usually, we are a team of 80 people consisting of 60 veterinary students, 20 veterinarians and other volunteers. We have our headquarters in Semonkong, but we also establish three or four satellite stations further afield to enable more people to bring their animals in for treatment. The underlying objective of the outreach is to spread the gospel, and the best way we in the veterinary profession can do that is through the animals."

During the 2024 outreach, the team castrated 25 equids over three days. They were sedated with medetomidine and each new gelding was sent home with pain medication as well as antibiotics, the use of which was explained to each owner by means of a translator. There were 45 farrier cases which entailed hoof trimming as well as some alignments. In general, the animals had very good hoof structure. Horses were also dewormed. This time only 301 cases of saddle sores were treated, which was substantially less than the almost 1 000 cases treated in 2023.

On the livestock side, a total of 19 133 small stock were treated in 2024. They were dewormed and 80% were given vitamins and minerals as well. Most clinical cases consisted of eye infections, lameness, or broken legs and traumatic wounds. Only 16 pigs were treated as not many are kept by the community.

A total of 4 317 cattle were processed and vaccinated against anthrax and botulism, as well as treated against internal and external parasites. Cattle with very low body condition scores received a vitamin B injection. Generally the body condition score among the cattle were good for that time of year.❖

For more information, contact Solitha Kruger on 081 043 0856.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Mycotoxin contamination and the nutritional content of maize targeted for animal feed

By Anthony Pokoo-Aikins, Callie McDonough, Trevor Mitchell, Jaci Hawkins, Lincoln Adams, Quentin Read, Xiang Li, Revathi Shanmugasundaram, Elsi Anna Rodewald, Pratima Acharya, Anthony Glenn, and Scott Gold

Cereal grains, especially maize, are a primary source of calories in animal diets worldwide (Dubey *et al*., 2020). Approximately 70% of the world's cereal grain is used in animal feed (Oliveira *et al*., 2014). Although production of crops has increased over the years, approximately 25% of the world's cereal grain harvest is wasted due to mycotoxin contamination making it unsafe for consumption (Marin *et al*., 2013).

Maize is more susceptible to mycotoxin contamination by various colonising fungi than other animal feed commodities such as wheat, barley, oats, and soya beans (Magnoli *et al*., 2019). An estimated 60 to 80% of agricultural products are contaminated with mycotoxins (Eskola *et al*., 2020), with 61% containing multiple mycotoxins (DSM, 2023).

Mycotoxins are a class of secondary metabolites produced by fungi that exert toxic effects on animals including humans (Liu *et al*., 2020). In the agricultural industry, mycotoxins cause losses in animal production due to reduced growth rates, decreased immunity and fertility, reduced egg, meat and milk production, and increased mortality (Thipe *et al*., 2020). The major mycotoxins that contaminate cereal grain are aflatoxin (AFB1), fumonisin (FUM), deoxynivalenol (DON), zearalenone (ZEA), T-2 toxin, and ochratoxin (OTA) (Zain, 2011).

The United States (US) has regulatory guidance levels established for AFB1, DON, and FUM but not for ZEA, OTA, or T-2. DON, ZEA, FUM and T-2 are considered to be primarily field mycotoxins, whereas AFB1 and OTA are considered to be primarily storage mycotoxins (Munkvold *et al*., 2019). However, the field mycotoxins have also been observed to increase in concentration when the grain is stored under favourable conditions for the fungi.

Infection of maize for feed

In addition to fungal growth on maize leading to mycotoxin contamination, it also, by necessity, results in changes in the nutritional content of the kernels as the fungus selectively consumes components of and develops in the maize kernels. Fungi consume specific plant nutrients changing the nutrient content of the colonised plant biomass (Vieira, 2003). Maize entering storage is frequently contaminated with fungal spores from the field, potentially leading to fungal growth (Vieira, 2003).

Factors potentially affecting maize during storage include high moisture content (above 13%), high relative humidity (70 to 75%), prolonged conducive temperature exposure (15 to 20°C for *Fusarium*, 25 to 30°C for *Aspergillus*), physical damage to kernels (such as mould and insect infestation), storage methods, and storage duration (Hossain *et al*., 2011; Rosentrater, 2022). Fungal growth in stored maize frequently leads to a measurable reduction in carbohydrate and fat levels (Vieira 2003). These changes in nutrient profile are predicted to have a negative impact on poultry feed conversion ratio if not taken into consideration during feed formulation.

Fungal growth can change other aspects of the maize kernels, including colour. If colour data can be correlated to mycotoxin content, this could be another avenue by which grains could be cheaply screened for mycotoxin contamination. Poultry producers routinely screen incoming grain for mycotoxins, especially AFB1, but do so less frequently for other major mycotoxins such as FUM and DON.

Concentration levels of DON in grains have been shown to change during storage; this creates the possibility that grain which passed inspection can have increased toxin levels when later removed for use (Venslovas *et al*., 2022). Additionally, FUM and DON are frequently found in the same grain source and at levels below regulatory thresholds (Weaver *et al*., 2021).

Recent studies indicate that sub-regulatory levels of multiple mycotoxins in the same feed can have negative synergistic effects on poultry gut health, performance, and food safety (Shanmugasundaram *et al*., 2022). Although several surveillance papers have examined the occurrence and co-occurrence of mycotoxins, most use small sample sizes. Here, we analysed 328 maize samples obtained from grain elevators, feed mills, and farms in the Southeastern US, a major producer of broiler meat, for four major mycotoxins of poultry production concern and examined their co-occurrence.

Mycotoxin analysis

Of the 328 samples, 82,93% were below the level of detection (LOD) on the HPLC-MS/MS and were thus recorded as having no AFB1 (*Figure 1*). The remaining 17,07% of samples were found to contain concentrations of AFB1 between 0,6 to 939µg/kg: 6,4% were below the 20µg/kg regulatory action level for young animals, 7,62% contained between 20 and 100µg/kg, and 3,05% showed amounts greater than the 100µg/kg regulatory action level for chickens.

All 328 samples had detectable levels of one or more fumonisins ranging from 19 to 47 300µg/kg. FB1 was detected in all samples and ranged from 19 to 24 680µg/kg. A total of 2,44% of the samples had no detectable levels of FB2, while samples with detectable levels of FB2 positive samples ranged from 2 to 15 320µg/kg. FB3 in positive samples ranged from 1 to 9 540µg/kg with 1,22% of the samples having no detectable FB3. All samples were under the 100 000µg/kg guidance level.

Of the 328 samples, 69,82% had detectable levels of DON ranging from 15 to 9 640µg/kg. None of the samples were above the 10 000µg/kg advisory level. A total of 43,60% of the samples tested had detectable levels of ZEA. Samples that had ZEA ranged from 4 to 8 093,5µg/kg. There are currently no regulatory guidelines for ZEA.

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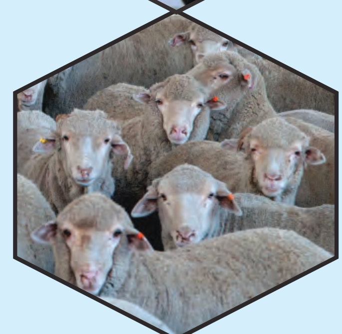

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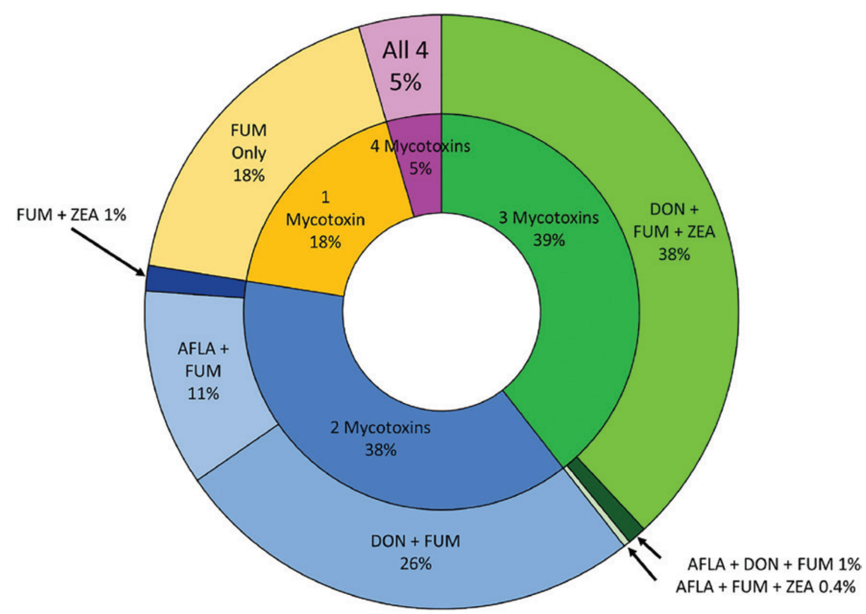
Figure 1: Distribution of the number of mycotoxins detected in individual maize samples (inner ring) and (outer ring) the distribution of specific combinations of mycotoxins (aflatoxin [AFB1], deoxynivalenol [DON], fumonisin [FUM], and zearalenone [ZEA]) making up the co-contaminations indicated.



A total of 81,71% of the 328 samples were contaminated with multiple mycotoxins. The most common number of mycotoxins in a sample was two. Of the 328 samples, 4,88% had all analysed mycotoxins present (AFB1, FUM, DON, and ZEA) (*Figure 1*). Most of the samples that had three or more mycotoxins present (120 out of 126) had DON, ZEA, and FUM present.

FUM was the most frequently occurring mycotoxin and was present in all samples (*Figure 1*). DON was the second most frequent mycotoxin and was present in 69,82% of samples. ZEA was the third most frequently occurring mycotoxin and was present in 43,60% of all tested samples. AFB1 was the least frequently occurring mycotoxin and was present in 17,08% of the 328 samples, with an average level in the positives of 82,49µg/kg. This is below the 100µg/kg level for mature poultry but above the 20µg/kg level for young animals.

Proximate analysis of maize

Protein ranged from 5,98 to 9,05% with a standard deviation of 0,46%. Fat content ranged from 2,07 to 3,77% ±0,24%. Moisture content was more variable with a range of 10,95 to 17,77% ±0,93%. The fibre content ranged from 1,73 to 2,09% ±0,06%. Starch ranged from 57,61 to 66,51% ±,05%.

Nutritional content and colour

AFB1 was negatively correlated with fat content (P = 0,007; slope = 0,033) and negatively correlated with the L* (lightness) colour value (P = 0,007; slope = -0,842). DON was positively correlated with starch (P < 0,001; slope = 0,037). FUM was positively correlated with protein (P = 0,008; slope = 0,072) and moisture (P = 0,019: slope = 2,353), and negatively correlated with starch (P < 0,001; slope = 0,026). ZEA was negatively correlated with starch (P = 0,034; slope = 0,034).

Discussion

Maize is widely used in animal feed, but it is often contaminated with mycotoxins in the field, during harvest, and in storage before being used. Generally, the bulk of poultry feed is made up of maize (Loy and Lundy, 2019). Mycotoxin-contaminated maize can often cause production and health issues when fed to animals, especially when there is co-contamination with multiple mycotoxins, which can result in synergistic impacts (Shanmugasundaram *et al*., 2022). The Food and Agriculture Organization of the United Nations estimates that 60 to 80% of grain is contaminated with mycotoxins (Eskola *et al*., 2020). There is therefore the need to screen maize for use in animal feed.

In this study, we analysed maize samples for AFB1, DON, FUM and ZEA. We found all analysed maize samples to be contaminated with at least one mycotoxin (FUM) and over 80% to be contaminated with multiple mycotoxins. A recent study on different raw feed ingredients in the US found 98,6% of their samples had at least one mycotoxin and 90,2% with two or more, and that FUM was the most common mycotoxin present (Weaver *et al*., 2021).

In this study, 17,08% of the tested samples contained AFB1. This is relatively high compared to Munkvold *et al*. (2019) and Kosicki *et al*. (2016), who compared AFB1 values in Polish maize from 2011 to 2014. The highest amount of AFB1 detected was 939µg/kg in our study and 0,18µg/kg in Kosicki *et al*. (2016). However, the number of samples analysed by Kosicki *et al*. (2016) for each harvest year was less than 20, so the difference in results could be due to a small sample size.

A seven-year study monitoring maize grain in the US found that 7,6% of samples contained AFB1 (Weaver *et al*., 2021). Storing maize for over six months was associated with an increase in the concentration of AFB1 by threefold (Sasamalo *et al*., 2018; Venslovas *et al*., 2022). Economic losses due to AFB1 contamination in US maize average US$225 million annually (Ayofemi Olalekan Adeyeye, 2020).

Presence of mycotoxin

All 328 samples analysed had detectable levels of FUM. In contrast, Kosicki *et al.* (2016) found FUM in 24 to 94% of samples depending on the sample harvest year. Weaver *et al*. (2021) found FUM present in 69,3% of US maize samples. A similar study reported 90% FUM, 80% DON, 46% ZEA and 18% AFB1 detection in Latin American maize (Magnoli *et al*., 2019). The differences in FUM results could be due to geographical location, climatic conditions, soil health, storage duration and conditions, sample size, or sample year.

FUM B1 (FB1) was detected in all samples that were analysed and ranged from 0,019 to 24 680µg/kg. Similarly, Gilbert-Sandoval *et al.* (2020) reported FB1 in 98% of maize sampled in Mexico City with concentrations ranging from 79 to 1 589µg/kg. Weaver *et al*. (2021) found FB1 in 65,7% of samples with a maximum of 52 500µg/kg. In the current work, 97,56% of samples had detectable levels of FB2 ranging from 0,8 to 15 320 µg/kg. Weaver *et al*. (2021) found FB2 to be present in 53,4% of samples with a maximum of 5 640µg/kg. Gilbert-Sandoval *et al*. (2020) found FB2 in all samples, with concentrations ranging from 24 to 524µg/kg. A total of 99,09% of tested samples had detectable levels of FB3.

In contrast, Weaver *et al*. (2021) reported 41,8% of samples to have FB3. Samples with detectable levels of FB3 ranged from 1 to 9 540µg/kg, while the maximum amount of FB3 in Weaver *et al*. (2021) was 2 800µg/kg. Kosicki *et al*. (2016) only reported total FUM levels. FUM is often found in maize and animal feed, but contamination normally occurs preharvest (Munkvold *et al*., 2019). In our samples, FUM was present in all three forms, but FB1 made up the majority in most of the samples.

Here, 69,82% of the samples had detectable levels of DON. Similarly, Kosicki *et al*. (2016) found that 76 to 100% of samples tested positive for DON, Weaver *et al*. (2021) found 75,7% DON positive samples, and Twaruzek *et al*. (2021) found that 98% of samples surveyed between 2015 to 2020 in Poland had some levels of DON. In this study, samples that had detectable levels of DON ranged from 30 to 9 640µg/kg.

Weaver *et al*. (2021) reported a maximum level of 26 970µg/kg of DON, while Kosicki *et al*. (2016) reported a maximum of 6,690 µg/kg in 2014. None of the samples we tested were above the 10 000µg/kg advisory level. The difference in maximum detected levels of DON between our study and others could be due to sampling occurring before or after batches leave the maize grower's farm, or from sampling different climates as DON occurs more often in cooler and drier climates. The maximum concentration of DON we detected was just under the regulatory limits. This would be expected due to some of the samples having been pre-screened for high mycotoxin content.

Of the 328 maize samples we tested 43,40% had detectable levels of ZEA ranging in concentration from 4 to 8 093,5µg/kg. Kosicki *et al*. (2016) found ZEA in 88 to 100% of samples depending on the year. The differences in results between this study and that of Kosicki could be due to variables such as location, year, and sample size. Weaver *et al*. (2021) reported that 21,2% of samples had ZEA. Kosicki *et al*. (2016) reported a maximum ZEA level of 521µg/kg, while Weaver *et al*. (2021) had a maximum ZEA of 2,894µg/kg. Although ZEA is not regulated, it frequently (100% in this study) occurs in combination with other mycotoxins and may work synergistically with other mycotoxins to increase their effects.

The maximum values for FUM and DON found here were below their regulatory limits, while the maximum value for AFB1 was more than nine times the regulatory limit. This data seems to support the hypothesis that AFB1 is a storage mycotoxin while DON and FUM are primarily generated while maize is in the field. Screening maize for toxins before sampling would keep the concentrations of field-generated toxins below regulatory levels, while toxins produced in storage potentially accumulate above regulatory levels after initial mycotoxin screenings. Re-testing of feed ingredients immediately before feed manufacture should provide a valuable avenue for decreasing mycotoxin-related losses as mycotoxin levels, particularly AFB1, can increase during storage.

On multi-mycotoxin contamination, the most commonly co-occurring three mycotoxin combinations were DON, FUM and ZEA contaminating 36,59% of samples. Only 4,88% of the samples had all four analysed mycotoxins (AFB1, DON, FUM and ZEA) present. Similar to our findings, Weaver *et al*. (2021) reported that 90,2% of samples were contaminated with multiple mycotoxins. These results suggest, and agree with previous studies, that the co-contamination of mycotoxins, especially DON, FUM, and ZEA, occurs very frequently in maize. Although most samples were below regulatory levels, co-contamination could lead to decreased poultry production.

Nutrient content of feed

Mycotoxins, even at subclinical or low levels, pose problems for farm animals, as was recently shown for poultry (Shanmugasundaram *et al*., 2022). While toxin concentrations should be examined for synergistic effects when in combination, the correlation of nutrient and mycotoxin content of feed ingredients should also be investigated and accounted for in formulations (Vieira, 2003; Bryden, 2012). Changes in the nutritive values of protein, fat and starch can be caused by fungi breaking down maize to generate fungal biomass, carbon dioxide, water, heat, and mycotoxins (Krska *et al*., 2012; Rosentrater, 2022). We found that samples containing AFB1 were correlated to a significant decrease in fat content.

Many studies have reported a correlation between AFB1-producing fungi and high oil content in grains (Chang *et al*., 2004; Wilson *et al*., 2004; Dhingra *et al*., 2009; Ma *et al*., 2015). Atanda *et al*. (2011) reported that storing grains with moisture levels higher than 13% coupled with a temperature between 10 and 40°C can result in elevated mycotoxin contamination.

Contrary to our results, Venslovas *et al*. (2022) found a decrease in moisture to correlate with AFB1 contamination. Previous research has shown that fermentation of spent brewers' grains and other agricultural products by *Aspergillus* species can increase protein content (Fan *et al*., 2023). In contrast, Zubair *et al*. (2011) reported that AFB1 contamination correlated with increased moisture and decreased protein in walnuts. Alamu *et al*. (2018) examined baby foods and found that AFB1 contamination was correlated with decreased protein. DON contamination was negatively correlated with protein and positively correlated with starch. Contrary to our results, Venslovas *et al*. (2022) reported an increase in protein in DON-contaminated maize silage. These findings seem to contradict other research that had shown DON to inhibit protein synthesis (Pestka and Smolinski, 2005).

The presence of FUM in the maize samples was associated with a significant increase in protein and moisture as well as a significant decrease in starch. Sanchis *et al*. (2006) reported that moisture was associated with an increase in FUM production in grain. ZEA levels were negatively correlated with starch content levels. To date, little research has been published examining the correlation between ZEA levels and starch content. Matthäus *et al*. (2004) showed that starch content in grain samples inoculated with ZEA-producing fungi was lower than uninoculated samples after allowing time for the fungi to colonise the grain. In this study, none of the examined mycotoxins had a significant effect on fibre.

In contrast to our results for fibre, Awuchi *et al*. (2020) modelled the effects of various mycotoxins on the fibre contents of grains and found that mycotoxins including AFB1 were positively correlated with fibre levels. This could partially explain the fluctuations in the nutrient content of different batches of maize received at feed mills.

A more thorough understanding of the effects of mycotoxin levels on the nutrient content of maize will allow animal feed formulators to account for the changes in nutrient content caused by mycotoxin-contaminated maize when formulating feed. Comparing the results of multiple studies on this effect can contribute to a more thorough understanding of how individual mycotoxins affect the nutrient content of feed components.

It is also important to note that the cultivar, grade, harvest, and storage time of maize can affect the nutrient content of maize (Mut *et al*., 2022). However, this data was not available for the samples collected in this study due to the samples being obtained from sources that store maize in bulk from multiple fields.

Previous studies have examined potential correlations between mycotoxins and various visual characteristics of maize. Some of the methods that have been used to analyse the colour of maize include using RGB values of pixels in computer images (Steenhoek *et al*., 2001). Also, BGY fluorescence is a common test for AFB1 contamination in maize (Chavez *et al*., 2020). Other methods such as near-infrared spectra, x-ray images, colour images, and physical properties have been used alone or in combination to try to determine fungal infestation in maize (Pearson *et al*., 2006).

Less work has been published on examining CIE values and mycotoxin levels. In our study, we found a strong negative correlation between the CIE L value (lightness) and AFB1 contamination. This shows another potential avenue of visual analysis to detect mycotoxin contamination in maize.

In conclusion

These results demonstrate that mycotoxins are associated with a change in the nutrient profile of maize. This can affect animal health and performance even before mycotoxicosis affects animals directly. Co-contamination with multiple toxins seems to be very common, with FUM being the most common co-contaminant, in this study. Further research is needed to better understand the relationship between mycotoxins and the nutrient properties of maize, to quantify the effects of mycotoxin co-contamination in feed, and to develop methods to reduce mycotoxin accumulation in grain/feed storage.

This article was condensed for publication in *AFMA Matrix*. For the full article and references, visit *www.doi.org/10.1016/j.psj.2024.104303* or send an email to anthony.pokoo-aikins@usda.gov.

A new era in mycotoxin risk management

By Elmarie Smit

The increasing prevalence of mycotoxins in animal feed poses significant risks to livestock health and productivity. In response to these challenges, dsm-firmenich developed a groundbreaking product range, Mycofix®, aimed at managing mycotoxin risks more effectively.

The essential role of this product range was discussed during the first leg of dsm-firmenich's mycotoxin awareness tour in October 2024 in Gauteng (the second was hosted in the Western Cape). Speakers included Dr Dian Schatzmayr, research and development (R&D) programme director for dsm-firmenich, Dr Veronika Nagl, a senior scientist at dsm-firmenich, Dr Sander Janssen, mycotoxin risk manager: Europe, Middle East and Africa, and André de Vries, dsm-firmenich business development manager for sub-Saharan Africa.

Understanding mycotoxin risks

Mycotoxins are toxic compounds produced by certain moulds that can contaminate food and cause health problems in humans and animals. Thy are found worldwide in grain and oilseed crops. The chemical compounds are very stable; once formed, they are difficult to destroy. Different fungi produce different mycotoxins. They can be highly detrimental to livestock health, leading to issues such as poor growth, immune suppression, and reproductive problems. With mycotoxins being a persistent issue in agricultural production, it has become crucial for feed manufacturers and producers to adopt effective risk management strategies.

Dr Schatzmayr explained that traditional approaches to mycotoxin management have often been limited to a single strategy, typically adsorption, where the focus is on binding toxins to prevent their absorption in the gut. However, this approach alone is often insufficient, especially given the complex and variable nature of mycotoxin contamination. Mycofix®'s innovative approach integrates three distinct strategies to offer a comprehensive solution: biotransformation, adsorption, and bioprotection.

Triple-action approach

- *Biotransformation* involves the enzymatic breakdown of mycotoxins into non-toxic metabolites. By altering the chemical structure of the toxins, biotransformation effectively eliminates their toxicity. This approach is particularly beneficial for addressing mycotoxins such as zearalenone (ZEN), fumonisins (FUM) and deoxynivalenol (DON), which can lead to reproduction and other production problems in livestock.
- *Adsorption* involves the physical binding of mycotoxins to prevent their absorption in the animal's digestive system. Mycofix® formulations contain advanced binders that are highly effective in adsorbing a range of mycotoxins. Binding these toxins prevents their uptake into the bloodstream, reducing their harmful effects on animal health and performance.
- *Bioprotection* focusses on mitigating the toxic effects of mycotoxins that may still enter the system. It provides immune and liver support, and strengthens the intestinal barrier and tight junctions in the presence of mycotoxins.

This triple-action approach allows for a more holistic and effective response to mycotoxin contamination.

Tailored solutions

The Mycofix® range currently available in the South African market includes Mycofix® Plus 5.Z and Mycofix® Select 5.0.

Mycofix® Plus 5.Z is specifically designed for reproducing poultry, swine, ruminants, and aquaculture. One of its key components is ZENzyme®, an innovative enzyme that targets ZEN, a common mycotoxin that, due to its estrogenic properties, poses serious risks particularly in breeding animals. De Vries highlighted the impressive results observed with ZENzyme®, noting its effectiveness in reducing the negative impact of ZEN on reproductive health.

Mycofix® Select 5.0, on the other hand, is a more generalised product designed to provide comprehensive protection across a broader range of mycotoxins. It is suitable for use across multiple animal species and aims to mitigate the effects of different mycotoxins, making it a versatile option for producers dealing with varied feed contamination scenarios.

A comprehensive portfolio

The focus on Mycofix® is part of dsm-firmenich's broader strategy to enhance its mycotoxin risk management portfolio across South Africa and sub-Saharan Africa. According to De Vries, the region faces unique challenges when it comes to mycotoxin contamination due to the diverse climate conditions that can favour mould growth.

During the event, the speakers emphasised the importance of adopting a multi-faceted approach to mycotoxin management, especially in markets such as South Africa where climate variability can lead to unpredictable contamination patterns. They pointed out that relying solely on adsorption is no longer sufficient, given the evolving mycotoxin landscape and the increasing awareness of mycotoxins beyond aflatoxins, such as fumonisins, ochratoxins, DON and ZEN.

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Antimicrobial resistance in poultry feed: Implications for public health and poultry production

By Thabo Nkabinde, director, Agri Space

Antimicrobial resistance (AMR) in pathogens such as *Salmonella enterica* within the poultry industry is a significant public health challenge worldwide. The overuse of antibiotics in poultry feed during the production stage has driven the evolution of resistant bacterial strains, which threaten both animal health and human safety throughout the food chain.

In South Africa, where poultry is a dietary staple and a critical agricultural sector as we import most poultry meat, the impact of AMR pathogens has become an urgent concern. The routine use of antibiotics in poultry feed, particularly for growth promotion, promotes resistance to bacterial pathogens, leading to the emergence of multidrug-resistant (MDR) strains (World Health Organization [WHO], 2018).

This editorial examines the sources of AMR in poultry feed, mechanisms of resistance development, public health and economic impacts of AMR, and strategies for reducing its prevalence. With AMR persisting in poultry production, a co-operative effort among industry, government, and consumers is necessary to ensure food safety and sustainable practices.

The importation of poultry meat into South Africa has raised concerns over AMR due to the widespread use of antibiotics in poultry feed in exporting countries during production. Many of these countries use antibiotics in poultry feed not only to treat infections but also as growth promoters, which contributes to the emergence of MDR bacteria. As antibiotic-treated poultry meat enters South Africa, it brings with it resistant strains, such as *Salmonella enterica* and *Escherichia coli* (*E. coli*), that can persist through the food chain, heightening AMR risks for South African consumers.

The importation of foreign MDR strains complicates local AMR management efforts, increasing the risk of AMR transmission within communities and challenging public health initiatives focussed on domestic control of AMR in poultry products (Ramatla *et al*., 2022; Eguale *et al*., 2017).

Sources of AMR in poultry feed

Contamination in poultry feed from AMR pathogens arises from multiple sources, including infected raw ingredients, environmental exposure, and inadequate biosecurity in feed processing and storage. *Salmonella* serotypes, such as *S. typhimurium* and *S. enteritidis*, are resistant to multiple antibiotics and have been found in poultry feed. These serotypes are especially concerning as they can persist in the broader environment, including animal waste, soil, and water, which may introduce further contamination risks (Algammal *et al*., 2023).

Feed contamination often originates from the use of animal by-products or low-quality ingredients. Poor storage conditions can further exacerbate contamination by creating an environment that promotes bacterial growth. Cross-contamination during feed processing due to insufficient hygiene contributes to the transmission of AMR bacteria. Consequently, MDR *Salmonella* strains reach the food chain and, eventually, the consumers who are the end users (Ramatla *et al*., 2022).

Imported meat is often produced using antibiotics, and feed ingredients are sometimes subject to limited quality control, especially in regions with less stringent regulations. Such contaminants in feed can introduce resistant bacteria into local poultry production, complicating AMR management and contributing to the spread of multidrug-resistant (MDR) pathogens across borders (Eguale *et al*., 2017).

Mechanisms of resistance

The development of resistance in *Salmonella* strains is primarily driven by selective pressure from the continuous use of low-dose antibiotics in poultry feed and treatment to alleviate diseases. This practice promotes the survival and growth of resistant strains while inhibiting non-resistant bacteria (Mazel, 2006).

Mechanisms of AMR development include genetic adaptations via plasmid transfer, integrons, and transposons, which facilitate resistance gene spread among bacterial populations. Integrons, for example, capture and transfer genes encoding resistance to multiple antibiotics, accelerating the spread of MDR bacteria within poultry systems. These gene transfer systems enable bacteria to adapt and persist despite control efforts (Algammal *et al*., 2023).

Over time, these mechanisms have allowed highly resistant *Salmonella* strains to evade typical treatment protocols, presenting a risk to both poultry health and the efficacy of antimicrobials critical to human health.

Public health impact

The public health implications of AMR in poultry feed during production are extensive, as resistant *Salmonella* strains can transfer to humans through various routes, including direct consumption, environmental exposure, or cross-contamination during food preparation. Resistant infections are challenging to treat and require alternative antibiotics with greater side effects or reduced efficacy.

In South Africa, where poultry is a primary protein source, particularly in South Africa since it is the cheapest source of protein, AMR *Salmonella* infections add to healthcare burdens, including increased hospitalisation, longer recovery, and a higher risk of complications in vulnerable populations (WHO, 2018).

Resistant infections in humans typically require broad-spectrum antibiotics, which can disrupt gut microbiomes, causing additional health complications. When AMR pathogens are established within a community since the AMR will also occur in humans, their spread becomes harder to control, and the economic and healthcare costs escalate (Eguale *et al*., 2017).

Economic impact

AMR in *Salmonella* and other pathogens presents considerable costs for South African poultry producers, affecting productivity, compliance, and market access. With the rise in demand for antibiotic-free poultry, producers must adopt stringent practices to eliminate or reduce antibiotics in feed, involving increased investment in biosecurity, alternative feed formulations, and monitoring, all of which increase operational costs (World Organisation for Animal Health [WOAH], 2022).

AMR restricts international trade, where antibiotic-free and pathogen-free certification is increasingly necessary. This restricts the competitiveness of poultry producers who use traditional methods reliant on antibiotics. Producers, therefore, must invest in alternatives such as probiotics, prebiotics, and organic acids to maintain productivity while meeting export standards, adding additional costs (Algammal *et al*., 2023).

The economic impact extends to costs related to outbreaks linked to AMR of *Salmonella*. If contamination is detected, producers may face costly product recalls and damage brand reputation. Outbreak management within poultry operations also incurs resource-intensive efforts, including decontamination and adjusting management practices, which add to operational costs.

The prevalence of antimicrobial resistance in poultry production is not limited to South Africa – it is a significant issue across multiple African nations, particularly Nigeria and Egypt. These countries face similar challenges in managing AMR, with studies showing that poultry industries in Nigeria and Egypt use antimicrobials extensively to promote growth and control disease in poultry flocks (Okon *et al*., 2022).

The use of antibiotics as a growth promoter in these nations has led to the emergence of MDR pathogens such as *Salmonella* and *E. coli*, which complicate AMR management due to the cross-border nature of poultry trade and the shared environmental impacts. As poultry meat and feed are traded across regions, AMR patterns in one country can easily influence others, increasing the necessity for co-ordinated policies and monitoring systems to manage AMR on a regional scale (Okon *et al*., 2022).

Strategies for mitigating AMR

Reducing AMR in poultry feed requires a comprehensive approach that includes antimicrobial stewardship, alternative feed strategies, and improved biosecurity.

Key strategies include:

- **Restriction of antibiotic use in animal feed:** The most effective approach is limiting antibiotics in feed to therapeutic uses, eliminating their role in growth promotion. Regulatory bodies such as the WHO recommend limiting agricultural antibiotic use to curb AMR. South African regulatory policies on antimicrobial use can reduce bacterial resistance, slowing the development and spread of AMR (WHO, 2018).
- **Alternative feed additives:** Probiotics, prebiotics, and organic acids are increasingly used as alternatives to antibiotics in poultry feed during the production stage. These additives improve gut health, supporting natural immunity in poultry and reducing infection incidence. Probiotics, for example, help establish a healthy gut microbiome that inhibits pathogen colonisation, while organic acids create an acidic environment unfavourable to *Salmonella*. These alternatives reduce dependency on antibiotics, contributing to lower AMR rates (WOAH, 2022).
- **Enhanced biosecurity practices:** Implementing biosecurity measures, such as sanitation protocols and secure feed storage, reduces contamination risk. Biosecurity practices include monitoring to detect contamination early and prevent AMR pathogen spread within production facilities. Effective biosecurity also requires frequent inspections, staff training, and environmental monitoring (Ramatla *et al*., 2022).
- **Vaccination of poultry:** Vaccination reduces *Salmonella* loads in poultry by targeting specific pathogens such as *S. typhimurium* and *S. enteritidis*. Combined with restricted antibiotic use, vaccination offers a sustainable approach to disease prevention that minimises AMR development risk (WOAH, 2022).

Regulatory framework

Global regulatory bodies are enforcing policies promoting responsible antimicrobial use in poultry production. In South Africa, the Animal Feed Manufacturers Association (AFMA) has established guidelines encouraging producers to adopt antimicrobial stewardship. These guidelines align with national and international initiatives, such as those by WHO and the WOAH, to mitigate AMR in agriculture (WHO, 2018).

AFMA's guidelines emphasises high feed hygiene standards, improved feed formulation, and reduced antibiotic use. These standards help South African producers adopt best practices that contribute to global AMR prevention efforts. International frameworks by WHO and WOAH support these efforts by providing surveillance, monitoring, and enforcement structures to manage AMR across poultry operations (WOAH, 2022).

Conclusion

The challenge of AMR in *Salmonella* within poultry production requires collaborative action. In South Africa, where poultry is an accessible protein source, AMR in poultry feed affects public health, economic stability, and agricultural sustainability. By limiting antibiotic use, implementing alternative feed additives, enhancing biosecurity, and enforcing vaccination, producers can reduce AMR risks, ensuring safe, sustainable poultry production.

Regulatory frameworks and industry initiatives, such as those of AFMA, will be essential in addressing AMR on national and local levels. Through science-based approaches, South Africa's poultry industry can join the global effort to combat AMR, ensuring safe food and resilient agricultural practices for the future.

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Inorganic phosphorus sources and their availability in poultry

By Dewald Steyl, Feed First

Phosphorus (P) is an essential nutrient in poultry diets and is critical for bone development, nutrient metabolism, and protein synthesis (Li *et al*., 2016). After calcium, P is the second most plentiful mineral in the body and although most are found in the skeleton, P is present in all cells of the body. Poultry diets are typically formulated to meet the P requirements of the bird by using mainly two different sources; plant-based ingredients (cereal grains and oilseed meals) and inorganic sources of P (Vier *et al*., 2019).

Historically, most of the P in plant-based ingredients was considered unavailable as it is bound to phytate (Van der Klis and Versteegh, 1999), which led to the oversupply of inorganic P sources to ensure adequate supply of available P (Viljoen, 2001). Today, poultry is fed closer to their actual requirements, while the utilisation of previously unavailable P in plant-based ingredients is enhanced by using exogenous enzymes such as phytase.

Although phytase has enabled the reduction in the amount of inorganic P added to poultry diets, the total replacement of inorganic sources, especially in younger broilers, is not well documented (Bello *et al*., 2022).

Phosphate availability

Inorganic P sources include dicalcium phosphate (DCP), monocalcium phosphate (MCP) or a mixture of the two called mono-dicalcium phosphate (MDCP). The availability of P from different sources is important as it enables the producer to compare the potential value of one phosphate against another, allowing one to screen sources of high availability for inclusion in poultry diets (Payne, 2005).

Research indicates a difference in the availability of P between different feed phosphate sources (Van der Klis and Versteegh, 1999) and even between the same generic classes of phosphate sources (Waibel *et al*., 1984). MDCP is an example of a source classified within the same generic class but with potentially different available P values.

The higher the MCP:DCP ratio in MDCP, the higher the available P content. An indication of the ratio between MCP and DCP can be obtained from the water solubility of the product. Assuming that pure MCP is 100% water soluble and DCP is water insoluble, a 50:50 mixture would be approximately 50% water soluble. P water solubility is positively correlated to the MCP molecule content in inorganic P sources and thus the digestibility of feed phosphates (NRC, 2011). The higher the water solubility, the higher the digestibility and availability of the P to the animal. Citric acid soluble P analyses point to the chemical nature of the product and indicate the presence of tricalcium phosphate within the MDCP.

P that is more than 90% soluble in water-soluble P and citric acid-soluble P tests is highly nutritional (Guéguen, 1970). Undesirable elements present in inorganic phosphates such as heavy metals (fluorine, arsenic, cadmium, lead and mercury) can potentially accumulate in animal products and the environment, and these levels must be always adhered to (Viljoen, 2001). *Table 1* indicates the maximum levels allowed for undesirable elements as determined by the European Union (EU).

It is evident that the total P value of inorganic phosphate sources is not enough to consider when formulating poultry diets, and can be misleading if not interpreted with the percentage of solubility. For example, DCP anhydrate has a P content of 20% while the dihydrate form has a P content of 18%. When we take the digestibility coefficient (55% versus 78%) into account (*Table 2*), the dihydrate form will deliver more P to the animal. Dissolution by gastric acid progresses more slowly for anhydrous than hydrous DCP. There is a 25 to 30% greater incorporation of P into the bone for hydrous compared to anhydrous DCP. This is however only applicable when formulating on a digestible P value for all feed sources (Viljoen, 2001).

Table 1: Maximum levels of undesirable elements in inorganic phosphorus sources according to EU standards.

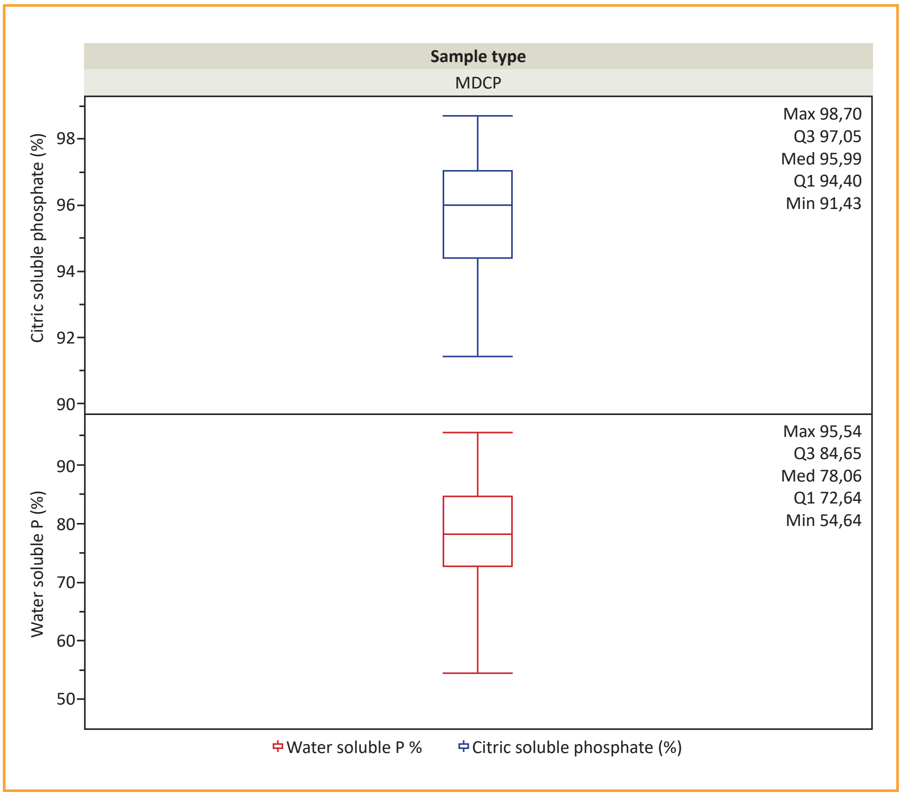
Undesirable elements	EU standards
Fluorine (F)	Max 0,2%
Arsenic (As)	Max 10 ppm
Cadmium (Cd)	Max 10 ppm
Lead (Pb)	Max 30 ppm
Mercury (Hg)	Max 0,1 ppm

Table 2: Digestibility coefficients of P in poultry. (Source: CVB, 2018)

Product	Total P content (%)	Digestible coefficient (%)[1]	Digestible P (%)
MCP	22,6	85	19,21
MDCP	21	79	16,59
DCP dihydrate	18,2	78	14,20
DCP anhydrate	20	55	11

[1]*Digestible phosphorus coefficient for poultry.*

Figure 1: The water-soluble and citric acid-soluble phosphorus of mono-dicalcium phosphate samples (n = 301) analysed by Feed First from 2018 to 2024.



In conclusion, the P water solubility percentage and citric acid solubility percentage indicate the quality and P availability of the inorganic P source used, and should form part of the standard wet chemistry schedule in the feed mill. *Figure 1* demonstrates the variation in the P water solubility of MDCP analysed by Feed First over the past six years.

Although the total P values meet the required specification, they might not reflect the amount available for utilisation by the bird. In addition, the P water solubility percentage will also enable the feed formulator to assess the economic value of the inorganic phosphate sources between different suppliers, without relying on the total P value alone. Further research is necessary to develop new *in vitro* tests and regression equations so we can accurately predict the *in vivo* digestibility of P using these *in vitro* test results.

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

Profitability through amino acid balancing for dairy cows

By Ranier van Heerden, ruminant business manager, Evonik Africa (Pty) Ltd

Dairy producers face constant pressure to be more efficient due to irregular climatic and economic conditions and increased public awareness of environmental impacts and animal welfare issues. The focus is on dairy cows' protein and amino acid nutrition due to the negative effects of excessive nitrogen excretion on the environment, the cost of protein supplements, and the increasing public demand for milk protein.

These pressures could partly be alleviated by increasing the efficiency of dairy cows utilising protein and amino acids, ultimately meeting their amino acid absorption requirements, satisfying public demand for milk protein, and reducing nitrogen excretion into the environment.

Protein fractions

Dietary crude protein (CP) in dairy diets refers to the feed's total nitrogen (N) content multiplied by a factor of 6,25 based on the assumption that all protein contains 16% N. Therefore, CP represents a collective term for N-containing compounds (e.g., non-protein N [NPN such as urea, ammonium sulphate], soluble protein, rumen degradable protein [RDP] and rumen undegradable protein [RUP, bypass protein]). Each protein fraction can be further divided into various sub-classes based on different digestion kinetics, including the rate of degradation in the rumen and the rate of passage out of the rumen.

Rumen degradable protein is broken down in the rumen into by-products (e.g., peptides, amino acids [AA] and ammonia) and utilised by microbes as essential nutrients. Rumen microbes also require fermentable metabolisable energy to ferment plant-based fibre into volatile fatty acids (e.g., acetic, propionic, and butyric acid), which supply 60 to 75% of the cow's daily metabolisable energy requirements.

The RUP fraction not degraded in the rumen, combined with microbes flowing out of the rumen and endogenous proteins, represents metabolisable protein (MP). Microbial protein represents 50 to 80% of the total MP flowing to the cow's small intestine.

After reaching the cow's small intestine, MP is enzymatically broken down into various AAs (essential [EEA] and non-essential), which can potentially be absorbed by the cow and used for maintenance, growth, gestation and lactation. Each AA is absorbed and utilised for various functions (e.g., milk protein yield) with different efficiencies and is also influenced by various other factors (e.g., cow status, level of performance, diet composition). Dairy cows do not have a CP requirement per se but rather a requirement for MP, specifically the EEA content thereof.

Oversupplying dietary protein

Ruminants tend to have lower N use efficiency compared to other species, with only 25 to 35% of dietary N consumed by dairy cows being converted into milk protein. The remainder is excreted as urinary-N and faecal-N, with the majority of N being excreted through urine. An estimated 60 to 80% of urinary N is excreted in the form of urea. Faecal N is converted to ammonia by bacterial degradation, where bacteria secrete an enzyme called urease, which converts the urea in urine to ammonia.

This leads to ammonia volatilisation and is influenced by atmospheric temperature, airspeed, manure or urine pH, floor space and manure moisture content. This threatens air quality and contributes to surface water eutrophication, nitrate contamination, as well as the acidification of soil and water. In its gaseous form, ammonia can chemically bond with nitric and sulfuric acids to form ammonium nitrate and ammonium sulphate, which are sometimes associated with respiratory problems in humans.

Excess N in the diet influences the environment and the cow because there is a high metabolic energy cost associated with the excretion of N as urea in urine. This could lead to lower production outputs because less energy is available for production.

Excess ammonia in the rumen is absorbed and transported to the liver, where it is converted to urea. Urea diffuses freely through cell membranes, raising high blood urea N (BUN) values and consequently milk urea N (MUN) levels. High BUN levels can negatively impact cow reproduction and performance. The oversupply of dietary N in dairy cow diets is not limited to environmental pollution and reduced cow performance, health and reproduction but also results in major economic losses due to the high cost of protein and energy supplements that do not improve cow performance.

Suggestions and recommendations

- *Constantly monitor the barn, parlour and feed mixing area*: Early indicators of sub-optimal protein supply include declines in milk production and quality below expected levels, low peak milk production in early lactation cows, poor persistence in later lactation cows, and MUN levels outside the usual range of 8 to 14mg/dl.
- *Regularly evaluate cow manure colour, texture and consistency*: Excessive intake of RDP can cause loose manure, while darker and dryer manure indicates heat-damaged silages and roughages.
- *Establish the optimal EAA concentration in MP*: Formulate diets based on the stage of lactation, level of production, cow pregnancy status, and production system. Lower-producing cows, such as those in later lactation, have lower protein and AA needs than high-producing cows and cows in early lactation.
- *Optimise rumen function and microbial protein yield*: Since microbial protein has a superior AA profile (Sok *et al*., 2017), particularly for lysine (Lys) and methionine (Met), formulate diets to maximise MCP yield. Monitor histidine levels, as microbial protein tends to be low in diets dominated by grasses and legumes.
- *Supply high-quality dietary protein sources*: These sources are generally high in either Lys or Met. Utilise a variety of feedstuffs to ensure accurate nutrient levels in the diet. As cow performance increases, the proportion of EAA requirements met by microbial protein alone decreases.
- *Use supplemental rumen-protected amino acids*: To meet the cow's EAA requirements (i.e., Met) and theoretical optimal Lys:Met ratio in MP, rumen-protected AA can be used successfully. However, when using rumen-protected AA be sure of the product's rumen-bypass rate, bioavailability and metabolisable amino acid supply to be able to accurately do an economic evaluation.

Supplementing methionine

Methionine plays several critical roles in metabolism, which can improve cow performance, aid in transitioning through the onset of lactation, improve reproduction, and improve calf performance due to carry-over effects.

Since Met is often the most limiting AA for dairy cows, the effects of rumen-protected Met (RPM) supplementation (e.g., ethyl-cellulose protected) are significant:

- Significant improvement in cow performance (milk volume, persistency, and solids) and improved NUE while feeding modern diets, low dietary CP diets and during heat stress (Patton, 2010; Guyader *et al*., 2023; De Oliveira *et al*., 2024).
- Pre-and post-partum supplementation of RPM increases pre-partum DMI, lactation performance (yield, protein concentration, and energy-corrected milk), reduces negative energy balance and negative protein balance 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, which engage in lipid metabolism (Chandler and White, 2017).
- Improved liver function, inflammation status and oxidation stress by lowering blood fatty acid and β-hydroxybutyrate levels and increasing neutrophil and monocyte function (Batistel *et al*., 2017 and Han *et al*., 2018).
- Blood, milk, and liver biomarkers indicate 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 enhances the activity of skeletal muscle genes related to the transportation of various nutrients, biological processes that generate energy, tissue protein replenishment, and co-ordination 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, and changes in DNA methylation (Bonilla *et al*., 2010), and lowers pregnancy losses (Toledo *et al*., 2017).
- The addition of RPM to the dairy diet increases the rate of utilisation of some AA and improves the protein efficiency of others (Vailati-Riboni *et al*., 2019)
- It improves calf performance via foetal programming as a methyl donor (epigenetics and DNA methylation) and mTOR regulator (cell growth and activity and greater nutrient transport from the maternal to foetal circulation through nutrient transporters) (Krog *et al*., 2018 and Ma *et al*., 2019).
- Cows supplemented with RPM during gestation and the transition period have calves that are heavier at birth, grow better (average daily gain), and have 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 in terms of cow performance, reproduction, and health status during the transition. This is in addition to subsequent lactations and improved calf health and performance, thus improving the whole production system's efficiency, sustainability, and profitability.

References available on request. Email raniervanheerden@gmail.com for more information or visit *www.mea.evonik.com*.

Phytogenic feed additives as natural antibiotic alternatives in animal health and production: A review of the literature of the last decade

By Jing Wang, Lufang Deng, Meixia Chen, Yuyan Che, Lu Li, Longlong Zhu, Guoshun Chen, and Tao Feng

Antibiotics have long been used as growth promoters to increase productivity in animal production (Hashemi and Davoodi, 2011). Long-term antibiotic use can result in the accumulation of antibiotic residues in meat and meat products, which may lead to antibiotic resistance in humans. In 2006, the European Union (Reg no 1831/2003/EC) banned the use of antibiotics as growth promoters in animals. Other countries have since developed policies to reduce or ban antibiotic use in animal production.

Antibiotic-free animal products have improved market opportunities and have grown exponentially in recent years (Gadde *et al*., 2017). To achieve safe livestock and poultry production, new, natural, and safe feed additives are needed.

Various antibiotic alternatives, including enzymes, probiotics, prebiotics, inorganic acids, medicinal plants, immunostimulants, and management practices, have been used to enhance animal health and performance. Phytogenics are heterogeneous compounds with different biological activities considered to have some similar benefits as antibiotic growth promoters (Rossi *et al*., 2020; Kuralkar and Kuralkar, 2021).

Numerous herbal products have been demonstrated to have beneficial effects and medicinal properties, including antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory activities, without adversely affecting growth and feed efficiency, and are therefore used as growth-promoting feed additives in livestock production (Kumar *et al*., 2014; Lillehoj *et al*., 2018; Kuralkar and Kuralkar, 2021).

There is an increasing preference for natural products because they are considered to have less undesirable side effects than synthetic products (Laudato and Capasso, 2013). The development of plant-based feed additives has become a research hotspot and is significant for the healthy development of animal husbandry and the improvement of animal product quality.

Phytogenic feed additives are pharmacological plant components that have various benefits for animals and animal production, including improved growth performance, health, reproduction, and product quality, and reduced emissions and toxicity. Herbal products are accessible, easy to prepare, and affordable. Moreover, they generate less residues, are less toxic, and have less side effects in animal product production, and are generally safe for humans.

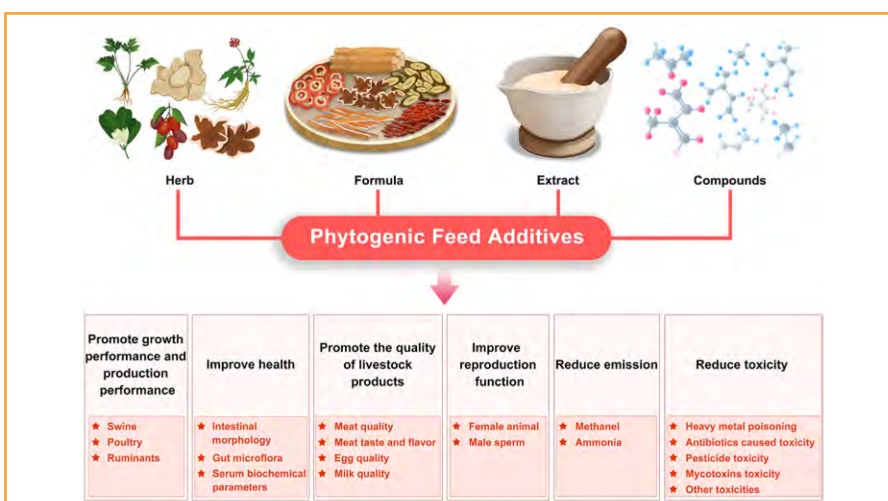
However, plants contain numerous pharmacologically active ingredients in various amounts that can vary from batch to batch; therefore, the effectiveness and mechanisms of phytogenic feed additives have not been fully elucidated. Known mechanisms of action include antimicrobial, immunomodulatory, antioxidant, and intestinal microbiota-regulatory activities. The integration of metagenomics, transcriptomics, proteomics, and network pharmacology tools may help elucidate the characteristics and mechanisms of phytogenic feed additives and develop feasible and cost-effective methods to use plant-derived additives as effective antibiotic alternatives in animal production.

In this review, we aimed to provide a comprehensive overview of the current state of research on the effects of phytogenic feed additives in improving the health status and growth performance of livestock animals and an overall view of the usability of phytogenic feed additives as potential antibiotic alternatives and as a nutritional strategy in animals.

Phytogenic feed additive function

The main aim of the livestock industry is to improve zootechnical performance. The use of phytogenic feed additives or herbal plants for livestock nutrition can improve animal health and performance (Rossi *et al*., 2020). Phytogenics can promote animal growth, production, and reproduction performance, and improve livestock product quality (*Figure 1*). In addition, they have other beneficial effects,

Figure 1: Overview of phytogenic feed additives, including main classifications and functions.



including the reduction of methane and ammonia emissions and of the toxicity of heavy metals, antibiotics, and mycotoxins (*Figure 1*). Accordingly, phytogenic feed additives have gained substantial attention in livestock production in recent years.

Promotion of growth performance and production performance

Antibiotics have long been used as growth promoters to enhance productivity in animal production (Hashemi and Davoodi, 2011). Because of antimicrobial resistance development, the use of antibiotics as growth promoters has been gradually banned and therefore, alternative growth promoters have received increasing attention. Numerous herbal products having multiple biological functions are used as growth promoters to improve production efficiency in the animal industry (Gong *et al*., 2014; Rossi *et al*., 2020). Currently, phytogenic feed additives are widely used in feeding programs for swine, poultry, and ruminants.

In swine, the effect of phytogenic feed additives has been widely demonstrated. Yan *et al*. (2011a) investigated a mixture of herbal extracts of buckwheat, thyme, curcuma, black pepper, and ginger as a feed additive in growing pigs and suggested it as an antibiotic alternative because it increased feed intake and growth performance.

A herbal feed additive consisting of benzoic acid and essential oils of thymol, eugenol, and piperine promoted piglet growth performance by improving average daily gain, average daily feed intake, apparent total tract digestibility of nutrients, and energy (Silva Júnior *et al*., 2020). A blend of *Cinnamomum zeylanicum* and *Trachyspermum copticum* essential oils and the blend plus plant extracts of *Mikania micrantha* and *Garcinia lanceifolia* did not affect growth performance when compared with no-additive and antibiotic controls; however, it did improve some lipid profiles, immune responses, and intestinal microbial populations in piglets (Samanta *et al*., 2021).

Dietary supplementation of commercial phytogenics in sows during gestation/lactation improved litter size and live births as well as the composition and bioactivity of colostrum and milk, which may benefit offspring health and performance (Reyes-Camacho *et al*., 2020; Nowland *et al*., 2021).

The effects of plant extract feed additives on poultry growth performance have been extensively studied, with relatively consistent results. Numerous plant extract additives have been demonstrated to improve growth performance, nutrient digestibility, feed efficiency, and intestinal health in poultry (Abdelli *et al*., 2021; Seidavi *et al*., 2022).

Dietary supplementation of Digestarom Poultry, which comprises more than 30 essential oils and phytogenic compounds, significantly increased bodyweight gain, while lowering the feed-to-gain ratio in broiler chicks (Murugesan *et al*., 2015). Along with positive effects on total-tract digestibility, intestinal function, and beneficial microbial colonisation, this product has demonstrated efficacy as a substitute for antibiotic growth promoter in poultry.

Plant extracts have also yielded positive results in other poultry species. Cinnamon (*Cinnamomum verum*), garlic (*Allium sativum*), ginger (*Zingiber officinale*), oregano (*Origanum vulgare*), and other plant extracts significantly improved bodyweight gain and feed availability in turkey and quail (Al-Shuwaili *et al*., 2015; Mehdipour and Afsharmanesh, 2018; Gernat *et al*., 2021). Positive effects were also observed in laying hens. The inclusion of peppermint (*Mentha piperita* L.) leaves in a Hy-Line brown laying hen diet significantly increased egg weight, egg production, and egg mass in a dose-dependent manner (Abdel-Wareth and Lohakare, 2014).

Health improvement

Herbs and herbal medicines are potential sources of nutrients and therapeutics and can have significant health benefits in humans and animals (Kuralkar and Kuralkar, 2021). Phytogenic feed additives have been demonstrated to strengthen animal health defence, mainly by improving the physiological status of the intestinal ecosystem and enhancing immune system functions.

Intestinal health is extremely important for overall animal health. Herbs and extracts can exert beneficial effects on the digestive tract, including stimulating digestive function, reducing pathogenic stress, and promoting the establishment of a beneficial intestinal microbiota. Intestinal crypts and villi are lined by epithelial cells that play important roles in digestive function. Herbal feed additives can increase the villus height-to-crypt depth ratio in the ileum, jejunum, and duodenum, indicating their beneficial effects in maintaining intestinal health and improving nutrient digestion and absorption (Lin *et al*., 2020).

The intestinal mucus layer governs nutrient absorption and protects the underlying epithelium against enteric pathogens. A phytogenic feed additive containing carvacrol, anethol, and limonene modulated broiler intestinal mucin composition and mucosal morphometry and increased duodenal mucus layer thickness (Tsirtsikos *et al*., 2012). Dietary cinnamon stimulated the gene expression of mucin 2, an important mucus layer component (Ali *et al*., 2021).

Intestinal microbiota abundance and composition are regulated by nutrients. Phytogenic feed additives can exert health and growth-promoting effects by maintaining intestinal microbiota equilibrium. Dietary supplementation of an essential oil from Brazilian red pepper increased intestinal *Lactobacillus* counts and lowered the incidence of diarrhoea in weaning pigs (Cairo *et al*., 2018). Diets containing essential oils of eugenol, thymol, and piperine combined with benzoic acid (Silva Júnior *et al*., 2020) reduced the numbers of pathogenic bacteria *Campylobacter* and *Escherichia-Shigella* in the intestines of weaned piglets, indicating their potential to improve intestinal health in piglets soon after weaning.

Phytogenic feed additives exert positive effects on several serum biochemical parameters, which are animal health indicators. Chinese herbal feed additives positively influenced serum biochemical parameters of protein synthesis and metabolism, liver synthetic function, and pancreatic and renal health in swine, indicating their potential in sustaining a healthy host environment, which contributes to better growth performance (Lin *et al*., 2020).

Additionally, phytogenic feed additives can improve immune function as reflected by certain serum biochemical parameters. Inclusion of 0,1% of a mixture of herbal extracts (YGF251) in a broiler diet increased the serum immunoglobulin (Ig) G content (Begum *et al*., 2014). Ashwagandha (*Withania somnifera*) administration in broiler chickens improved haemoglobin, packed cell volume, total leukocyte count, and antibody titers against viral diseases, such as infectious bursal disease and bronchitis, suggesting an improved haematological profile and immunological status (Mushtaq *et al*., 2012; Pant *et al*., 2012).

In growing pigs, eugenol and cinnamaldehyde exhibited lymphocyte-enhancing activity, although growth performance was not improved (Yan and Kim, 2012). Essential oil products containing thymol and cinnamaldehyde reduced inflammatory mediator and interleukin (IL)-6 levels and increased the lymphocyte proliferation rate, phagocytic rate, and IgA and IgM levels in the plasma of weaning pigs (Li *et al*., 2012a, b).

Modes of action

Exploring the potential action mechanisms of phytogenic products is complicated by their complex composition. Different active components have different functional properties and may act on different targets and play different roles via multiple pathways. Phytogenic additives can exert beneficial effects by directly suppressing the proliferation of pathogens, regulating intestinal microbial composition, enhancing immune functions, and alleviating oxidative stress, thus improving phenotypic traits, such as growth and production performance, and physical health (*Figure 2*).

Some molecular mechanisms of phytogenic additives, such as epigenetic regulation, transient receptor potential channel activation, and quorum sensing disruption, have been gradually revealed by molecular biology and cell biology studies in recent years (*Figure 2*). However, the mechanisms of numerous plant-derived additives in livestock animals are still being explored.

Antimicrobial activities

Herbs and plant extracts exhibit broad-spectrum antibacterial activities against both gram-negative and gram-positive bacteria (Mahfuz *et al*., 2021; O'Bryan *et al*., 2015). *In vitro*, condensed and hydrolysable tannin-rich extracts showed strong antimicrobial activity against *Campylobacter jejuni* (Anderson *et al*., 2012), and ethanolic cinnamon extract against *Salmonella aureus* (Bonilla and Sobral, 2017). *Brachyspira intermedia*, a poultry pathogen, and *Brachyspira hyodysenteriae*, a swine pathogen, were highly sensitive to cinnamaldehyde *in vitro* (Verlinden *et al*., 2013; Vande Maele *et al*., 2016). Numerous studies have reported on the *in vivo* antimicrobial effects of phytogenic additives in animal feeds, particularly the inhibition of intestinal pathogens, and their health-promoting effects.

Salmonella infection is an ongoing issue in poultry farming and causes extensive economic losses. Cinnamaldehyde feed supplementation effectively reduced *Salmonella* colonisation, spread, and egg contamination in layer chickens and broiler chickens (Upadhyaya *et al*., 2013, 2015). *In vivo* studies in broilers have demonstrated the antimicrobial efficacy of quercetin in inhibiting the growth of bacteria such as *Salmonella enterica* serotype Typhimurium, *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* in the intestine (Iqbal *et al*., 2020).

E. coli and *Salmonella typhimurium* are frequently isolated in pig farms and cause intestinal diseases in piglets. Dietary resveratrol significantly reduced faecal *Salmonella* and *E. coli* counts and reversed the adverse effects of weaning stress in piglets challenged with these two pathogens (Ahmed *et al*., 2013). As enteric diseases caused by intestinal pathogen infection adversely affect animal growth and production performance, phytogenic feed additives may serve as antibiotic alternatives to reduce the use of antimicrobials in animal production.

Antioxidant activity

In many herbs and spices used in animal nutrition, antioxidation is the most important biological activity. Oxidative stress causes numerous health problems and diseases in animals. Antioxidants help relieve oxidative stress by reducing free-radical intermediates and are therefore effective agents to prevent diseases. Certain herbal additives have been suggested to be useful as antioxidants in animal feeds to protect animals from oxidative stress at specific physiological stages or in certain environments.

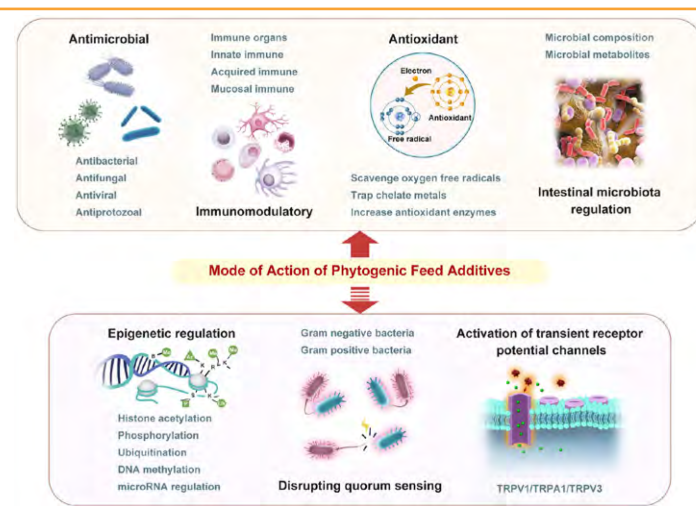
In animal nutrition, antioxidants are appreciated to act mainly as health stabilisers. The administration of carvacrol or thymol enhanced the antioxidant capacity in broilers as observed by increased antioxidant enzyme activity and reduced lipid oxidation and MDA levels, improving production performance (average daily gain and feed efficiency) (Hashemipour *et al*., 2013; Hoffman- Pennesi and Wu, 2010).

Thyme essential oil improved intestinal function and epithelial integrity in broilers by decreasing the MDA content in the duodenal mucosa via its antioxidant activity (Placha *et al*., 2014). The antioxidant capacities of quercetin (Sohaib *et al*., 2015), resveratrol (Sridhar *et al*., 2015), allicin (Wang *et al*., 2014), and curcumin (Wang and Zhang, 2014) and their associated benefits for body health and production in broilers have also been reported.

Intestinal microbiota regulation

Intestinal microbes modulate host physiological activities and therefore, any change in the intestinal microbiota affects animal physiology. Many plant ingredients are not absorbed directly by the host, but are first transformed by the intestinal microbiota.

Figure 2: Potential modes of action of phytogenic feed additives.



Increasing evidence indicates that plant-derived additives have a regulatory effect on the intestinal microbiota composition, which may contribute to the conversion of plant ingredients into active metabolites (Lin *et al*., 2021).

On the one hand, phytogenic additives can directly affect microbial abundance and diversity, and on the other hand, they can be converted by the intestinal microbiota into bioavailable, bioactive, or even toxic metabolites that have various biological roles. Both the regulated microbiota and transformed metabolites may contribute to health maintenance and disease suppression.

Potential negative effects

The effects of phytogenic feed additives on livestock animal health and production range from neutral to beneficial for many different reasons. The composition and concentration of bioactive substances are the most important factors influencing the effects of plant-derived additives. For a single plant species, the plant parts used (e.g., root, bark, stem, leaf, flower, pollen, fruit, seeds), geographical location (altitude, soil), harvesting weather (sunlight, rainfall), and environmental factors (temperature, humidity) can lead to obvious differences in the derived products.

Different origins and different sources may also affect the phytochemical profile of a phytogenic product and thus, its effect on livestock animals, even when using the same amount of plant material. Plant extraction methods, including steam distillation, maceration, cold pressing, and solvent extraction, also influence the composition and ingredient concentrations of a plant product. Further, batch-to-batch variability also influences the active component composition of phytogenic products (Pan *et al*., 2020).

As the potential benefits of plant-derived feed additives can differ because of the large variability in product composition, it is difficult to compare their efficacy. Therefore, the truly active ingredient and its concentration in plants and plant-derived products have to be considered when using phytogenic products as antibiotic alternatives in animal production. Moreover, some herbal products are rapidly degraded in the stomach, which also affects their effectiveness. Appropriate release techniques, such as encapsulation or other coating technologies, should be considered when using these compounds as feed additives (El Asbahani *et al*., 2015; Sherry *et al*., 2013).

Furthermore, the efficacy of phytogenic feed additives depends on the diet, growth stage, microbiota, and health status of an animal. Animal management and rearing conditions (age, genetics, challenges, environmental conditions) may also contribute to the inconsistency of results obtained with phytogenic feed additives (Abdelli *et al*., 2021; Yang *et al*., 2015a). To ensure the effectiveness of phytogenic feed additives in animals, several factors and conditions need to be considered to determine which product to use and how to use it.

Most phytogenic feed additives studies have shown positive effects in livestock animals. Nevertheless, several negative effects have been reported. Some herbs have drug-like actions that can interact with other dietary components. Some herbs contain prohibited substances such as salicylates, heroin, caffeine, and steroids (Williams and Lamprecht, 2008).

These may have side effects or toxicities, ranging from mild to severe. High doses of phytogenic feed additives generally cause more negative effects. To their positive effects, tannins may have antinutritional effects; high tannin levels in livestock animal feeds negatively affect appetite and protein digestibility because of their binding effect (Gilani *et al*., 2012; Faehnrich *et al*., 2016).

In the context of sperm preservation, high concentrations of oregano, splinter bean (*Entada abyssinica*), rosemary, and pomegranate exerted negative effects on some sperm parameters or were even detrimental to sperm function (Ros-Santaella and Pintus, 2021). Therefore, attention has to be paid to the safety of phytogenic products and the conditions in which they exert biological effects when considering them as feed additives in livestock animals.

Conclusions and final remarks

As natural products, phytogenic products have several advantages over antibiotic agents, including cost-effectiveness and a lower likelihood of resistance development. Therefore, they are perceived as ideal substitutes for antibiotics, and research interest in and the application of phytogenic products are increasing.

Phytogenic feed additives have well demonstrated beneficial effects on growth, performance, health, production, reproduction, and emission reduction and toxicity reduction in both monogastric animals and ruminants. While, given the process influence and batch-to-batch variation, more research on effect comparison between purified monomers and extracted products and evaluation of batch-to-batch differences are recommended in the future. Moreover, considering quality control, safety concerns, and inconsistent results, more *in vitro* and *in vivo* studies are required to elucidate their quality, safety, and effectiveness.

Phytogenic feed additives belong to different chemical classes and generally are a mixture of bioactive compounds; therefore, various mechanisms of action or synergistic effects may underlie their beneficial effects. Several potential mechanisms of action, including antimicrobial, immunomodulatory, antioxidant, intestinal microbiota-regulatory activities, have been well established. The mechanisms of phytogenic products in epigenetic regulation, TRP channel activation, and quorum sensing are still in an early stage of investigation and therefore not yet fully understood. Future research will have to explore more widely available, inexpensive, and effective phytogenic feed additives and comprehensively elucidate their biological mechanisms.

Another aspect that needs to be highlighted here is the standardisation of the evaluation systems for phytogenic feed additives, which is difficult to achieve because of the wide variety in extracts and formulas. However, standardisation is essential for more efficient and conclusive evaluation of phytogenic feed additives for use in livestock animals. In summary, phytogenic feed additives have strong potential to replace antibiotics in animal feeds, but more studies are needed to expand the understanding and utilisation of phytogenic feed additives to promote animal health and production.

This article was shortened for publication in *AFMA Matrix*. Visit *www.doi.org/10.1016/j.aninu.2024.01.012* or email chengs@gsau.edu.cn or fengtao@baafs.net.cn.

NIRS and fermentation extract: Achieving precision nutrition

By Dr Dimcho Djouvinov and Gwyneth Jones, AB Vista

Realising the high genetic potential of modern dairy cows means their nutritional needs must match requirements as much as possible. Formulation software with integrated models of nutrient requirements is usually applied to achieve this in the most efficient manner. No matter what optimisation programme is used, the proper ration formulation should include a choice of different ingredients and feed additives.

In dairy cow nutrition, many feedstuffs are used in various regions and seasons depending on their availability, price, and milk price. The quality and nutrient characteristics of these feeds and ingredients can be extremely variable due to different factors such as climate and growing conditions, harvesting, conservation, and processing.

Hence, nutritionists should have good knowledge of ingredients available for the relevant dairy herd for which they do diet optimisation. The simplest approach is to refer to the book values published, but one should keep in mind that they may differ significantly from the actual nutrient contents.

Analysis made easy

Because of the inherent variability of ingredients, there is a need for routine analysis with wet chemistry often regarded as the gold standard in feedstuff analysis; however, this can be costly and time-consuming. As an alternative, instead of being measured directly, nutrients can be predicted by near-infrared reflectance spectroscopy (NIRS). NIRS analysis offers a rapid, non-destructive method of analysing feedstuffs.

NIRS calibrations are built by collecting wet chemistry data on many samples plus the spectra generated by scanning on an NIRS machine, followed by generated mathematical regressions. Based on spectra and relevant NIRS calibrations, the instrument can predict different contents of moisture, protein, etc. (anything organic and in concentration >0,01%). When calibrations are built over several years and include seasonal and geographical variations, the robustness of these calibrations can bring the error of results very close to that of wet chemistry. In addition, NIRS scanning allows the prediction of nutrient contents of many feed samples from silos or batches, resulting in more representative data.

Traditionally NIRS is seen as a large instrument placed on a bench in a laboratory, and while this is often still the case, in recent years the size of spectrometers has been miniaturised to the point where you can now carry one in your handbag allowing the device to be taken away from the laboratory to the field. In addition to being more portable, these hand-held NIRS (HHNIRS) devices are also very simple and straightforward to use.

Hand-held devices have a wavelength coverage and resolution which allows a similar calibration accuracy to that of a benchtop instrument and within the expected uncertainty of the reference method (for instance ±1 to 1,5% for soya bean meal crude protein by Dumas/Kjeldahl methods).

Incorporating analytical data of feeds into the ration formulation system allows more precise optimisation to meet the nutrient requirements of animals and to reduce safety margins, which in turn reduces diet costs.

Evaluating maize silage

In geographical regions with suitable climate conditions dairy producers rely on maize silage as the main forage in cow feeding, providing a significant proportion of energy and nutrients. This means that the nutritional value of maize silage should be correctly evaluated. In case of over- or underestimation, the higher the proportion of this feedstuff in daily dry matter intake (DMI), the bigger the gap is between the requirements of cows and the actual supply of energy and nutrients. Having reliable analysis of maize silage allows better prediction of cow performance and reduces the risk of feeding an imbalanced ration with consequent negative productive effects.

Maize silage as a final product fed to cows may vary significantly due to many factors affecting its quality: type of cultivars, climate and soil conditions, crop management, irrigation, and vegetation stage at harvesting.

Hybrids with thick woody stalks contain higher amounts of lignin which is indigestible and reduces the feeding value of maize plants. Genetic companies promote silage-type maize hybrids with specially selected characteristics of the plant: high total yield of DM with a high proportion of cobs, high digestibility of vegetative parts of plants and an appropriate Food and Agriculture Organization of the United Nations number (expression of a range of factors used to measure crop maturity – a higher number indicates a longer growing season) suited to the harvest date.

To showcase the variability in maize silage, composite samples of maize silages from each of 19 different silo clamps from dairy farms in countries from Central and Eastern Europe (CCE), including Bulgaria, Romania and Serbia, were scanned by HHNIRS and nutrient content predicted by NIRS calibration (*Table 1*).

Variable maize silage quality

The data obtained reflected quite variable qualities of maize silage produced at different farms and countries. The main variations were found in DM and starch content. The lowest values of these two parameters were reported for those silage clamps, produced from whole maize plants, grown as a second crop on irrigated land, but harvested at the early vegetation stage with undeveloped grain.

High DM and high neutral detergent fibre (NDF) content of maize silage may be

Table 1: Nutrient content of maize silages (n = 19) from CEE (harvested 2023) and CVB feed tables, 2021.

Parameters	Minimum	Maximum	Mean	SD	CV, %	Typical*
Metabolisable energy, MJ/kg DM**	11	13,4	11,01	0,70	5,6	11,05
Dry matter, %	15,3	38,6	29,1	5,64	19,4	32,4
Crude protein, %DM	8,8	9,7	9,1	0,32	3,5	6,9
Neutral detergent fibre, %DM	43,4	53,9	45,1	4,35	9,6	38,2
Acid detergent fibre, %DM	24,1	31,1	27	2,28	8,5	21,3
Starch, %DM	12,6	27,8	21,4	4,88	22,8	33,4
Ash, %DM	3,3	4,5	3,7	0,69	18,8	3,7
Fat, %DM	1	3,2	1,7	0,67	39,7	3,1

**Data for maize silage with 30-34% DM according to CVB, 2021. ** Calculations based on proximate values, NRC, 2021.*

Table 2: Proximate and metabolisable energy content of maize silages from CEE.

Parameters	CEE average	Specific farm
Dry matter (DM), %	29,12	20,55
Crude protein, % DM	9,13	9,46
Neutral detergent fibre, % DM	45,07	48,92
Acid detergent fibre, % DM	26,95	28,96
Starch, % DM	21,43	15,28
Fat, % DM	1,70	2,04
Ash, %	3,67	3,48
Metabolisable energy, MJ/kg DM*	9,72	9,60

**Calculations based on proximate values, NRC, 2021.*

associated with advancing plant maturity at harvest. In addition, if maize plants experience drought stress during the growth period they quickly increase their NDF proportion, while the starch content does not exceed 15 to 25 percentage units due to insufficient grain content.

Dry matter, NDF, and starch determine a significant proportion of energy and nutrients in the maize silage and consequently, variations in their levels can significantly affect the final feeding value of ration formulated for dairy cows.

Incorporating actual analytical values of nutrients in maize silage into the formulation software database contributes to the correct balance of the diet. That is why it was of interest to look at a specific farm (with poorer than average silage quality) to see what the consequences would be if the average values were used instead of the farm-specific data. For example, the introduction of proximates from HHNIRs scans for the average and for a specific farm, silage samples in NDS Professional (CNCPS, Version 6,5) resulted in the ME values shown in *Table 2*.

NDS Professional was used to optimise diets for milking cows with different scenarios (*Table 3*) based on maize silage as a main forage, but applied either with its average or with specific farm nutritional values as indicated in *Table 2*.

Silage quality and milk yield

In the first approach for diet formulation for a specific dairy farm, the average data for silage was taken to match cow needs for 34kg daily milk yield (diet 1). It resulted in a predicted feed efficiency of 1,44. However, when for the same ratio, instead of the average numbers, nutrient values of

Table 3: Dairy cow rations formulated with different quality of maize silage.

Ingredients, kg	Average CEE data (diet 1)	Specific farm data (diet 2)	Specific farm data, balanced (diet 3)
Maize silage, average quality	22	0	0
Maize silage, specific farm	0	22	30
Lucerne hay	3,6	3,6	3,6
Wheat straw	1	1	1
Maize grain	5,1	5,1	5,32
Wheat grain	3,3	3,3	3,41
Soya bean meal, 46%	1,8	1,8	1,8
Rapeseed meal, 34%	1,2	1,2	1,2
Sunflower meal, 33%	2,3	2,3	2,3
Protected fat, 98%	0,35	0,35	0,35
Vitamins and minerals	0,52	0,52	0,52
Feed cost, €/kg milk	7,62	7,62	8,50
Predicted milk yield, kg/d	34,1	30	34,1
Cost, €/kg milk	0,223	0,254	0,249
Predicted feed efficiency, milk kg/kg DM	1,44	1,38	1,44
Nutrients			
Dry matter content, %	57,3	52,7	47,4
DMI, kg/d	23,6	21,7	23,6
Forage, % DM	44	40	43
Concentrate, % DM	56	60	57
ME, MJ/h/d	244,3	225,4	245
Me, % required for 34kg milk	100,2	92,2	100,4
MP, g/h/d	2555	2367	2557
MP, % required for 34kg milk	100,8	95,7	100,6
CP, % DM	16,9	17,6	16,9
Starch, % DM	28	26,4	26,7
NDF, % DM	31,2	35,8	31,9
ADF, % DM	20,2	16,9	20,4

**Calculating the feed cost/head/day it was assumed that the prices of maize silage in all diets are equivalent.*

Table 4: Dairy cow rations with added 'on top' or with matrix crude fermentation extract.

Ingredients, kg	Basic diet (diet 3)	Basic diet + CFE on top (diet 4)	Basic diet + CFE with matrix (diet 5)
Maize silage, specific farm	30	30	31
Lucerne hay	3,6	3,6	3,6
Wheat straw	1	1	1
Maize grain	5,32	5,32	5,3
Wheat grain	3,41	3,41	2,94
SBM, 46%	1,8	1,8	1,8
RSM, 34%	1,2	1,2	1,2
SFM, 33%	2,3	2,3	2,1
Protected fat, 98%	0,35	0,35	0,30
Vitamins and minerals	0,52	0,52	0,52
Crude fermentation extract		0,004	0,004
Predicted milk yield, kg/day	34,10	35,23	34,10
Predicted feed efficiency, milk kg/kg DM	1,44	1,49	1,47
Nutrients			
Dry matter content, %	47,4	47,4	46,2
DMI, kg/d	23,65	23,65	23,2
Forage, % DM	43	43	45
Concentrate, % DM	57	57	55
ME, MJ h/d	245	250	244
ME, % required for 34kg milk	100,2	102,7	100,2
MP, g/h/d	2 554	2 613	2 542
MP, % required for 34kg milk	100,6	103,9	101,6
CP, % DM	16,9	16,9	16,8
Starch, % DM	26,9	26,9	26,5
NDF, % DM	31,9	31,9	32,4
ADF, % DM	20,4	20,4	20,8

specific silage samples were applied (diet 2), a significant shortage of metabolisable energy (8%) and metabolisable protein (6%) was found. Feeding such a diet would only produce 30kg milk yield instead of a targeted 34kg, with a strong reduction of feed efficiency to 1,38 and an increase of milk cost from €0,223/kg to €0,254/kg in diets 1 and 2, respectively.

The reason for this deficiency was the poor quality of the maize silage produced at the farm: lower DM and starch content and higher levels of NDF and acid detergent fibre (ADF) compared to the average contents (*Table 2*). To compensate for this and to keep the diet balanced to match 34kg milk production and better feed efficiency, it was necessary to increase the amounts of the maize silage and slightly elevate the amounts of maize and wheat grains (diet 3). As a result, the daily feed cost per head was increased by 11,5% compared to the other rations.

It is clear that feeding low-quality silage would either suppress the performance of cows or require the inclusion of more expensive ingredients in total mixed rations (TMR), which in turn would elevate the milk cost. To avoid such a scenario, the goal should be the production of good-quality maize silage with proximate parameters close to those of 'normal' silage (*Table 1*, CVB 2021 data).

To reduce the risk of over- or underestimating their quality, silages produced must be sampled and analysed for nutrient composition and diets balanced accordingly.

Nutrient utilisation

As indicated by NIRS analysis, maize silages may have highly variable nutrients, including NDF and ADF contents (*Table 1*).

Improving the digestion and utilisation of NDF from the forage components allows for the release of extra energy from the diet. Traditionally, pre-treatment of forages was based on either chemical or mechanical means, but a novel approach has been developed by AB Vista. A crude fermentation extract (CFE) from *Trichoderma* mixed with the TMR, covers the feed particles and quickly starts to form pits or holes in the fibre surface, suggesting that the pre-digestion process of fibre fractions occurs before consumption.

After the treatment, NIRS scanning of a significant number of samples predicts a reduction in NDF content and improvements in ME by 0,7MJ/kg DM in maize silage. Pre-treatment of cow rations with this fermentation extract when added 'on top' suggests extra energy supply and improved performance. An alternative solution is to apply the matrix of ME = 0,7MJ/kg DM silage (*Table 4*) and to maintain the level of production.

On top application of crude fermentation extract in diet 4 contributes to a better energy supply and meets the requirements of cows for 35,2kg daily milk yield and improves feed efficiency to 1,49. Introducing the energy uplift to the maize silage (diet 5) helps to reduce the amounts of grains and protected fat, to increase the proportion of forages and improve feed efficiency while maintaining milk yield.

Conclusion

The quality of maize silages varies in a wide range which requires regular analyses. NIRS scanning is a rapid and reliable tool to obtain representative on-farm data regarding the nutrient content of maize silages. Introducing the nutrient values from analytical results allows more precise diet formulation and performance prediction through ration optimisation for dairy cows, and reduces the risk of potential financial losses when low-quality silages are fed.

Using crude fermentation extract for the degradation of fibre fractions may help in the improvement of performance and feed efficiency in milking cows.

For more information, visit *www.abvista.com*.

Relationships between individual animal variation in DM intake, and animal performance and feed efficiency of finishing beef cattle

By MR Beck, VN Gouvêa, JK Smith, JA Proctor, PA Beck, and AP Foote

It has been suggested that dry matter intake (DMI) of ruminants is largely controlled by gastrointestinal fill (i.e., physical gut distention; Forbes, 2007) in high-roughage diets and through chemotaxis signalling, such as osmotic or volatile fatty acid receptors (Forbes, 2007), or hepatic oxidation (Allen, 2014) in low-roughage diets.

In contrast, the minimum total discomfort theory attempts to unify the different theories of DMI regulation and posits that animals consume feeds in a manner that minimises their discomfort (Forbes, 2007). Accordingly, day-to-day variation in DMI from individuals may reflect an animal adjusting their intake in response to short-term aversions to feed intake resulting from some stimuli that induce discomfort (malaise, metabolic disorders, etc.).

Variation in dry matter intake

Variation in day-to-day intake has been demonstrated to reduce DMI and average daily gain (ADG) in several production systems. For example, cattle with greater naturally occurring variation in supplement intake have lower performance and supplement conversion efficiencies (Horn *et al*., 2005; Williams *et al*., 2018). Sheep with naturally occurring greater variation in DMI of forages had less average DMI and ADG (Garrett *et al*., 2021a, b).

In finishing beef cattle, some studies have demonstrated that imposed variable day-to-day DMI reduces growth performance (Soto-Navarro *et al*., 2000; Pereira *et al*., 2021), although others have not (Cooper *et al*., 1999; Schwartzkopf-Genswein *et al*., 2004), and still others determined that cattle with greater naturally occurring day-to-day variation in DMI had greater ADG (Schwartzkopf-Genswein *et al*., 2011).

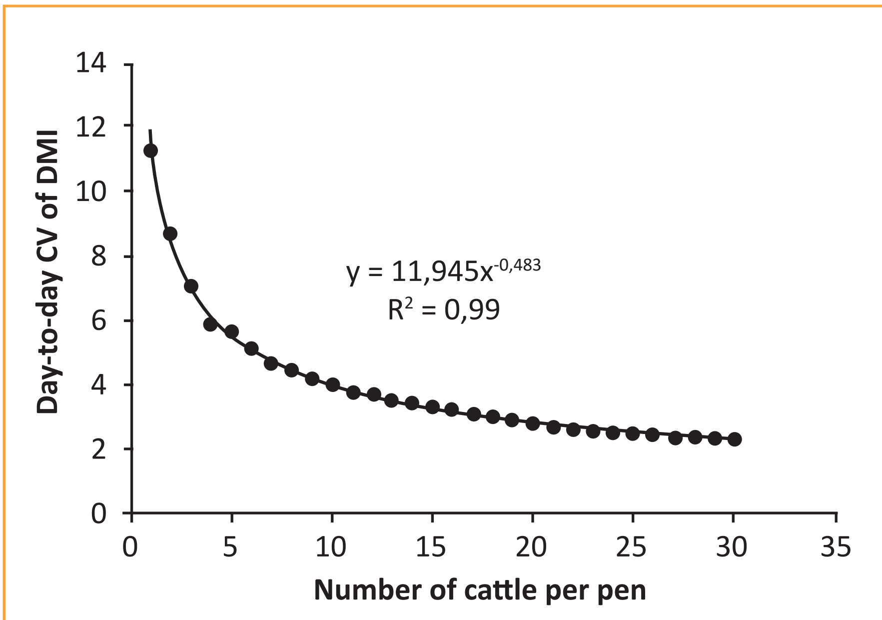
Several of the studies compared an *ad lib* intake treatment group with imposed DMI variation treatment groups and did not report the day-to-day variability of DMI of the *ad lib* group (Cooper *et al*., 1999; Soto-Navarro *et al*., 2000; Schwartzkopf-Genswein *et al*., 2004). It has been suggested that perhaps the inconsistent relationship between day-to-day variation in DMI and production traits may be because control treatment groups were already undergoing discomfort due to day-to-day variation in DMI (Pritchard and Bruns, 2003).

Accordingly, studies that assess direct associations between day-to-day variation in DMI with production traits of individuals may be a better approach than comparing treatment groups with imposed day-to-day variation to elucidate the consequences of day-to-day variation in DMI.

Variation in DMI of individual cattle is apparent when cattle are fed individually; however, it tends to disappear or become greatly diminished when cattle are group-fed. It has been proposed that individual variation in DMI does not disappear when cattle are group fed, but rather is masked by their pen mates (Schwartzkopf-Genswein *et al*., 2011). Accordingly, understanding how individual variation in DMI influences average DMI, growth, feed efficiency, and carcass traits could provide evidence that management practices which minimise individual variation could improve economic outcomes for producers.

Furthermore, statistically significant relationships between DMI variation and indexes of feed efficiency, such as residual

Figure 1: Simulated data illustrating the relationship between number of animals per pen and day-to-day coefficient of variation (CV) in DMI. The simulated data used a mean (11,3kg DMI/d) and SD (1,11 kg/d) from the average of the three studies used in this experiment (*Table 1*). Simulations were performed for 30 animals across 200 d on feed. The day-to-day CV across the 200 simulated days on feed decreased exponentially with increasing animals per pen.



feed intake (RFI), residual ADG (RADG), and residual feed intake and gain (RIG; Berry and Crowley, 2012), may provide an explanation for variation in feed efficiency between animals. Recently, Galyean and Hales (2023) proposed novel means of assessing day-to-day variation of DMI of cattle, as opposed to merely using the day-to-day CV. One of these proposed methods was the Euclidean distance (ED), which is essentially the distance between two data points. To our knowledge, the relationships between ED and DMI, growth performance, feed efficiency, and carcass traits have not been explored.

Accordingly, the objective of this experiment was to assess the relationship between CV and ED with DMI, ADG, carcass characteristics, and measures of feed efficiency, including G:F, RFI, RADG, and RIG. It was hypothesised that animals with greater variation in DMI would have less-desirable production outcomes and feed efficiency. An additional objective of this experiment was to use simulated data to demonstrate how the day-to-day CV of DMI would be expected to decrease with increasing numbers of animals per pen.

Table 1: Mean (SD) of DMI, growth performance, measures of feed efficiency, and measures of individual animal DMI variation.

	Experiment		
Item[1]	**Beck *et al.* (2023)**	**Proctor *et al.* (2024)**	**Foote *et al.* (2024)**
n	42	53	55
Days on feed	92	80	63
Initial BW,[2] kg	521 (31,4)	525 (30,1)	518 (26,7)
Final BW,[2] kg	661 (39,8)	680 (39,7)	613 (35,0)
DMI, kg/d	11,0 (1,26)	10,8 (0,83)	12,2 (1,23)
ADG, kg/d	1,52 (0,212)	1,94 (0,304)	1,51 (0,254)
G:F	0,138 (0,01387)	0,180 (0,02635)	0,123 (0,01793)
RFI, kg DMI/d	0,0 (0,86)	0,0 (0,68)	0,0 (0,98)
RADG, kg/d	0,0 (0,15)	0,0 (0,27)	0,0 (0,21)
RIG	0,0 (0,96)	0,0 (0,79)	0,0 (1,07)
HCW, kg	406,2 (27,20)	407,9 (27,20)	386,7 (22,84)
DP,[3] %	64,1 (1,73)	63,8 (2,27)	65,0 (2,05)
REA, cm^2	92,2 (9,11)	99,9 (8,19)	90,7 (6,49)
BFT, cm	1,65 (0,353)	1,42 (0,425)	1,76 (0,397)
YG	3,33 (0,614)	2,77 (0,644)	3,39 (0,540)
Marbling score[4]	520,2 (74,72)	443,2 (67,33)	597,7 (99,24)
EBF, %	32,6 (2,18)	30,3 (2,55)	33,1 (2,06)
CV, %	9,3 (4,71)	9,5 (3,26)	16,7 (4,13)
ED	1,22 (0,179)	1,21 (0,107)	2,51 (0,420)

[1]G:F calculated as kg ADG per kg DMI; RFI = residual feed intake; RADG = residual ADG ; RIG = residual feed intake and gain; HCW = hot carcass weight; DP = dressing percentage; REA = ribeye area; BFT = back fat thickness; YG = yield grade; EBF = empty body fat; CV = individual animal DMI day-to-day coefficient of variation; ED = average Euclidean distance of DMI. [2]Initial and final BW are unshrunk. [3]Dressing percentage is calculated using a shrunk final BW. [4]Marbling scale: 100 to 199 = practically devoid (standard-); 200 to 299 = traces (standard+); 300 to 349 slight (select-); 350 to 399 = slight (select+); 400 to 499 = small (choice-); 500 to 599 = modest (choice0); 600 to 699 = moderate (choice+); 700 to 799 = slightly abundant (prime-); 800 to 899 = moderately abundant (prime0); 900 to 999 = abundant (prime+).

Results and discussion

Increasing animals per pen

Figure 1 presents the day-to-day CV of DMI across a simulated 200-d feeding period with increasing number of animals per pen (from 0 to 30, increasing in increments of one). The day-to-day CV of pen DMI ranged from 11% with one animal per pen to 2,2% with 30 animals per pen. An animal's feeding behaviour will likely be influenced by its cohorts (e.g., through bunk competition) and by feed availability in the bunk (Pritchard and Bruns, 2003), so that in a day where one animal consumes less feed, another animal in that same pen may compensate by consuming more.

This exercise demonstrates that day-to-day CV of DMI will decrease with increasing animals per pen just by random chance, albeit at a diminishing rate. This should be intuitive and expected, as the SD or CV of the experimental unit will decrease with increasing observational units within an experimental unit (e.g., animals per pen; Reuter and Moffet, 2016).

So, in the context of the current analysis, the pen-level variability (day-to-day CV of DMI) will decrease as the number of animals per pen increases, which is what occurred during these Monte Carlo simulations. The results of this Monte Carlo analysis also suggest that day-to-day variation in DMI of individual animals does not disappear when cattle are fed in a group, but are rather masked by their pen mates (Schwartzkopf-Genswein *et al*., 2011).

Table 1 presents the mean and SD of pertinent production variables for each of the three experiments used in this analysis. Interestingly, all three experiments had similar CV for average DMI across animals (7,6 to 11,5%). However, there were apparent differences in day-to-day DMI variation within individual animals across the three experiments. Beck *et al*. (2023) and Proctor *et al*. (2024) had numerically similar CV (9,3 and 9,5%, respectively) and ED (1,22 and 1,21, respectively). However, Foote *et al*. (2024) had 78% greater CV (16,7%) and 107% greater ED (2,51) than the average of Beck *et al*. (2023) and Proctor *et al*. (2024). This increased variability in day-to-day DMI may be associated with the feeding system used.

Both Beck *et al*. (2023) and Proctor *et al*. (2024) used Calan gate systems, where each animal was assigned their own bunk, whereas Foote *et al*. (2024) used the Insentec Roughage Intake Control system, which assigns multiple animals to a feed bunk (4,5 animals per bunk in this instance). In the Insentec Roughage Intake Control system, only one animal can consume feed at each bunk at a given time. Therefore, the increased day-to-day variability in DMI in the study of Foote *et al*. (2024) may have been related to bunk competition.

As such, an increased day-to-day variation in DMI and any subsequent effects on production traits should be considered when comparing experiments that employ Insentec Roughage Intake Control systems or similar systems (e.g., SmartFeed, C-Lock Inc., Rapid City, SD; GrowSafe Systems Ltd., Alberta, Canada) against systems within which animals are fed in their own bunk (e.g., Calan gates, individual pens). However, these findings should be further confirmed.

Feed efficiency

Residual feed intake was positively correlated with DMI (rp = 0,79; rs = 0,77; P < 0,01), indicating that steers that consumed more feed were less efficient. Furthermore, RFI was negatively correlated with G:F (rp = -0,51; rs = -0,51; P < 0,01), indicating agreement between these two measures of feed efficiency. These associations are expected and are similar to those reported in other experiments (Tedeschi *et al*., 2006; Cruz *et al*., 2010; Pereira *et al*., 2016). Efficient cattle according to the RFI index also had decreased YG (rp = 0,18, P = 0,03; rs = 0,21, P = 0,01) and tended to have less BFT (rp = 0,14, P = 0,10) and EBF (rp = 0,14, P = 0,09) according to Pearson correlation. Efficient cattle according to RFI were associated with decreased BFT (rs = 0,16, P = 0,05) and EBF (rs = 0,18, P = 0,02) with Spearman's correlation.

Other research has also reported relationships between carcass characteristics and RFI. For example, some researchers have reported negative correlations between RFI and EBF (Basarab *et al*., 2003; Tedeschi *et al*., 2006), and others have reported that low-RFI cattle had lower BFT (Nkrumah *et al*., 2007; Pereira *et al*., 2016), which supports the tendency for a positive correlation between BFT and RFI determined in the current study.

In contrast, other experiments have not demonstrated a relationship between RFI and carcass traits (Jensen *et al*., 1992; Cruz *et al*., 2010; Bonilha *et al*., 2013). The discrepancy in the literature for the relationship between RFI and carcass traits may be due to the nonuniform way that RFI is calculated, which typically occurs within a group of cattle, making direct comparison of RFI across studies difficult. However, the trend for RFI to be associated with poorer carcass traits related to body fat (i.e., BFT and EBF) has led some to suggest applying an adjustment to RFI for carcass composition (Basarab *et al*., 2003).

The current findings have interesting implications for feedlot profitability. On the one hand, efficient cattle according to RFI also had the highest G:F, and G:F is the greatest contributor to cost of gain in a feedlot (Retallick *et al*., 2013). On the other hand, efficient cattle according to the RFI index had lower YG and leaner carcasses, indicating a potential lower carcass value if sold on a grid-based marketing system.

Residual average daily gain

Residual ADG was positively correlated with ADG (rp = 0,86; rs = 0,84; P < 0,01) and G:F (rp = 0,96; rs = 0,95; P < 0,01), indicating that more efficient animals had greater ADG and G:F. These relationships are expected and have been reported elsewhere (Berry and Crowley, 2012; Kelly *et al*., 2019; Lancaster *et al*., 2021).

Residual ADG was also positively correlated with HCW (rp = 0,17, P = 0,04) when using Pearson correlation, but not for Spearman's correlation (rs = 0,12, P = 0,17), and negatively correlated with marbling score (rp = -0,20, P = 0,02; rs = -0,25, P < 0,01). Kelly *et al*. (2019) likewise reported a small but significant positive correlation between RADG and HCW (rp = 0,15) and a negative correlation between RADG and intramuscular fat (rp = -0,11).

It appears that more efficient cattle according to the RADG index will have greater HCW, with a potential sacrifice of marbling score. The regression equation used to calculate RADG includes average metabolic BW, and so the index is independent of BW; however, cattle with greater RADG may have larger frame size and mature BW, thereby possibly explaining the positive association with HCW and the negative association with marbling score.

Measure of efficiency

There is concern that some cattle identified as efficient based on RFI may have low ADG with relatively low DMI, and as such RIG has been suggested as an alternative selection index (Berry and Crowley, 2012). Residual feed intake and gain were negatively correlated with DMI (rp = -0,70; rs = -0,67; P < 0,01) and positively correlated with G:F (rp = 0,68; rs = 0,69; P < 0,01). Additionally, RIG was more strongly associated with RFI (rp = -0,98; rs = -0,97; P < 0,01) than RADG (rp = 0,54; rs = 0,53; P < 0,01), indicating that RIG is weighted by RFI more than RADG, at least in the present investigation. This is due to RFI having a wider range in values (-2,77 to 1,97) than RADG (-0,77 to 0,46), and thereby RFI contributed more to RIG than RADG in the current data set.

The RIG measure of efficiency was proposed to select for animals with decreased DMI, as occurs with the RFI index, and with greater ADG, as occurs with the RADG index (Berry and Crowley, 2012). However, the stronger association between RIG and RFI than between RIG and RADG in the current study would suggest that selection based on the RIG index would result in trends similar to selection based on the RFI index. An investigation into the RIG index with a larger number of cattle may be necessary to determine whether this finding holds true.

The RIG index was also negatively correlated with calculated YG (rp = -0,18, P = 0,03; rs = -0,23, P < 0,01) and tended to be negatively correlated with BFT (rp = -0,14, P = 0,09) and positively correlated with REA (rp = 0,14, P = 0,09). Using Spearman's correlation, the RIG index was associated with BFT (rs = -0,20, P = 0,02) and REA (rs = 0,17, P = 0,04). This may suggest that selecting for more efficient cattle based on the RIG index will cause higher-yielding but leaner carcasses, which may decrease the value of the carcass if sold on a grid-based marketing system.

The CV and ED methods to assess day-to-day variability were highly correlated (rp = 0,77; rs = 0,83; P < 0,01). This agrees with the results of the study by Galyean and Hales (2023), in which they simulated DMI with the same average DMI but different day-to-day SD of either 0,125, 0,250, 0,375, or 0,500kg/d, which resulted in day-to-day DMI CV of 1,4, 2,9, 3,8, and 5,6%, respectively. The sum of the Euclidean distance increased with the increasing day-to-day CV of simulated DMI. Based on these findings, Galyean and Hales (2023) concluded that Euclidean distance was an acceptable means to assess day-to-day variability of DMI.

The negative association between CV and RFI in the current experiment implies that animals with greater day-to-day DMI variability were more efficient. However, this increased efficiency was likely driven

by a disproportionately larger reduction in DMI than in ADG. Cattle with decreased DMI are often more efficient. This may be due to slower ruminal passage rates that result in greater nutrient digestibility (Okine and Mathison, 1991). Furthermore, as metabolisable energy intake increases, recovered energy in fat tissues increases at a much faster rate than in lean tissues (Geay, 1984). This holds true over a wide range of BW. An increase in G:F is expected with an increasing proportion of energy intake going toward lean tissues, because fat tissues are more energy dense.

The ED measure of day-to-day DMI variability was negatively correlated with ADG (rp = -0,55; rs = -0,61; P < 0,01), G:F (rp = -0,49; rs = -0,50; P < 0,01), and RADG (rp = -0,57; rs = -0,56; P < 0,01). Additionally, ED was negatively correlated with DMI when using Spearman's (rs = -0,27; P < 0,01) but not when using Pearson's (rp = -0,12; P = 0,15) correlation coefficients. The negative associations between ED and G:F and RADG suggest that cattle with greater day-to-day DMI variability were less efficient. Furthermore, the ED was negatively correlated with HCW (rp = –0,33; rs = –0,39; P < 0,01) and positively correlated with dressing percentage (rp = 0,24; rs = 0,32; P < 0,01).

The recency of using ED as a measure of day-to-day DMI variability (Galyean and Hales, 2023) makes it impossible to compare these findings with other studies. Accordingly, these findings should be confirmed by future investigations.

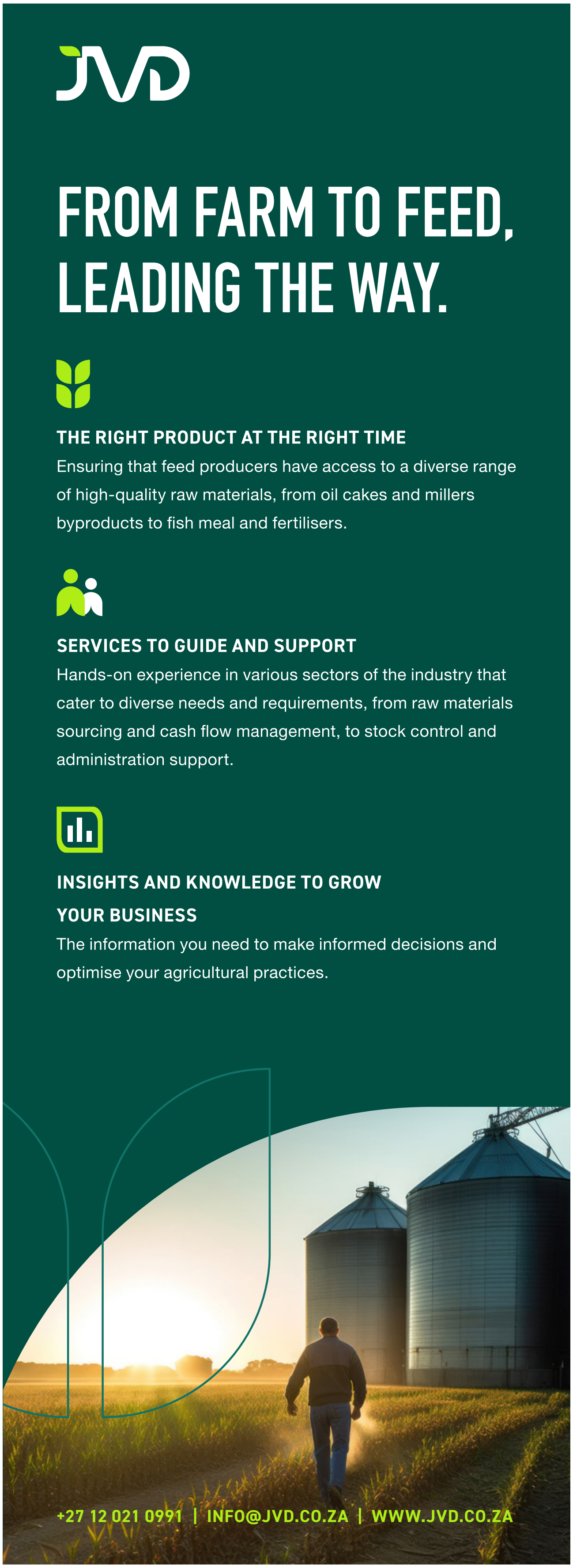
Applications

The results presented herein indicate that day-to-day variation in DMI is related to poorer production outcomes in finishing beef cattle for both assessment methods (i.e., CV and ED), although the outcomes that they are related to are not the same. Why the CV and ED methods are divergently related to production traits is unclear. However, as the two methods were determined using the same data, it may be due to innate differences in their calculation.

The CV was negatively correlated with DMI, ADG, HCW, BFT, YG, and EBF, whereas ED was negatively correlated with ADG, G:F, RADG, and HCW. It appears that day-to-day DMI variability is more strongly related to energy partitioning between fat and lean tissue when assessed using the CV method, whereas ED is more strongly related to absolute reductions in empty BW gain, independent of tissue type.

To our knowledge, this is the first work that has quantified the relationship between these methods of assessing day-to-day DMI variation and production traits of individual finishing beef steers. Although the current analysis used data from three separate experiments, these results should still be confirmed by future investigations. These future studies should especially be done with cattle started on feed at lighter BW and fed for a longer duration. It is possible that the associations measured here will not be as strong for cattle with longer days on feed.

This article was shortened for publication in *AFMA Matrix*. Visit *www.doi.org/10.15232/aas.2024-02583* for the full article or send an email to Matthew.R.Beck@usda.gov.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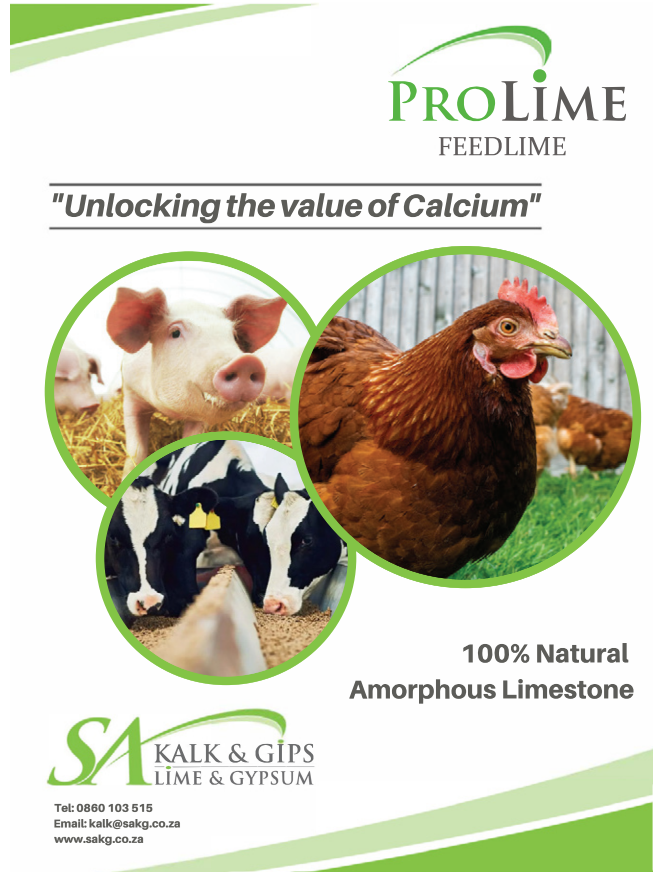
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Enhancing pig performance with organic selenium

By Laurentia van Rensburg, Alltech

Selenium deficiency is related to reduced growth and reproductive performance in pigs. As such, meeting animals' selenium requirements is one of the key factors in achieving optimal production efficiency, producer profitability and in providing consumers with a nutritious source of protein.

Selenium, which is an essential trace mineral, acts as an antioxidant. In pigs, it destroys peroxides before they can damage cellular membranes. This reduces the amount of vitamin E required to maintain the integrity of lipid membranes.

Selenium is a component of several antioxidant enzymes, including glutathione peroxidase, which protects against oxidative damage. Glutathione peroxidase is also important in redox control, the process of balancing oxidants and antioxidants with cells to regulate cellular reactions and maintain healthy function. Selenium is necessary for DNA repair and resistance to viral infections, and it enhances immune response, reproduction and growth.

Inorganic versus organic selenium

In nature, selenium exists in two chemical forms: organic and inorganic. Inorganic selenium can be found as selenite, selenate and selenide, as well as in the metallic form. In contrast, organic selenium is mainly found as selenomethionine (SeMet) in forages, grains, and oilseed meals. Animals receive selenium mainly in the form of SeMet and are thus better adapted to utilising selenium in this natural or organic form.

Plants absorb selenium from the soil in the form of selenite or selenate, then synthesise selenoamino acids, including SeMet, which represents about 50% of the selenium in cereal grains. The selenium concentration in soil varies significantly, affecting its availability to plants. In the case of acidic soil pH or low soil aeration, selenium can form insoluble complexes with iron hydroxide and become poorly available. Consequently, the selenium content of animal feed ingredients also varies. Dietary selenium supplementation is an effective means to overcome selenium deficiency and maintain the high productive and reproductive performance of livestock animals, including sows.

The major selenium supplements used for the past 50 years have been selenite and selenate, both inorganic forms of selenium. These inorganic forms have limitations such as high toxicity, interactions with other minerals, low efficiency of transfer to milk, meat and eggs, and inability to build and maintain selenium reserves in the body.

Organic selenium, such as SeMet, is better absorbed and retained in the body compared to inorganic selenium. Organic selenium enables animals to build and retain selenium reserves in tissues, improves antioxidant status and defence, and provides effective transport of selenium from the dam to the foetus and newly born piglet via placenta, colostrum, and milk.

Not all organic selenium is equal

The differences between inorganic and organic forms of selenium are widely recognised. However, there can also be substantial differences in toxicity, stability and efficacy between organic selenium products. The compartmentalisation of selenium within yeast differs according to the way it is prepared, affecting parameters such as shelf life, bioavailability and bio-efficacy.

Organic selenium yeast sources have displayed high levels of verified stability in premix, in compound feed, and after pelleting, albeit with further source-dependent differences noted between them.

Importance for the nursery period

The post-weaning period is critical in pig production, as piglets are exposed to stress factors that favour the development of pathogenic bacteria in the digestive tract, leading to growth retardation and diarrhoea. Adequate supplementation of organic selenium can minimise problems during post-weaning by defending the piglet's body against cellular damage from free radicals, which increase during this period due to changes in the piglet's diet and environment.

Studies have shown that replacing inorganic selenium with organic selenium can increase its absorption and biological activity. Research suggested that a 21-day-old weaning pig fed a practical diet requires 0,5 ppm supplemental selenium for about two weeks, which can be reduced to 0,35ppm by five weeks post-weaning. In the United States, the maximum allowable supplemental selenium is 0,3ppm. In a large sow and nursery trial, piglets from sows supplemented with 0,3ppm Sel-Plex – a yeast-based, selenium-enriched technology – throughout the nursery phase had fewer mortalities and culls.

Supplementation requirements

The amount of selenium needed to maintain different physiological functions can vary significantly. For example, a higher selenium requirement is usually necessary to maintain strong immune function, compared to the amount needed for growth and maintenance. This is particularly important for nursery pigs, which encounter numerous stressors and challenges.

The levels of other antioxidants and pro-oxidants in the diet can vary, and since selenium is an essential part of antioxidant defences, its requirement could differ depending on the diet. Current recommendations for the selenium requirement of pigs range between 0,15 and 0,3ppm, but in commercial conditions. The requirement might be higher depending on the level of stress.

For more information, visit *www.allaboutfeed.net.*

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AFMA INTERVARSITY WRITER'S CUP 2025: WINNER ROUND 1 / LITERATURE REVIEW

Digestible calcium in broiler production

By Kean Jacobs, University of Pretoria

The broiler industry is facing a severe problem related to the increased incidence of skeletal abnormalities. This not only raises concerns for animal health and welfare, but impacts growth performance and subsequently broiler operation profitability.

Kittelsen *et al*. (2017) estimated that between 14 and 30% of broilers show an incidence of lameness. This increased incidence is attributed to the rapid growth of broilers (Kittelsen *et al*. 2017), even though genetic selection for improved skeletal traits started in the early 1990s (Sanchez-Rodriguez *et al*., 2019). Julian (1998) has, however, attributed this to the metabolic imbalances associated with rapid growth.

One potential reason for these imbalances can be attributed to inaccurate supplementation of calcium (Ca) and phosphorous (P) in conjunction with the most recent recommendations, which are still based on a total Ca (tCa) and available P basis (Aviagen 2022; Cobb-Vantress 2022).

These metabolic imbalances of Ca and P are important to improve, as these macro-minerals are involved in several biological pathways, with bone development and mineralisation being the most essential. This traditional approach of formulating on a tCa basis disregards the variability between different Ca sources and their impact on the digestibility of both Ca and P. This is crucial, as any imbalance of either Ca or P significantly impacts the other.

One potential alternative is to improve the supplementation of Ca to formulate and supply this mineral according to the precise dietary needs of broilers. This requires moving away from the outdated tCa system to a more precise digestible Ca (dCa) system. While the adoption of digestible values for other nutrients, such as amino acids and P, has progressed, the tCa system has remained unchanged. This could largely be attributed to the low cost and abundance of Ca in broiler diets, in conjunction with the complex interactions between Ca and other dietary components (Walk *et al*., 2021).

Despite this, there has been a tremendous movement towards dCa in recent years (Angel 2018; Anwar *et al*., 2018; Angel, 2019a, 2019b; David *et al*., 2019; Li *et al*., 2021; Walk *et al*., 2021; Angel *et al*., 2022; David *et al*., 2023; Venter 2024b; Drysdale *et al*., 2024). This movement has prompted several authors to develop digestibility coefficients for Ca in common feed ingredients used in broiler diets (Anwar *et al*., 2015; Anwar *et al*., 2016a, 2016c; Anwar *et al*., 2018; David *et al*., 2019; Venter *et al*., 2023).

The published digestibility coefficients for limestone are, however, difficult to implement due to the variability between different limestone sources, which have physical and chemical differences (Gilani *et al*., 2022) that influence Ca digestibility, as well as their impact on other nutrients, especially P. These imbalances can also lead to pollution, as excessive minerals are excreted into the environment.

Calcium homeostasis

It is well known that Ca is one of the most abundant minerals found in the avian body, with 99% of Ca stored as hydroxyapatite in the skeleton (Adedokun and Adeola, 2013; Proszkowiec-Weglar and Angel, 2013). Ca is an essential mineral responsible for bone development. The remaining 1% of Ca is situated within cells, plasma, and extracellular fluid (Proszkowiec-Weglar and Angel, 2013), where it plays a role in several other vital biological processes (Hu *et al*., 2020). These processes include muscle contraction, blood clotting, cell adhesion, enzyme activation, metabolism, and intracellular signalling (Proszkowiec-Weglar and Angel, 2013).

To advance our understanding of a dCa system, it is crucial to first comprehend the mechanisms involved in Ca homeostasis and its significance. There are two distinctive pathways assisting in Ca uptake and transport through the intestinal wall in avian species: the passive and active uptake of Ca (Adedokun and Adeola, 2013; Proszkowiec-Weglar and Angel, 2013; Anwar *et al*., 2016b).

The transcellular or active transport of Ca is an energy-dependent or metabolically driven pathway. This pathway occurs in a three-step process: entry across the intestinal cell wall;

diffusion through the cell cytoplasm; and exiting across the cell membrane into the basolateral membrane. The paracellular or passive transport of Ca is an energy-independent or gradient-driven process. This process is characterised by the movement of Ca into the intestinal lumen through the tight junctions between cells along the chemical gradient.

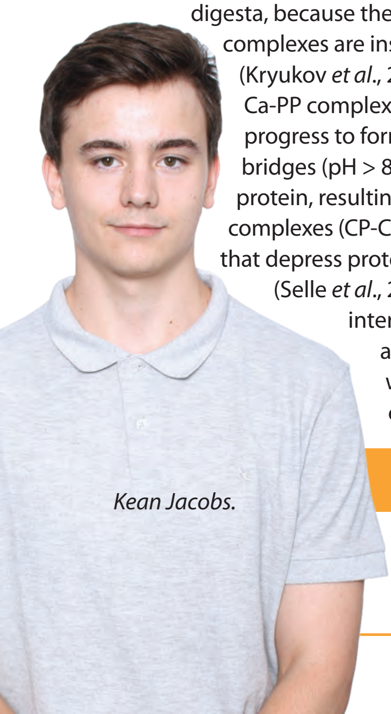
The active pathway is highly regulated by the plasma Ca concentrations, where Ca is controlled within a narrow range through a feedback mechanism involving the parathyroid hormone (PTH), the active form of vitamin D3 (1,25-dihydroxyvitamin D_3), calcitonin, and their respective receptors (Proszkowiec-Weglar and Angel, 2013). At high plasma Ca concentrations, passive transport occurs exclusively, as the active transport of Ca is inhibited. In low plasma Ca concentrations or increased Ca needs, both active and passive pathways facilitate the uptake of Ca in the intestine (Proszkowiec-Weglar and Angel, 2013; Anwar *et al*., 2016b).

Anti-nutritional factors

One complex interaction is associated with Ca and its chelation to phytic acid. Phytic acid (myo-inositol hexaphosphoric acid, IP_6) serves as the primary storage form of P in plant seeds, comprising between 60% and 80% of the total P content (Dersjant-Li *et al*., 2015). This form of P, chelated to Ca and referred to as phytate P (PP), is poorly available to broilers (Dersjant-Li *et al*., 2015; Babatunde *et al*., 2019).

In this chelation process, one phytic acid molecule can bind up to six Ca ions, negating up to one-third of Ca in the digesta, because these Ca-PP complexes are insoluble (Kryukov *et al*., 2021). These Ca-PP complexes can further progress to form cationic bridges (pH > 8,40) with protein, resulting in ternary complexes (CP-Ca-PP) that depress protein availability (Selle *et al*., 2012). These interactions associated with PP complexes are even further exaggerated with wide Ca:P ratio (Dersjant-Li *et al*., 2015). Due to the formation of these anti-nutritional PP complexes, phytase, a widely used endogenous enzyme, is employed to hydrolyse phytic acid and is commonly included in broiler diets globally (Tamim *et al*. 2004). As Ca is the dominant chelator to phytic acid in broiler diets, it is considered the limiting factor that influences phytase efficacy (Kryukov *et al*., 2021).

Apart from Ca-PP interactions, the extent of Ca anti-nutritional interaction is further extended to inorganic P. This is due to Ca forming insoluble Ca-P precipitates in the intestine, which limits the availability of these minerals (Rousseau *et al*., 2016). Despite the negative effects that Ca has on P and protein, it has also been shown to decrease dietary energy digestibility through the formation of soap precipitates (Tancharoenrat and Ravindran, 2014, Hamdi *et al*., 2015). These results show a more pronounced effect in diets with high absolute Ca and wide Ca:P ratios, exacerbating the anti-nutritional effects associated with them (Rousseau *et al*., 2016).



Kean Jacobs.

Limestone variability

Historically, it was presumed that Ca from limestone is highly bioavailable; however, it has been shown that this is not the case (Anwar *et al*., 2016 a, b). Several factors influence the bioavailability of Ca from limestone, depending on its chemical and physical properties. These properties include particle size, solubility, Ca concentration, geographical source, and the concentrations of other minerals, which are the main contributing factors influencing limestone's variability.

The particle size of limestone is dependent on the processing method and directly influences solubility, exhibiting an inverse correlation between particle size and limestone solubility. Thus, a decrease in limestone particle size leads to an increase in *in vivo* Ca^{2+} release, subsequently increasing Ca-PP complexes and decreasing the digestibility of both Ca and P (Kim *et al*., 2019). In a study done by Anwar *et al*., (2016a), different particle sizes of limestone (coarse versus fine) were evaluated, revealing a significant difference in digestibility between these sources (71 and 43%, respectively).

Despite this correlation, solubility is also influenced by the physical structure and geological origin of limestone (Kim *et al*., 2018; Gilani *et al*., 2022). Therefore, different limestone sources of the same particle size can exhibit varying solubilities and, concurrently, different digestibility.

Another factor to consider that influences Ca digestibility is the Ca contribution from different limestones. It is assumed by the National Research Council (NRC, 1994) to be around 38%; however, this value is dependent on the source and concentrations of other minerals (Anwar *et al*., 2016b). In a meta-analysis done by Gilani *et al*. (2022), significant variation was found among 641 sources across eight regions, ranging between 33,3 and 40%.

Conclusion

By understanding the factors that influence the digestibility of Ca and its effects on P and other dietary components, we can address concerns related to the inaccurate supplementation of these minerals. The traditional recommendation based on tCa with a fixed ratio of 2:1, along with available P, requires revision due to significant variations among limestone sources and their digestibility. This directly impacts the growth performance, profitability, sustainability, health, and welfare of broilers.

Given the impact and variability among different limestone sources, as well as their abundance in plant-based poultry diets, correlating *in vitro* analyses with wet chemistry analyses of Ca and P digestibility could facilitate the optimisation of formulations.

This movement towards a dCa system is supported by recent research that has developed a prediction equation (Angel *et al*., 2023) for limestone, enabling accurate estimation of digestibility coefficients for various limestone sources. This has been identified as a limiting factor in formulating on a dCa basis in broiler diets (Anwar *et al*, 2016a, b; Kim *et al*., 2018; Li *et al*., 2021). This aligns with the aforementioned Ca digestibility coefficients for common feed ingredients, making this advancement possible.

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Contracts of employment: Types and uses

Supplied by the LWO Employers Organisation

South African legislation requires the employer to provide an employee with the details of his or her employment. A written employment contract, which outlines and confirms the terms and conditions of employment, must be implemented in the workplace. This will assist the employer in limiting future disputes through proactive management. The employment contract is also one of the key elements the Department of Employment and Labour investigates during inspections.

It is crucial that the employer determines which type of contract to conclude with the employee, taking into consideration the operational requirements of the company. There are two types of contracts, namely permanent and temporary.

Permanent contract

The following must be noted when choosing a permanent contract:

- A permanent contract has a start date but no end date.
- If an employee is employed for longer than three months, without there being a justifiable reason stipulated in the employment agreement, the employee will be considered a permanent employee until the contrary is proven.
- A permanent contract may be subject to a trial period. If an employer is not satisfied with an employee's performance, the correct procedures must be followed before an employee is dismissed during or after the expiry of a trial period.

Temporary contract

The temporary contract should not differ from the permanent contract, except for the term of employment. There are two types of temporary contracts: a fixed-term and a project-based contract. With any temporary contract, the employee must still be given statutory notice before his or her services are terminated.

The following should be considered with each of these contracts:

Fixed-term contract

The start and end date of the contract must be stipulated. As a rule, a fixed-term contract may only be in place for a period of three months. However, specific exceptions apply to a contract that exceeds three months: There must be a justifiable reason and this reason must be stipulated in the employment contract.

Examples include:

- The employee replaces another employee who is temporarily absent from work.
- The employee was employed due to a temporary increase in the volume of

work (this work is not expected to last longer than 12 months).
- The employee is employed to perform seasonal work.
- The employee has already reached the normal retirement age in the workplace.

Project-based contract

In terms of a project-based contract, the employee is only employed until the completion of a certain project. The project will have a start date but, at the time of concluding the contract, the project's end date is not yet known. In this case, the employment agreement must stipulate that the employee will perform services up to and including the completion of a project. The contact must also include specifics pertaining to the type of project. The contract will expire once the project is completed.

The administration side

Once the employer has decided what type of contract to offer the employee, all the employee's personal details and information must be included in the contract before the employee receives it. The contract must also be discussed with the employee in the presence of a witness, and a copy of the contract given to the employee.

Not only are the details of employment required by legislation; it also regulates the terms and conditions of employment between an employer and employee. This is the foundation of the working relationship between the parties and by confirming this in writing in the employment agreement, uncertainties and potential friction are reduced.

Contracts that are fair

The employment contract can be of immense value to the employer if used effectively. However, if the employment contract is abused, it can pose great risks to the employer. Employees rely on their employment contracts for stability and security in the workplace. Unilateral or one-sided adjustments can disrupt this stability, leaving employees uncertain regarding their rights and future.

By maintaining a commitment to honouring the terms of the contract, employers can provide employees with a sense of security and confidence, allowing them to focus on their work and contribute positively to the business.

South African labour legislation and relevant case law require employers to adhere to the terms and conditions agreed upon in the contract. These terms may never be less favourable than those set out in the *Basic Conditions of Employment Act, 1997 (Act 9 of 1997)*, or *BCEA*, as well as *Sectoral Determination 13* which regulates labour relations in the agricultural sector.

When the terms and conditions of employment are fair, employees feel valued and respected, leading to greater job satisfaction and productivity. On the other hand, unilateral changes to the employment contract cannot only create a power imbalance and breed dissatisfaction among employees, ultimately harming the business's overall performance – it can also constitute unfair labour practice.

Changes and legal stipulations

Businesses operate in a challenging economic climate and other external forces can leave a business with little choice but to realign, restructure and reorganise to become more competitive or to maintain an existing position in the market. Restructuring is the act of reorganising a business's structures (legal, ownership, operational or other structures) for the purpose of making it more profitable or better organised for its present requirements.

It is vital that employers always follow the correct procedure as specified by labour legislation whenever any changes are made to employees' terms and conditions of employment.

If an employer intends to restructure or make organisational changes in the near future, it is vital to consider the following:

- Communication is key. Change is difficult and can leave employees feeling anxious. We advise employers to be open and clear as to why changes are needed and to explain the business's needs and goals, as well as make regular announcements to all employees in terms of progress made. Restructuring is more likely to be successful when managers understand the fundamental strategic problem or opportunity the business faces.
- Consult with employees in respect of suggestions and ideas, as well as to gain feedback. Often a combination of ideas can lead to the best solution. Employees operating in a specific structure will be able to identify challenges the employer may have overlooked.
- Plan ahead. Implementing changes smoothly will directly impact on how quickly and efficiently the process will be finalised.
- Consistently commit to quality over quantity in all aspects of the business, from the very beginning. This can greatly relieve an employer's need to restructure later on.
- Seek professional assistance. Because restructuring is not a regular occurrence, most employers are not that experienced with regard to the correct procedures to be followed, which poses a huge business risk to the employer.

Notes about fixed-term contracts

Employers often make four common mistakes regarding fixed-term contracts:

Mistake 1: No written employment contract

One of the biggest mistakes employers make is not implementing written employment contracts, or settling for a generic employment contract that offers minimal protection when there is a dispute in the workplace.

The employee is employed from the moment he or she accepts employment, irrespective of how the relationship is recorded – via an oral or written agreement. A written agreement (employment contract), however, creates clarity by confirming the terms and conditions of employment agreed upon and protects the employer in terms of the employment relationship going forward.

The employment contract can be of immense value to the employer if used effectively. Making a mindshift regarding employment contracts from an 'administrative burden' to 'risk mitigating tool' can save employers a lot of time and money in the long run.

Mistake 2: Disguising permanent employment

Unfortunately, it does happen that employers attempt to evade the statutory obligations in terms of labour legislation altogether, or attempt to evade permanent employment by employing people on a fixed-term basis. This is, however, a grave mistake and employers must clearly understand that to disguise what is in fact permanent employment in the form of a fixed-term contract is illegal.

It is crucial that an employer enters into the correct type of employment contract. Ask yourself: Is the position of a permanent/indefinite nature; or is the position of a temporary nature for a specific period of time or for a specific project?

Employees employed on a fixed-term basis for longer than three months will be deemed to be permanent, unless the longer fixed-term period is justifiable in terms of the *Labour Relations Act, 1995 (Act 66 of 1995)*, or the *LRA*.

Mistake 3: Creating an expectation

The employer must be careful not to create an expectation of permanent employment with the employee, which can easily happen when a fixed-term employment contract is renewed for a second or third (similar) period.

The more frequently an employer rolls over a fixed-term contract, the more reasonable the employee's expectation becomes that it will continue to be rolled over in the future, thus creating an expectation of permanent employment. Failing to renew such a contract can then be seen as an unfair dismissal.

If a fixed-term employment contract comes to an end and the employee remains in this position, legislation states that such an employee will be regarded as permanent. This means that the contract will be deemed to have been tacitly renewed on the same terms, except that the relationship will now be of a permanent duration.

Mistake 4: Different terms and rules

There is a myth that the same legislation, discipline, policies and procedures do not apply in the same way to fixed-term employees as it does to permanent employees. The only difference between a fixed-term and a permanent employee is the term of employment.

Fixed-term employees must be treated the same as permanent employees with regard to wages, leave and other benefits. Employees on fixed-term contracts must also be given equal access to opportunities to apply for vacancies, and is entitled to severance pay upon termination of employment where the employee is employed on a fixed-term contract exceeding 24 months.

Employee vs independent contractor

It is very important to distinguish between an employee and an independent contractor. The latter is appointed to perform work or provide a specific service to another person or business. They are not employees of the employer as they perform the work under their own business and is regarded as a service provider. Furthermore, the independent contractor is not obligated to perform the work him- or herself and may make use of assistants or employees to assist or perform the work.

> The employment contract is also one of the key elements the Department of Employment and Labour investigates during inspections.

An employee, on the other hand, is defined in the *BCEA* as any person, excluding an independent contractor, who works for another person or for the state and who receives, or is entitled to receive, any remuneration; and any other person who in any manner assists in carrying on or conducting the business of an employer.

Labour law governs the employment relationship, protecting the employee and not the independent contractor. Independent contractors need to approach the civil courts if there is a dispute regarding the contract/agreement, work done, payment, etc.

What does the law say?

The *LRA* sets out that, until the contrary is proven, a person who works for or renders services to any other person is presumed, regardless of the form of the contract, to be an employee if any one or more of the following factors are present:

- The manner in which the person works is subject to the control or direction of another person.
- The person's hours of work are subject to the control or direction of another person.
- In the case of a person who works for an organisation, the person forms part of that organisation.
- The person has worked for that other person for an average of at least 40 hours per month over the last three months.
- The person is economically dependent on the other person for whom he or she works or renders services.
- The person is provided with tools of trade or work equipment by the other person.
- The person only works for or renders services to one person.

Earning threshold aligned

This is not applicable if the person earns in excess of the earning threshold (currently set at R254 371,67 per annum). If any one of the aforementioned factors are present, the employer has the duty to rebut the presumption and prove that the person is not an employee but rather an independent contractor.

If the work arrangement involves persons who earn amounts equal to or below the earning threshold, any of the contracting parties may approach the Commission for Conciliation, Mediation and Arbitration (CCMA), to make an advisory award on whether the person involved in the arrangement is an employee.

Have a contract in place

While the wording of the employment contract is important, the true nature of the relationship between the parties is even more so. Employers are urged to ensure the terms of employment contracts are correctly worded. Equally important is having a written independent contractor's agreement in place with the service provider when using independent contractors.

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


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