Recent Advancement in Animal Nutrition Australia

27th - 28th July 2023, Hilton, Gold Coast

Conference Proceedings

RAAN CONFERENCE AUSTRALIA

Gold Coast 27th - 28th July 2023

une University of New England

Recent Advances in Animal Nutrition in Australia

All articles published in this volume were subjected to external peer review. The criteria for acceptance specify that the material presented be sound and advance scientific knowledge of animal nutrition and its application.

Published by Animal Science Department

School of Environmental and Rural Science
University of New England
Armidale 2351, NSW, Australia

Design and layout by Jason Hobbs

Citations: Articles in this volume should be referenced as follows:

[Author] [Title] In: Recent Advances in Animal Nutrition – Australia (2015) Abstracts (F Cowley) pp. [page numbers]. Animal Science, School of Environmental and Rural Science, University of New England, Armidale, NSW 2351 Australia

Welcome to confernece

On behalf of the organising committee, I welcome you to the 2023 Recent Advances in Animal Nutrition in Australia (RAAN-A) conference.

Recent Advances this year continues its tradition of fostering the sharing of the latest research in the field of animal nutrition across the most economically significant animal species, including poultry, pigs, sheep, cattle, companion animals and aquaculture. RAAN-A is one of the few conferences worldwide devoted to animal nutrition science across the species, and this unique meeting of intensive and extensive production systems, industry and research, makes it one of the most thought provoking and stimulating symposia in Australia.

Our program presents a mixture of the most significant recent animal nutrition advances internationally and locally. This year's plenary sessions cover a range of timely themes. The first day interrogates the role of animal nutritionists in feeding the world. Other plenary themes address the issues of nutritional effects on the microbiome, timed feeding (chrononutrition) and species-specific sessions. We are proud this year to have a session devoted to aquaculture nutrition, as an increasingly important source of protein for feeding the world sustainably. This year the plenary themes of the conference have been enhanced by over twenty contributed papers, as oral and poster presentations. The wide range of topics presented show animal nutrition to be a discipline that is far from settled science. Rather, the 21st century challenges of feeding animals ethically and sustainably are challenging animal nutritionists to new and better practices and knowledge.

All invited and contributed papers have been peer reviewed. Since 2013, and again this year, the RAAN-A conference has partnered with Animal Production Science for a special edition of the journal where all invited manuscripts will be published. The committee thanks all invited and contributing authors for sharing their research at this year's conference.

Special recognition goes to Kate Murphy and Jenny Lawler of KAM Events for their invaluable assistance in organising this year's conference.

The committee would like to thank all the sponsors, industry partners, speakers and participants for their contributions to the 2023 Recent Advances in Animal Nutrition – Australia Conference. The engagement between speakers and participants, industry and research are what makes this conference so dynamic and valuable in seeding ideas for the next suite of advances in animal nutrition.

The committee is looking forward to a lively RAAN-A 23 that gives everyone an opportunity to catch up on the recent advances in the field, and just as importantly, enjoy the networking and personal interaction opportunities which are such an important part of each RAAN-A conference.

Assoc Professor Fran Cowley
Chair – Recent Advances in Animal Nutrition – Australia
University of New England

2023 RAAN-A COMMITTEE




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CODE OF CONDUCT

Acknowledgement of Code of Conduct for the 2023 Recent Advances in Animal Nutrition Conference
By your attendance at the 2023 Recent Advances in Animal Nutrition you agree to abide by the code of conduct in relation to the prescribed items below.

Alcohol and Illegal Drugs Policy
You must not be in the possession of or under the influence of alcohol or illegal drugs while attending Conference sessions. Alcohol provided by the relevant venue/s may be consumed in a responsible manner at social functions.

Delegate Agreement
In accepting entry to the Conference, you agree to conduct yourself in accordance with the expectations of the above.

In circumstances where these expectations are not met, the Conference Organising Executive have the authority to refuse your entry to the Conference and request you to vacate the premises, and all fees and monies paid will be forfeited to the Conference.

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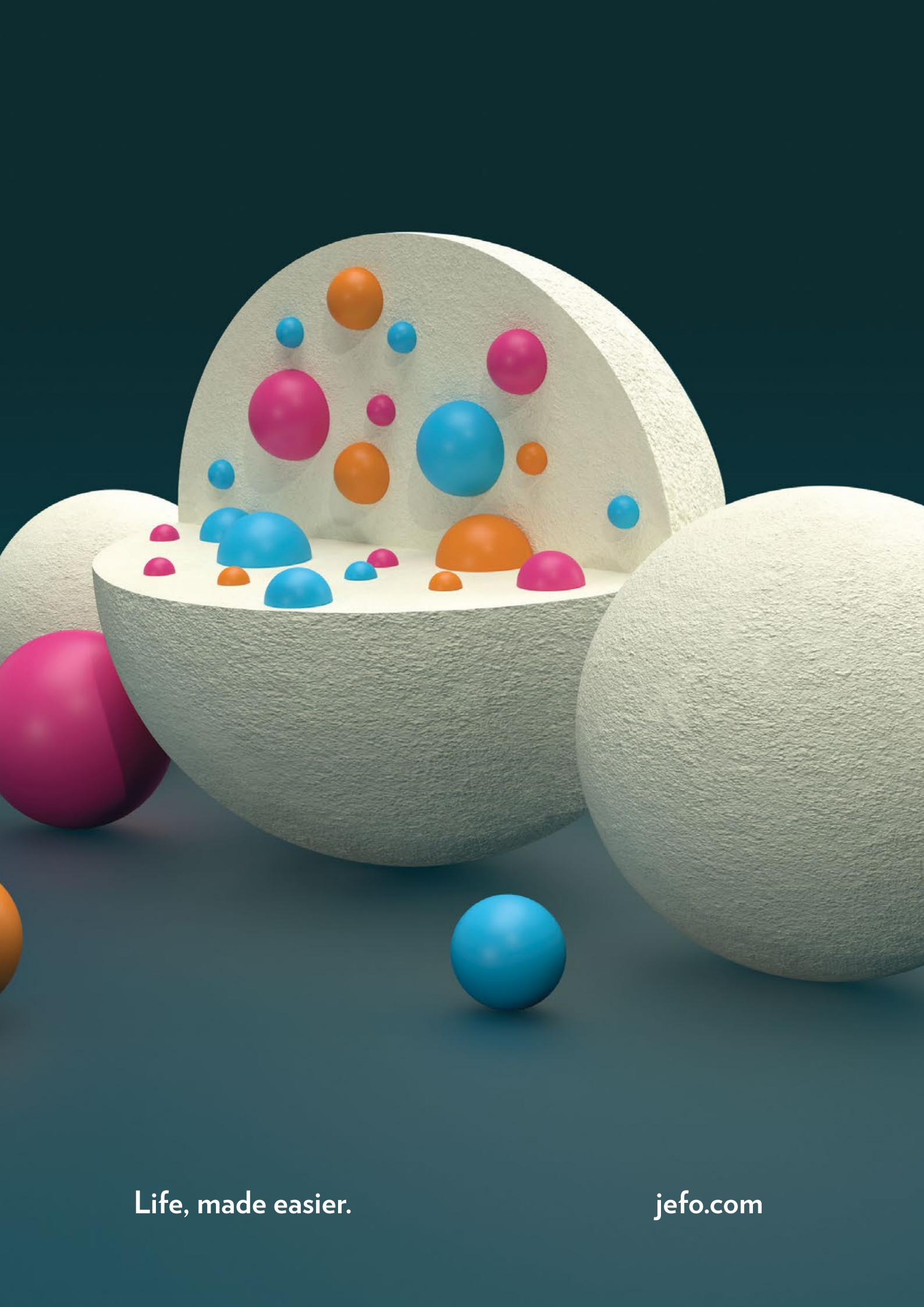
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Program

Wednesday 26 July 2023	
5.00-6.00pm	***Welcome Drink & Canapes***
Thursday 27 July 2023	
8.45 - 9.00 am	Welcome **Dr Fran Cowley**
9.00 – 11.15 am	**Opening session 1: Feeding livestock to feed the world** **Session Chair: David Pethick** ***Sponsored by USSEC***
9.00 - 9.20	**McClymont Rural Science Review, to reflect his wholistic view of animal agriculture**: The societal role of meat and the genesis of the Dublin Declaration **Dr Neil Mann**
9.20 - 9.40	The societal role of meat: The Dublin declaration and Australian animal agriculture **Dr Ian Lean**
9.40 - 10.10	Modelling a role for animal sourced food in sustainable diets **Dr Holland Dougherty**
10.10 - 10.40	**Cumming-Farrell Oration, to reflect their contributions in monogastric nutrition**: Net protein contribution from an intensive Australian pork supply chain **Dr Rob van Barneveld**
10.40 – 11.15	**Panel Discussion**
11.15 - 11.45am	***Morning Tea*** ***Sponsored by: SFMCA***
11.45 - 1.00 pm	**Session 2: Challenges of Aquaculture Nutrition**
11.45 - 12.15	Aquaculture nutrition in Australia: challenges and trends **Dr Ha Truong**
12.15 - 12.45	Market driven assessment of alternate aquafeed ingredients: seafood waste transformation as a case study **Dr Janet Howieson**
12.45 - 1.00	**Panel Discussion**
1.00 - 2.00 pm	***Lunch & Posters*** ***Sponsored by: BASF***
01	Evaluation of the effects of medium-term (57-day) omeprazole administration and of omeprazole discontinuation on serum gastrin and serum chromogranin A levels in the horse **Miss Bethanie Clark**
02	Effect of microalgae on *in vitro* rumen fermentation, gas and methane production **Mr Ishaya Gadzama**
03	Estimation of methane abatement by Asparagopsis supplementation of grazing cattle **Dr Roger Hegarty**
04	Early gut colonisation of bacillus probiotics in broilers in a leaky gut model **Mrs Jacoba Bromfield**
05	Modelling the consequences of individual animal selection in commercial livestock farming systems **Mr Thomas Keogh**
06	A short-term broiler digestibility bioassay for calcium and phosphorus **Dr Wayne Bryden**
07	Dose and the efficacy of probotic Bacillus amyloliquefaciens strain H57 **Dr Wayne Bryden**

***Please note this program is correct at time of printing*

08	Effects of dietary supplementation of pure benzoic acid and resinated benzoic acid (Benzocal-50®) on growth performance in Ross 708 broilers **Dr Haijun Liu**
09	Performance of broilers fed diets, containing graded inclusion of feather meal, formulated on the basis of total or digestible amino acids **Miss Yiman Sun**
10	Bacillus probiotics: A promising alternative for improving animal health and productivity **Mr Charlie Tran**
2.00 - 3.30 pm	**Session 3: Microbiome and Immunity**
2.00 – 2.30	The intersections between rumen and human gut microbiota research: What goes around needs to come around for one health? **Dr Mark Morrison**
2.30 – 3.00	Malnutrition of pregnant cows and the impact on passive immunity transfer to calves **Dr Luis Prada Silva**
3.00 – 3.20	**Panel Discussion**
3.20 - 3.50 pm	***Afternoon tea*** ***Sponsored: Ridley***
3.50 - 4.30 pm	**Session 4: Contributed papers**
3.50 – 4.00	Managing the equine lactic acid challenge: an *in vitro* investigation into the effects of postbiotic supplementation on stabilising equine hindgut pH **Miss Lauren Sheridan**
4.00 – 4.10	Prepartum protein supplementation increases colostrum and IgG1 production in Brahman cows **Mr Latino Gastao Dos Santos Coimbra**
4.10 – 4.20	Impact of drying methods on nutritional composition of black soldier fly larvae as animal feed ingredient **Mr Ishaya Gadzama**
4.20 – 4.30	An improved method to estimate heat production by growing sheep **Dr Holland Dougherty**
7.00-10.00 pm	***Conference Dinner***
Friday 28 July 2023	
9.00-11.00 am	**Session 5: Feeding poultry and novel feed ingredients**
9.00 - 9.30	The challenge to reduce crude protein contents of wheat-based broiler diets **Dr Peter Selle**
9.30 - 10.00	Advances in prebiotics for poultry: role of the caeca and oligosaccharides **Dr Natalie Morgan**
10.00 - 10.30	The role of black soldier fly larvae protein and fat in companion animal nutrition: challenges and opportunities from an industry perspective **Dr Anna Sutton**
10.30 - 11.00	**Panel Discussion**
11.00 - 11.30 am	***Morning Tea*** ***Sponsored by: Feedworks***
11.30 - 12.40 pm	**Session 6: Contributed papers** ***Sponsored by: JEFO***
11.30 – 11.40	Dose-dependent enteric methane mitigation in grazing sheep supplemented with Asparagopsis taxiformis **Dr Daniel Sitienei**
11.40 – 11.50	A multi-component protease improved growth performance and feed cost savings on nutrient-reduced growing-finishing diets containing highly diversified ingredients. **Dr Roger Campbell**
11.50 – 12.00	The use of on-animal sensors to assess individual intake of supplements in beef cattle. **Mrs Tamara Freitas-Kirk**

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12.00 – 12.10	Impacts of feeding lauric acid on performance of late-finishing, Improvac-treated male pigs. **Dr John Pluske**
12.10 – 12.20	Towards the use of more sustainable protein source investigating the nutrient content and amino acid digestibility of soybean meals from various origins in broilers. **Dr Bob Swick**
12.20 – 12.30	Does the falling-number value impact the adjusted digestible energy content of weather-damaged wheats for pigs? **Dr Charles Rikard-Bell**
12.30 – 12.40	Acidification of Sheep Urine Using Negative Dietary Cation Anion Difference (DCAD) and Different Levels of Crude Protein (CP) in Live Export Diets. **Mrs Ifa Hanafi**
12.40 - 1.40 pm	***Lunch*** ***Sponsored by: Elanco***
1.40 - 3.00 pm	**Session 7: Nutrition of grazing ruminants** ***Sponsored by: Olssons***
1.40 – 2.10	Revisiting tropical pasture intake – what's changed in 50 years? **Dr Ed Charmley**
2.10 – 2.40	Multispecies forages in the dairy feedbase: What is the biological business case? **Dr Anna Thomson**
2.40 – 3.00	Panel discussion
3.00 - 3.30 pm	***Afternoon tea*** ***Sponsored by: APRIL***
3.30 - 5.00 pm	**Session 8: Circadian Rhythms and chrono nutrition** ***Sponsored by: UNE***
3.30 - 4.00	**Annison-Leng Oration, to reflect their contributions in ruminant nutrition**: The importance of circadian rhythm in dairy nutrition **Dr Kevin Harvatine**
4.00 - 4.30	Interactions of diet and time to achieve precision nutrition of poultry **Dr Amy Moss**
4.30 - 4.50	Panel Discussion
4.50 - 5.00	Close **Dr Fran Cowley**

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INVITED SPEAKERS

Dr Ed Charmley

Ed comes from a farming background in the UK and received his Bachelors from Aberdeen University and a PhD from The Grassland Research Institute near Reading. After immigrating to Canada he specialized in forage utilization from both grazed and conserved herbage. His particular interests lay in optimizing forage use in the diet with animal performance and beef quality. Since 2005, Ed has worked for CSIRO in northern Australia where he has focused on beef production in extensive, sub-tropical rangelands and savannas. He is based in Townsville. His current research activities lie in the use of technology to record hard to measure animal and environmental variables in the field and understanding livestock methane emissions from extensive grazing systems. He has published widely in the scientific and farming press and manages a broad portfolio of livestock research within the CSIRO Agriculture and Food business unit.

Dr Holland Dougherty

Holland Dougherty joined CSIRO's Future Protein Mission in January and is based out of St. Lucia. She has a background in animal-level and system-level models of animal production, metabolism, and sustainability, as well as life cycle assessment and statistical analysis in Python and R. She recently completed a postdoc at NSW DPI/the University of New England where she was part of a team revising Australian livestock feeding standards for ruminants to better predict variability in growth rates and body composition. A self-described “statistics nerd”, she is broadening her skills and expanding into machine learning and sensor/accelerometer data analysis. In her spare time, she enjoys bushwalking, gaming, and trying to recreate recipes she saw on cooking shows.

Dr Kevin Harvatine

Kevin J. Harvatine is Professor of Nutritional Physiology at Penn State University. He grew up on his family’s dairy farm in Pennsylvania and received his BS in Animal Science from Penn State. He earned an MS from Michigan State University and PhD from Cornell University.

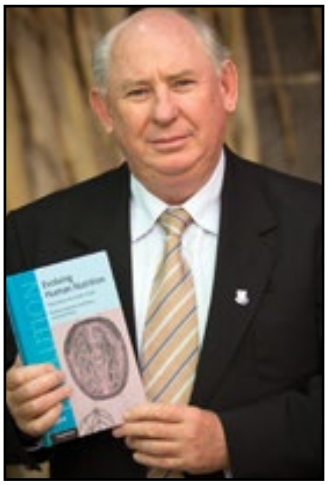
Dr. Harvatine’s research is focused on regulation of milk synthesis. His goal is to identify nutritional, environmental, and physiological factors that impact milk fat and protein yield and develop strategies to improve production, efficiency, and health. His research spans from applied nutrition to basic biology and provides both real-world applications to the dairy industry and a basic understanding of biological mechanisms.

Current ongoing projects focus on seasonal and circadian rhythms of feed intake and milk synthesis, effect of acetate and specific long-chain fatty acids on milk fat, omega-3 fatty acid metabolism, and management of diet-induced milk fat depression. His research program has been funded by USDA AFRI, commodity boards, and industry grants.

Dr Janet Howieson

Assoc Prof Janet Howieson is part of the Food Science and Technology team at Curtin University. She has worked on multiple post-harvest projects with the seafood industry, including in the areas of supply chain optimisation, new product development, processing innovation, quality and shelf-life, sustainable packaging and geographical provenance. Transformation of seafood waste and use in various sectors including in the aquaculture industry has also been a research priority.

Dr Neil Mann



Neil Mann recently retired as Professor of Human Nutrition in the School of Agriculture and Food Science, at the University of Melbourne. Having previously held the position of Professor of Nutritional Biochemistry and Head of Food and Nutrition Science at RMIT University for many years.

Neil has over 30 years' experience in nutrition research, co-ordinating clinical trials in the areas of long-chain fatty acids, obesity, diabetes, hunter-gather diets and aspects of metabolic syndrome. Having a farming background he also specializes in the connection between agriculture, food production and nutrition.

Professor Mann has provided his diverse expertise to many roles within the Nutrition Society of Australia (NSA), as a Trustee of the Asia Pacific Region International Life Sciences Institute (ILSI), and Scientific Director of the International Diabetes Institute - Food GI testing program.

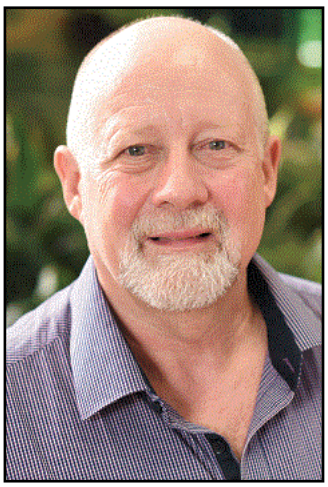
He was also a Visiting Research Fellow at Oxford University, School of Anthropology over a three year period researching human diet history and co-authoring a scientific text on the subject (Evolving Human Nutrition: Implications for Public Health: Ulijaszek, Mann & Elton, CUP 2012). He has authored over 80 refereed research papers in high impact factor international nutrition and medical journals, and presented at more than 100 national and international conferences, many as an invited speaker.

Professor Mann was one of a team of international professors who first provided rebuttal to “The Lancet” regarding the extreme negative health impacts of meat presented by the Global Burden of Disease (GBD, 2019) Risk Factors Collaborators, pointing out the serious flaws in the publication. This was followed up by his presentation at the international summit in Dublin and the subsequent “Dublin Declaration”.

Dr Natalie Morgan

Dr Natalie Morgan is currently Senior Lecturer in Animal Science at Curtin University, Perth. Prior to this role she was Lecturer in Animal Science and Research Fellow in Poultry Nutrition at the University of New England, Armidale. Her main area of interest is feed enzymes and carbohydrate chemistry in poultry diets. She completed her doctorate thesis and a year as a post-doctoral research fellow and lecturer at Nottingham Trent University, England, before moving to Australia. She is currently researching the use of xylanases to produce xylo-oligomers and the prebiotic effects of these in broiler chickens and laying hens, and factors that cause variation in feed ingredients, particularly focussing on non-starch polysaccharides.

Dr Mark Morrison



Mark Morrison's scientific expertise resides in the fields of microbial physiology, genetics, and genomics, with a career-long focus on the gastrointestinal microbiota of humans, ruminants, and other herbivores. He is committed to the translation of microbial genomic and metagenomic datasets into a sound biological framework, producing novel diagnostic, organismal, and enzyme-based technologies. During his academic tenure in the USA, he led the team that produced the first genome sequences for ruminal isolates of Ruminococcus and Prevotella spp.; these taxa are now widely acknowledged to also play a key role in establishing human gut "enterotypes". He returned to Australia in 2006 as a CSIRO Science Leader and was also one of CSIRO's five Capability Platform leaders (in Transformational Biology). During that time his research with CSIRO scientists, French and Australian clinicians produced a series of well-cited papers foundational to establishing the concept of gut microbial "dysbiosis" in Crohn's disease.

His team also produced a world-first: using DNA sequence data to direct the isolation of a "new" bacterium from a species-rich microbial community. He has been Professor and Chair of Microbial Biology and Metagenomics at the University of Queensland Frazer (nee Diamantina) Institute since 2013, and science lead for gastrointestinal function with the Princess Alexandra Hospital Department of Gastroenterology and Hepatology. Morrison was elected Fellow of the Queensland Academy of Arts and Sciences in 2022 and remains as Australia's representative (as a founding member) of the International Human Microbiome Consortium, in addition to his roles with other advisory and review groups for international research institutes, industry, and grant agencies.

Dr Amy Moss

Dr Moss is a postdoctoral fellow researching nutritional strategies to improve the efficiency and sustainability of chicken-meat and egg production at the University of New England. Dr Moss' current research projects include exploring the precision nutrition of poultry, including the interactions between nutrition, physiology and genetics

Dr Ian Lean

Ian's general interests are in improving the profitability of ruminant production. He is Managing Director of Scibus, a company that conducts research and consults to dairy and beef producers, within and outside of Australia. He is an adjunct Professor at the University of Sydney and has more than 200 published works and around 12,000 citations.

He has extensively published on the interactions of nutrition with production, reproduction and health and been a keynote speaker at numerous international conferences in the USA, Canada, UK, EU, South America, South Africa, Australia and New Zealand, presenting on those topics, meta-analysis and study design.

In the field, Scibus consults with dairy and beef producers across Australia and other countries. Scibus is also recognized for leadership and excellence in meta-analytic research and works with public and private research organizations to deliver high quality research on transition nutrition of dairy cows, calf feeding and ruminal acidosis.

Since 1990, Ian has also been active in discussing the implications of increasing population on food availability and the roles of technology and activism in addressing these. He has a deep knowledge of factors influencing farm profit from a biological and economic perspective and has presented nationally and internationally on these. He likes cows and people and tolerates most other species.

Dr Anna Sutton

After 18 years leading Kemin Nutrisurance Pet Food Division across the Asia-Pacific, where she gained extensive experience across petfood and petfood raw materials, Anna Sutton launched Sustainable Pet Food Ingredients (SPFI). Through SPFI. Anna provides product development and nutritional formulation support from concept to launch for petfood brands locally and internationally, across multiple product formats.

In addition to formulation, Anna has a strong interest in raw materials and works with clients to develop and launch novel and sustainable raw materials for petfood applications, bringing them insights from a formulation, market, food safety and oxidation perspective. Anna gained her undergraduate degree from University of Glasgow in Physiology and her PhD from the University of Manchester in cell physiology.

Dr Anna Thomson

Anna is a research scientist working at the Ellinbank Smart Farm for Agriculture Victoria Research with an interest in optimising pastures. She originates from the UK and completed her PhD at the University of Reading in 2017 on the topic of feeding legume forages to dairy cattle, namely clover and lucerne silages. She continued to work at Reading in a post-doctoral position, overseeing two long-term research projects:

The DiverseForages Project on multispecies swards; and a long-term study on low protein diets for dairy cattle. The DiverseForages project was a five-year undertaking exploring the agronomy and feeding value of multispecies pastures. In 2019 she moved to Melbourne, Australia and now works on novel technologies for monitoring pasture quantity and quality within the Pasture Smarts project – a part of the Dairy Feedbase initiative.

Her future research plans include testing multispecies forages in an Australian dairy context to determine if they can be a productive, resilient, and environmentally beneficial forage source that is well adapted to future climate scenarios. The topic of multispecies pastures will be the focus of her talk at this conference, and she will present a review of the latest research in this promising area.

Dr Ha Truong

Dr Ha Truong is a Research Scientist at CSIRO with expertise in novel feed ingredients and digestive physiology and function of shrimp and poultry. Her current research focuses on the development of sustainable ingredients for use in aquaculture feed, including marine-derived ingredients, microbial biomass, single cell proteins and by-products.

She is also developing techniques for assessing shrimp ingredient digestibility, gut transit rate and feed attraction.

Dr Robert Van Barneveld

Robert van Barneveld is Group CEO and Managing Director of the Sunpork Group of Companies which includes SunPork Farms (farming approximately 51,000 sows across Australia and 3,000 sows in New Zealand), PIC Australia, Swickers Kingaroy Bacon Factory and SunPork Fresh Foods. Collectively the Group produces approximately 20% of Australia's pork.
In addition to his work with SunPork, Dr van Barneveld is also a Director of the Australasian Pig Research Institute Ltd, Chairman of the Autism CRC Ltd and is a Non-Executive Director of the ASX-listed Ridley Corporation (Australia's largest stockfeed manufacturer). He was formerly a Director of Australian Pork Ltd and Porkscan Pty Ltd.

In addition to his corporate roles, Robert has extensive experience as a scientist and nutritionist for pigs and poultry in Australia and overseas and specializes in the characterization and understanding of feed ingredients. He has worked widely with feed mills and livestock producers in Asia over the past 30 years and has a PhD in amino acid nutrition of monogastric.

Robert is a Fellow of the Australian Institute of Company Directors, a Fellow of the Australasian Pig Science Association, a Life Member of Autism Queensland, is a Registered Animal Nutritionist and is an Adjunct Professor within both the School of Environmental and Rural Science at the University of New England and the School of Agriculture and Food Sciences at the University of Queensland.

Dr Peter Selle

Peter Selle joined the Poultry Research Foundation within The University of Sydney in 2002 and was appointed Adjunct Associate Professor in 2011. Peter has published around 150 papers in peer-reviewed journals since 1999. His initial interest was in dietary phytase and exogenous phytase, then sorghum as a feed grain for chicken-meat production, the practice of whole grain feeding and starch: protein digestive dynamics.

However, since 2015 there has been an increasing focus on the development of reduced-crude protein broiler diets. There are both compelling reasons and, equally, daunting obstacles to the development and acceptance of reduced-crude-protein diets, especially when based on wheat. In 2022, Peter was awarded the degree of Doctor of Veterinary Science for his thesis "Towards sustainable chicken-meat production".

Dr Luis Silva

Dr Luis Silva is an Associate Professor at QAAFI, University of Queensland, leading research in ruminant nutrition. Luis comes from a coffee and dairy farm and brings perspective from another major producer of beef, Brazil, where he had a previous appointment at the University of Sao Paulo. With large international experience, Luis has spent a sabbatical year at AgriBio, Melbourne, and has completed his PhD at Michigan State University, working with the nutritional/physiological modulation of ruminant development. Luis has considerable research linking cattle nutrition with physiological mechanisms and genomic tools and has coordinated several research projects investigating mechanisms to improve the efficiency of tropical cattle production.

His work is published in 51 peer-reviewed scientific articles and several book chapters. Luis has also acted as the main advisor for 7 PhD students and 16 Master students.

Session 1

The societal role of meat and the genesis of the Dublin Declaration

Neil Mann[1]

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The current concern and re-evaluation of the role of animal-sourced foods for human consumption has arisen as a result of the Lancet publication on the Global Burden of Diseases, Injuries, and Risk Factors Study (Murray *et al.* 2020), which alarmingly estimated premature death and disability to red meat consumption at 36 fold higher than previously estimated. This finding was strongly challenged by a concerned group of scientists (Stanton, Mann *et al*. 2022) who raised serious doubts about the conduct of the GBD study and lack of adequate peer review. These concerns led to a subsequent international summit (Societal Role of Meat - Dublin, October 2022), which examined the science behind the substantial benefits of animal-sourced foods for human health and the importance of animals in human farming practices. Particular emphasis of the summit was the evaluation of the critical role of meat in human evolution over the last 3.5 million years and current day reliance on animal foods for a range of specific micronutrients as well as protein with a complete amino acid profile.

The societal role of meat: the Dublin Declaration with an Australian perspective

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It is clear that the societal role of meat is being challenged with ideological and simplified logic without substantiation from robust data-driven science. With this background, the international summit titled 'The societal role of meat – what the science says' was held in Dublin, Ireland, during October 2022, to provide evidence-based evaluations and the Dublin Declaration was signed by over 1000 scientists. In this paper, we provide a synopsis of the summit and then give context for evaluating the societal role of meat in Australia. The key themes of the summit were the essential roles of meat in (1) diet and health, (2) a sustainable environment and (3) society, economics and culture. Evidence clearly showed the role of meat as a nutrient-dense source of high-quality protein and micronutrients that can be safely consumed by humans. Further, the complementary role of livestock in agricultural systems was highlighted with both plant- and animal-based agriculture reliant on each other to maximise the efficient production of food. Thus, from both an Australian and world perspective, very little food considered to be human-edible is fed to livestock. The role of livestock in rural societies across the world was emphasised to underpin regional and national economies, with particular importance in those countries with developing economies to facilitate growing wealth to 'step out' of poverty and provide gender equality. Meat production, particularly from ruminants, is a critical part of Australian primary production and it is concluded that the Dublin Declaration is highly relevant to Australia. Finally, concern regarding future funding and organisation of research and extension is discussed. There is a need to continue funding highly collaborative programs that bring a broad range of disciplines together, in conjunction with undergraduate and postgraduate teaching to underpin the social license to operate for meat and livestock production.

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Modelling a role for animal sourced food in sustainable diets

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The role of livestock in sustainable food systems is an area of ongoing development, requiring a careful balance of assessment at the animal, system, and human nutrition/wellbeing levels. However, such assessments are made more difficult by the lack of consensus in methods and perspectives, and many studies focus on only one of the above levels, leading to a "race to the bottom" focus to minimize impacts in terms of carbon footprint or other single indicators, many of which are poorly correlated (Ridoutt *et al*. 2017, Harrison *et al*. 2021). This misses the biophysical flows between systems, supply chains and/or stages of production, leading to biased results that may not reflect the true context and impact of food production (Harrison *et al*. 2021). To address this, a circular agriculture/circular economy perspective can be applied, specifically capturing nutrient flows and recycling of mass and nutrient between and within food chains or other processes (Van Zanten *et al*. 2018, 2019). Such methods can be used to compare the net impacts of different proposed changes on not just specific product systems, but product sectors, or even on a global level.

Sustainability must also be defined in terms of the metrics used and their context. Assessing systems or products without factoring in the "why" of a product can lead to simplistic, inaccurate comparisons that mask the underlying biophysical drivers of such differences, leading to incorrect policy and/or consumer messaging (Harrison *et al.* 2021). Assessment and comparison of the sustainability and impacts of specific foods must be defined in terms of the metrics used and their context, such as variation in nutrient quality/density between products, and the different roles foods play in human diets and cultural practices (Biesbroek *et al*. 2023). For example, comparing land required to produce a kilogram of beef to that used for poultry or nuts ignores differences in potential productivity and suitability for use as cropland. Instead, rankings based on total land use may show the opposite when products are compared in terms of arable land usage and scarcity (Ridoutt & Navarro Garcia 2020, Lee *et al*. 2021). Similar issues arise in relation to water use (Ridoutt *et al*. 2018) and greenhouse gas emissions (del Prado *et al*. 2023).

Such context and perspective are key when examining animal-sourced foods, which account for 39% global protein intake (FAO, 2023) and are a vital source of high-bioavailability vitamins, minerals, and essential fatty acids (White & Hall 2017, Leibe *et al*. 2020), particularly for marginalized populations at higher risk of malnutrition (Adesogan *et al*. 2020). Livestock also play an important role in reducing food waste: 1/3 of world livestock diets are human-inedible crop residues and byproducts, which livestock turn into high-quality protein while minimizing food-feed competition (Mottet *et al*. 2017, 2018). Modelling the circular aspects of livestock agriculture and their role as upcyclers of human leftovers into food and fertilizer is essential to obtaining accurate assessments of current and future food systems, but such assessments are still an emerging area of the literature.

Holistic assessment of the net impacts of proposed changes to food production systems must include the net impacts on three specific levels: a) the animal level (impact of changing feeds/management on feed intake, metabolism, efficiency, animal-level emissions, and product quality), b) system-level (system-level emissions, land/water/resource use, nutrient flows in/out), and c) the human food supply (quantity and quality of essential nutrients supplied, ensuring that the socio-cultural and nutritional needs of all populations are met, realistic assumptions re: human diets and essential/discretionary intake). Many studies include one or two of the above aspects, but those considering all three are far fewer. To truly assess the sustainability of food systems, all three levels of impact must be considered to ensure that assumptions about animal performance and product quality hold true with regard to larger-scale assumptions about efficiency, sustainability, and human nutrient supply.

Net protein contribution from an intensive Australian pork supply chain

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Debate surrounding the adverse consequences of feeding human-edible feedstuffs to livestock can be addressed through calculation of the net protein contribution (NPC) of the production system. If the NPC is greater than 1.0 for the production system, then there are net benefits from the system for human populations with an ever-increasing requirement for protein and amino acids.

The aim of this paper was to calculate the NPC for an Australian pork supply chain on the basis of the unique characteristics of Australian ingredients. While calculation of NPC is not complex, intimate knowledge of the source of the nutrients and their quality, and interpretation of their human-edible protein fractions is essential if an accurate estimate is to be achieved. The NPC for an Australian pork supply chain was calculated using (a) actual, published or estimated values for human-edible fractions of feedstuffs, (b) the percentage of protein available within raw materials considered to be human edible, (c) recommended amino acid scoring patterns for infants, adolescents and adults, (d) published, and calculated from standard reference nutrient databases, digestible indispensable amino acid scores, (e) carcase yields and carcase composition from published studies, and (f) actual feed formulations, feed volumes and production data from a large Australian pork supply chain. The NPC for the assessed Australian pork supply chain was 3.26. This means the supply chain generates more than three times the human-edible protein it consumes in the process.

This NPC is higher than previously published values, largely because of the composition of Australian pig diets, but demonstrates the positive value that livestock production systems make to human food supply. Livestock systems are often targeted as net consumers of vital nutrients such as protein and amino acids and the diversion of these nutrients from human diets. If production systems focus on the utilisation of waste streams, co-products and human-inedible feedstuffs, then they can make a net contribution to human-edible protein supply.

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Session 2

Aquaculture nutrition in Australia: Challenges and trends

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This review provides an outline of some of the challenges facing nutritionists in the Australian aquaculture industry. It commences with a brief description of how aquaculture nutrition differs to that for terrestrial livestock – the challenges of providing nutrition in aqueous environments, the diversity of species and the high trophic level of most.

Specific challenges of aquaculture nutrition are then discussed in further detail, including the difficulty of measuring feed intake and digestibility, the limited ability to use carbohydrates for carnivores, and the specific requirements of species for lipids including cholesterol, phospholipids, long-chain PUFA and carotenoids.

The review then examines how environmental, social and governance (ESG) concerns are leading to new trends in nutrition for the Australian industry. This includes topics such as the replacement of wild-caught fish meal and fish oil (FMFO), in terms of both sources of omega-3 lipids and protein. For the former, possible solutions include greater use of seafood trimming, algal oil, and GMO derived products. For the latter, solutions can include use of livestock render, plant protein meals, fermented products, and insects.

Nutrient discharge is also a concern for the industry and nutritionist can assist by improving digestibility and nutrient retention from feeds. Finally, the carbon footprint of aquaculture is leading to new directions for industry and in turn for the field of aquaculture nutrition.

Full manuscript available at: https://www.publish.csiro.au/an/pdf/AN23078

Market driven assessment of alternate aquafeed ingredients: Seafood waste transformation as a case study

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With an increase in worldwide demand for seafood, the current plateau (or decreased) production from wild harvest fisheries has resulted in rapid growth of the aquaculture sector. Aquaculture relies on quality ingredients such as fishmeal (FM), but cost and environmental concerns has led to the investigation of a variety of alternate plant, animal by-product and microbial sources as aquafeed ingredients. Evaluation of alternative aquafeed investigations has traditionally focussed on the growth and immune status of the fed fish and has not always considered market driven assessments of the final edible product. One of the commonly researched groups of alternative ingredients is seafood waste which, after transformation, has beneficial nutritional characteristics. Transformation, which includes rendering, enzyme hydrolysis and as a feed source for insects and microbial species, is intended to provide stability and enhance logistical feasibility of the waste as an aquafeed ingredient. This review discusses transformed fish waste in aquafeeds and queries the inattention to some of the market and end-user implications (composition, edible safety and quality, sustainability metrics and consumer perceptions) of this approach.

Full manuscript available at: https://www.publish.csiro.au/AN/AN23064

Session 3

The intersections between rumen and human gut microbiota research: What goes around needs to come around for one health?

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We live in a microbial world, with their products and services central to both the structure and function of natural and managed ecosystems. The impact from microbes growing anaerobically was first characterised in the 19th Century, but it was the development of techniques by Hungate (as modified by Bryant) in the mid-20th Century that enabled the culture-based study of the microbes from the rumen and human gut.

In some respects, the study of these microbial habitats was conducted as “parallel universes” throughout the remainder of the 20th Century, driven in part by the divergence in the key research priorities and outcomes ascribed to each host. For example, rumen microbes in the context of animal nutrition and productivity, and the human gut microbiota particularly in the context of infection and inflammation affecting health and disease. However, there have also been key periods of intersection between the interests in rumen and human microbiota that have been synergistic to the field of microbiology in general, and the study of host-microbe interactions, particularly.

The consequences of these intersections include the era of cultivation-independent assessments of the microbiota and more recently, “microbiome” research. However, what goes around also comes around, highlighted by the need to go “back to the future” to provide the expertise in rumen and human gut microbiology that will bring microbial genomes to life, and translate the microbiome into meaningful one-health outcomes.

Malnutrition of pregnant cows and the impact on passive immunity transfer to calves

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Nutritional management in rangeland beef cattle systems prioritizes optimal body condition scores at calving for improved fertility and reproductive success. However, this focus often overlooks short-term dietary deficiencies before calving, which can lead to adverse outcomes for neonatal calves. This review explores the effects of beef cow malnutrition during the periparturient period on colostrum production, lactation onset, and passive immunity transfer to calves. Additionally, it discusses the long-term impact of such malnutrition on the offspring. By understanding how nutritional interventions affect the transition from gestation to lactation, it becomes possible to enhance calf health and survival in arid tropical environments through improved nutritional regimens.

Research reveals that commonly occurring short-term dietary restrictions, particularly protein deficiencies, can disrupt the hormonal equilibrium resulting in reduced colostrum volume and quality, hindering calf growth and increasing mortality risks. Furthermore, dietary restrictions during this period affect critical physiological processes like mammary gland blood flow and fetal small intestine development. The review explores how these constraints influence colostrum production and immunoglobulin absorption by neonatal calves.

Additionally, it highlights the significance of addressing other common nutrient deficiencies such as phosphorus and water and investigates the potential benefits of supplementing microbial products to enhance rumen function and protect cows from inflammation. Ultimately, addressing malnutrition during pregnancy is essential to prevent negative impacts on offspring performance, including alterations in carcass composition and muscle marbling. Consequently, cattle producers who aim for superior muscle marbling in the carcass using costly genetics should give priority to enhancing nutritional programs for late-pregnant cows.

In conclusion, a comprehensive understanding of the effects of malnutrition during the periparturient period on colostrum production, passive immunity transfer, and overall calf health is crucial for developing effective nutritional interventions that improve colostrum production, passive immunity transfer, and overall calf health in rangeland beef cattle systems.

Session 4

Managing the equine lactic acid challenge: an *in vitro* investigation into the effects of postbiotic supplementation on stabilising equine hindgut pH

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Dysbiosis of the intestinal microbiome is an identified precursor to hindgut acidosis and subsequent illnesses such as laminitis, colic and colonic ulcerations. Microbial diversity and the degree of fermentation are heavily influenced by diet, with high non-structural carbohydrate rations the greatest risk to microbial imbalance.

The inclusion of a postbiotic additive could provide an accessible and affordable solution to maintaining healthy gastrointestinal microbe populations and reduce the incidence of hindgut acidosis, with positive results observed in studies surrounding gastrointestinal support of ruminants, swine and poultry (Humam *et al.* 2019; Wegh *et al.* 2019). It was hypothesised that the inclusion of postbiotic in batch culture would reduce the degree of pH decline and lactate accumulation during fermentation. *In vitro* batch cultures with equine faecal inoculant were prepared with either low starch (LS) or high glucose (G) substrate to represent normal and acidic fermentation respectively.

Treatments of 2.8×10^{-4} g (T1) and 5.6×10^{-4} g (T2) of postbiotic Diamond V XPC were added to each substrate to investigate the effects on pH, gas, volatile fatty acid (VFA), and D-lactate production against controls when incubated at 39 °C for 48 hours.

Cultures containing G had a significantly ($P < 0.001$) quicker decline in pH than LS at 6 and 12 h (Figure 1). Postbiotic concentration had a linear relationship with pH decline in G and observed significantly higher ($P < 0.001$) pH of +0.15 for T1 and T2 recording +0.66 and +0.27 compared to the control at 6 h (pH 5.03) and 12 h (pH 4.88) respectively. VFA analysis (mmol/L) showed increased production of propionic, and acetic acids ($P < 0.001$) across substrates with postbiotic at time 12 h and 36 h. D-lactate concentrations were greater in G than LS ($P < 0.001$) at 12 h and dropped significantly in G at 36 h ($P < 0.001$). Postbiotic inclusion in G reduced lactate at 36 h ($P < 0.001$) but not 12 h.

Under the conditions of this study, the addition of postbiotic Diamond V XPC reduced the severity of pH decline in high non-structural carbohydrate rations and increased production of VFAs, however it did not inhibit D-lactate accumulation at 12h, providing some evidence of protection of lactate utilising bacteria to moderate pH, but not inhibition of lactate producers.

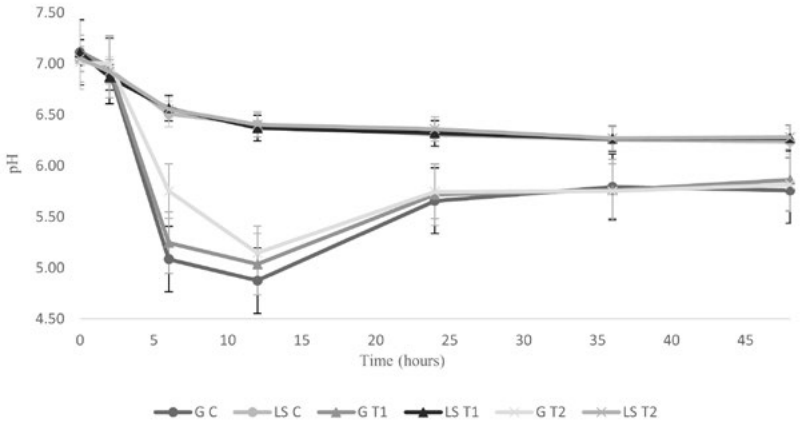

Figure 1:

The effect of postbiotic treatment levels on mean pH fluctuations of fermentation in batch cultures inoculated with glucose and low starch substrates over 48 hours.

Error bars represent standard errors.

LS= Low starch; G = Glucose; C = control; T1: treatment level 1; T2: treatment level 2

1. Humam, AM, Loh, TC, Foo, HL, Samsudin, AA, Mustapha, NM, Zulkifli, I, Izuddin, WI (2019) Effects of feeding different postbiotics produced by Lactobacillus plantarum on growth performance, carcass yield, intestinal morphology, gut microbiota composition, immune status, and growth gene expression in broilers under heat stress. Animals 9, 644

2. Wegh, CA, Geerlings, SY, Knol, J, Roeselers, G, Belzer, C (2019) Postbiotics and their potential applications in early life nutrition and beyond. Int. J. Mol. Sci. 20, 4673.

Prepartum protein supplementation increases colostrum and IgG1 production in Brahman cows

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The most consistent risk factor for high neonatal calf mortality rates in tropical Australian beef cattle systems is nutritional deficiencies in pregnant cows, and it is believed to be mediated by delayed colostrum and milk delivery to neonates (Fordyce *et al*., 2022; Muller *et al*., 2022). Nonetheless, there is limited information on prepartum supplementation's effect on Brahman cows' colostrum quality and the modulating hormonal mechanism (Silva *et al*., 2022).

This study evaluated the effects of late pregnancy supplementation on regulatory hormone profiles, especially progesterone (P4), IgG1 production and delivery to calves, and early-life calf growth. Late-pregnant Brahman cows (n=36) were stratified on live weight (519 ± 45.43 kg) into four blocks, each assigned randomly to 3 pens (experimental units) per treatment. Pens were randomly allocated to NoSupp, *ad libitum* Rhodes grass hay; Protein, NoSupp plus 1 kg/d of a 39% crude protein supplement; ProteinY, Protein plus 14 g/d *Saccharomyces cerevisiae* fermentation products (NaturSafe, Diamond V, USA).

After birth, the newborn calves were allowed to suckle naturally without interference from the research team for at least 6 hours. Pregnant cow plasma was sampled three times per week. Calf plasma was sampled twice by five days of age, and calves were weighed several times before two weeks of age. Data were analysed using the linear mixed-effects model, function *lmerTest*-package in the R environment within RStudio (R version 4.0.2). Pregnant cow plasma P4 was modelled fitting a mixed segmented model with treatment and days prepartum as fixed effects, and block as random. Immediate prepartum protein supplementation of cows increased plasma urea (4.2 v 2.5 mol/L; P < 0.01), decreased non-esterified fatty acids (0.9 v 1.1 Meq/L; P < 0.01), increased colostrum IgG1 (103 v 73 g/L; P = 0.03), tended to increase colostrum protein concentration (12.7% v 10.7%; P = 0.07), and had no effect on colostrum fat concentration (2.56% v 3.67%; P = 0.13).

Protein supplementation also increased the calf growth rate (1.2 v 1.0 kg/d; P = 0.01). Yeast fermentation product inclusion in the supplements increased calf plasma IgG1 (50 v 32 g/L; P = 0.02) and tended to increase plasma gamma-glutamyl transferase (2189 v 773 IU/L; P = 0.06), total protein (82 v 73 g/L; P = 0.08) and globulin (58 v 46 g/L; P = 0.09).

To further investigate the association between prepartum plasma P4 and transfer of passive immunity, calves were classified into three groups according to plasma IgG1 (Low, Medium, High). Protein supplementation reduced plasma P4 one day before calving (3.2 v 6.2 nmol/L; P = 0.05) and pre-calving plasma P4 was inversely related to the transfer of passive immunity
(P = 0.01; Figure 1)

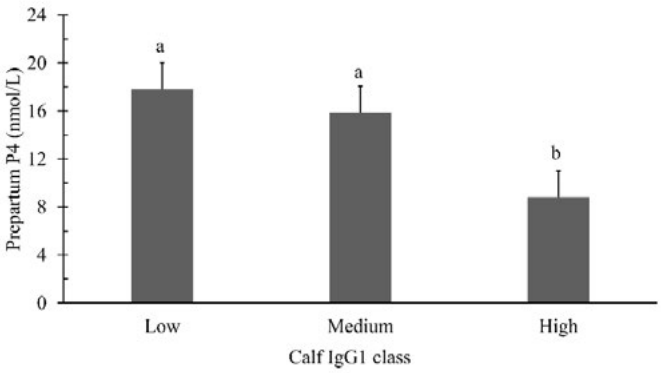

Figure 1. The relationship between plasma progesterone one day before calving and calf plasma IgG1

We concluded that prepartum protein supplements increase colostrum quality and improve the passive transfer of immunity to calves, as well as their growth, in Brahman cows consuming low-quality diets.

1. Fordyce G, et al (2022) Anim. Prod. Sci. 63 (4), 365–377
2. Muller J, et al (2022) Repro. Domest. Anim. 57 (10), 1176-1166
3. Silva LFP, et al (2022) Anim. Prod. Sci. 62 (10), 983–992

Impact of drying methods on nutritional composition of black soldier fly larvae as animal feed ingredient

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The animal feed industry relies heavily on soybean meal and fishmeal as the main sources of protein, but these ingredients are costly and scarce. Therefore, finding alternative protein sources that are environmentally friendly and sustainable is crucial for the production of meat, milk and eggs. Insects have been considered as potential feed resources that can provide protein and fat for animals (Van Huis and Oonincx, 2017).

Among insects, the black soldier fly (BSF) larvae *Hermetia illucens* L. can convert organic food waste into high-quality protein and fat for livestock, aquaculture and pet feed. However, the nutritional value of BSF larvae as a feed ingredient may depend on various factors, such as the rearing substrate and the methods used for killing and drying (Larouche *et al*., 2019; Huang *et al*., 2019) and product fractionation (e.g., defatting).

To the best of our knowledge, there has been no study to date conducted in Australia to compare the post-harvest drying technologies and the nutritional value of BSF larvae as animal feed ingredients. The present study evaluated the effect of four drying methods: 1) freeze-drying (FD), 2) low-temperature air-drying (LTA), 3) high-temperature oven-drying (HTO), and 4) microwave-drying (MD) on the nutritional composition of BSF larvae.

Organically raised BSF eggs (20 g) were grown to neonates on Mobius farms' standard nursery feed under controlled conditions (26°C temperature and 60% relative humidity).

A standard feed substrate consisting of a blend of pre-consumer food wastes from catering and restaurant businesses, farm gate wastes of vegetables and fruits, and a small amount of chicken starter mash was used to feed the neonate larvae from day 10 up to the grow-out stage. On day 20, the BSF larvae were separated from the frass using a mechanical sieve and the total live weight was determined (42 kg). The BSF larvae were progressively euthanized (blanched in water at 90°C for 40 seconds, followed by cooling in water at 15°C. The blanched and cooled BSF larvae were airdried and stored at -20°C in sealed plastic bags. Four drying methods were conducted in batches. Firstly, 2000 g of the frozen BSF larvae were oven-dried at 55°C for 18 h (LTA). Secondly, 750 g of the frozen BSF larvae were oven-dried at 170°C for 25 mins (HTO). Thirdly, 10,000 g of the frozen BSF larvae were freeze-dried for 72 hours in a commercial facility.

Lastly, 1000 g of the frozen larvae were dried in a commercial microwave oven for 20 mins. The proximate composition of the dried BSF larvae was evaluated following methods # 942.05; # 920.29 and # 920.29 of the AOAC (2002) and Van Soest *et al.* (1991) standards. Data were analyzed using the Mixed Model procedures (PROC MIXED) of SAS (SAS Inst. Inc., 2023).

The crude protein content was not affected by drying methods ($P = 0.45$), averaging 48.2 ± 0.36% DM, which was higher than those reported by Chia *et al*. (2020). This could be attributed to the rearing substrate (Barragán-Fonseca *et al*., 2019) and processing method (Son *et al.*, 2023). However, the crude fat and metabolizable energy content were influenced ($P < 0.05$) by drying methods.

The LTA larvae had greater ($P = 0.002$) crude lipid content (29.8 ± 0.45% DM), which resulted in higher ($P = 0.001$) metabolizable energy content (19.60 ± 0.11 MJ/kg DM) compared to the other drying methods. Drying is a common method to preserve insect products for longer periods of time (Hernández-Álvarez *et al*., 2021).

Overall, the results highlight the importance of selecting the appropriate processing methods to preserve the nutritional value of BSF larvae as a sustainable alternative to scarce and expensive protein sources such as soybean meal and fishmeal.

Table 1. Proximate composition of BSFL produced using different drying methods						
	Drying methods					
Parameters	**LBF-FD**	**LBF-LTD**	**LBF-HTD**	**LBF-MWD**	**SEM**	**P-value**
Moisture, %	3.87[b]	3.47[a]	5.57[d]	4.20[c]	0.07	<.0001*
Crude protein, % DM[1]	47.7	48.4	48.5	48.2	0.36	0.451ns
Crude lipid, % DM	28.4[b]	29.8	26.6[c]	26.5[c]	0.45	0.002*
Crude fibre, % DM	5.17[c]	5.07[c]	5.90[a]	5.53[b]	0.12	0.004*
Ash, % DM	8.80[a]	7.83[c]	8.87[a]	8.33[b]	0.07	<.0001*
NFE[2], % DM	9.90	8.87	10.13	11.47	0.60	0.087[t]
ME[3], MJ/kg DM	19.1[b]	19.6[a]	18.6[c]	18.8[c]	0.11	0.001*
[abcd]means within the same row with different superscripts differed significantly (P ≤ 0.05)						
*Significant; nsNot-significant; tTended; 1DM = Dry matter; 2NFE = Nitrogen-free extract = 100 – (Crude protein + Crude fat+ Crude fibre + Ash); 3ME = Metabolizable Energy; LBF-FD = Larvae Blanched Frozen-Freeze Dried; LBF-LTD = Larvae Blanched Frozen-Low Temperature Dried; LBF-HTD = Larvae Blanched Frozen-High Temperature Dried; LBF-MWD = Larvae Blanched Frozen-Microwave Dried; SEM = Standard error of mean (n = 3); MJ = Megajoules; kg = kilogram						

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An Improved Method to Estimate Heat Production by Growing Sheep

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Livestock feeding systems calculate energy transactions as the sum of energy used for maintenance and growth/production, with associated efficiencies (k_m and k_g) for the conversion of feed energy toward these purposes (Freer *et al* 2007, NASEM 2007). These efficiencies reflect the amount of heat (HP) produced from using metabolizable energy from feed (MEI) for maintenance and gain. This approach attributes variation in HP to variation in MEI and dietary energy density (M/D). However, in growing animals, HP also arises from changes in body composition (fat and protein) and composition of gain. A simple way has been devised to combine these two approaches to calculate total HP in growing sheep.

A mechanistic, dynamic model was developed to calculate body composition in growing ruminants (Oddy *et al* 2022). This model contains a fat pool (*f*) and three protein pools based on metabolic activity: muscle (*m*), viscera (*v*), and wool (*w*), and calculates HP internally from change in protein and fat pools and MEI.

In the model, HP (MJ/d) is calculated as:
$HP = b_1 \times m + b_2 \times v + (1-k_m) \times MEI + (1/k_p-1) \times (d_p/dt) + (1/k_f-1) \times df/dt$

Where (b1 x m + b2 x v) represents fasting heat production (FHP), which is influenced by effects of prior nutrition on muscle and visceral mass. Heat associated with feeding (HAF) is (1-km) x MEI, where km may be calculated from M/D as in Freer *et al* (2007). Heat associated with product formation and change in body composition (HPE) is calculated as ((1/kp-1) x (dp/dt) + (1/kf-1) x df/dt), where kp and kf are the partial efficiencies of protein gain and fat gain. Protein gain is the sum of change in *m*, *v*, and *w*, and fat gain is equal to net energy available for gain minus dp/dt.

When this model was fitted to the data from growing sheep described in Dougherty *et al* (2022a,b), optimal estimates for k_f and k_p were 0.7 and 0.4, respectively. The value of k_m was 0.7 and did not change with M/D, as seen in Clayton et al (2022).
In this approach the HP from MEI that contributes to the energy cost of maintenance is applied at all feeding levels. This enables HP associated with gain to be separated into the three sources of HP above: FHP, HAF, and HPE. This allows for more realistic representation of the dynamic contributions of MEI, protein mass, and changes in body composition to variation in HP.

The model performs similarly to the empirical model of Freer *et al* (2007) for predicting performance of growing lambs (Dougherty *et al* 2022a,b) (Table 1), but does so more flexibly).

This model reflects the parts of variation in HP that arise from feed, the animal, and the interaction of animal x feed, rather than assigning all variation to the feed as is seen elsewhere (Freer *et al* 2007, NASEM 2007), thereby improving representation of energy flows and sources of HP in growing animals. Calculating HP from independently estimated processes, with HAF equivalent to $1-k_m$ applied across all levels of feeding and assigning direct cost of fat and protein gain is more flexible than current systems. This results in a simpler and no less accurate way to predict body composition and energy requirements in growing animals than traditional feeding systems.

	Protein	Fat	Empty Body Weight
Revised Model	6.76%	16.31%	6.43%
Freer *et al* 2007	9.34%	15.04%	7.89%

Table 1. Root Mean Square Prediction Error (% Observed Mean) for protein, fat and empty body weight for the revised Model and Freer et al (2007).

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Session 5

The challenge to reduce crude protein contents of wheat-based broiler diets

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The challenge to reduce crude protein (CP) contents of wheat-based broiler diets is both justified and formidable because the performance of broiler chickens offered reduced-CP, wheat-based diets is usually compromised.

Moreover, broiler chickens offered wheat-based diets do not accommodate CP reductions as well as do those offered maize-based diets; this appears to stem from the higher protein concentrations and more rapid starch digestion rates of wheat. The higher protein concentrations of wheat than maize result in elevated inclusion levels of non-bound (synthetic, crystalline) amino acids (NBAA).

This may be an impediment, because non-bound and protein-bound amino acids are not bioequivalent and intestinal uptakes of NBAA are more rapid than their protein-bound counterparts. This leads to post-enteral amino acid imbalances and the deamination of surplus amino acids, which generates ammonia (NH_3).

Because NH_3 is inherently detrimental, it must be detoxified and eliminated as uric acid, which attracts metabolic costs. Moreover, inadequate NH_3 detoxification may seriously compromise broiler growth performance. Also, consideration is given to some intrinsic wheat factors, including soluble non-starch polysaccharides, amylase–trypsin inhibitors and gluten, that may hold relevance.

Several strategies are proposed that may enhance the performance of birds offered reduced-CP, wheat-based diets, including capping dietary starch:protein ratios, blending wheat with sorghum, whole-grain feeding in association with phytase, dietary inclusions of L-carnitine and the use of protected or slow-release amino acids. In future research, it should prove instructive to compare different wheats with a wide range of protein contents that, importantly, have been fully characterised for relevant parameters, to ascertain the most appropriate properties.

The successful development and adoption of reduced-CP, wheat-based diets would be an enormous advantage for the Australian chicken-meat industry as it would diminish the huge dependence on imported, expensive soybean meal.

Full manuscript available at: https://www.publish.csiro.au/AN/pdf/AN22419

Advances in prebiotics for poultry: role of the caeca and oligosaccharides

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Prebiotics are non-digestible carbohydrates that selectively stimulate the growth of beneficial bacteria. Prebiotic supplementation into poultry diets results in decreased rate of pathogenic bacteria colonisation in the gastrointestinal tract. It also enhances production of volatile fatty acids and lactic acid, which provide the bird with energy. This results in improved host gastrointestinal health and productive performance.

Oligosaccharides are the most notable prebiotics in poultry nutrition. Examples of prebiotic oligosaccharides include xylo-oligosaccharides, fructo-oligosaccharides, and galacto-oligosaccharides. Oligosaccharides are derived from hydrolysis of non-starch polysaccharides (NSP). They are manufactured from plant sources, synthesised by physiochemical methods or enzymatic processes.

The effects of oligosaccharides occur primarily in the caeca; oligosaccharides bypass the small intestine and reach the caeca, where they are readily fermented by beneficial bacteria, such as those in family *Lactobacillaceae* and *Bifidobacteriaceae.* Caeca function is generally poorly understood, despite extensive reviews and studies in this field. A deeper understanding of the factors that influence ability of the caeca to effectively utilise oligosaccharides is warranted. This would allow new prebiotic products and NSP- degrading enzymes to be developed, targeted to specific diets and scenarios. This is required, given the lack of consistency observed in the outputs derived from different studies assessing oligosaccharide efficacy in poultry diets.

A key hinderance to progression in this field is that authors rarely analyse the oligosaccharide content and composition in the test diets and products, or in the bird's gastrointestinal tract.

This review examines the mechanisms behind how oligosaccharides induce prebiotic effects in poultry, by identifying the role of the caeca in NSP digestion and identifying the impact of oligosaccharides on caeca microbiota and short chain fatty acid composition.

Full manuscript available at: https://www.publish.csiro.au/AN/pdf/AN23011

The role of insect protein in companion animal nutrition: Challenges and opportunities

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The pet food industry is a significant and rapidly growing market, with global sales estimated at over $100 billion USD in 2020. The market size for pet food was estimated at 22.9 million tons in 2020.

The number of cats and dogs being fed commercial pet food is also on the rise, with an estimated 62% of cats and 68% of dogs being fed commercial pet food in the United States alone with an estimated value of AUD 2.3 billion in 2020.

This represents a growth of 3.3% from the previous year, and the market is expected to continue growing with a forecast compound annual growth rate (CAGR) of 3.4% from 2021 to 2025. The demand for high-quality, specialized pet food products has led to consistent year-on-year growth in the industry. With this, the increasing demand for commercial pet food on a global scale comes with growing sustainability challenges that must be addressed.

In this paper, we will examine some of the opportunities for the use of black soldier fly larvae (BSFL) meal and oil in pet food formulations to reduce the environmental impact of pet food and pet ownership and deliver nutritional and functional benefits to our pets.

Session 6

Dose-dependent enteric methane mitigation in grazing sheep supplemented with Asparagopsis taxiformis

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Red seaweed (*Asparagopsis taxiformis*), whose main bioactive compound is bromoform, has attracted much research attention in the recent past because of its enteric methane (CH_4) mitigation potential. Earlier studies in sheep supplemented with Asparagopsis taxiformis in pen conditions showed a CH_4 reduction of up to 80% when bromoform concentration in the diet was about 22 mg/ kg feed intake (Li *et al*., 2016). In Australia, however, most of the sheep are raised in extensive grazing systems, and there is a need to demonstrate this potential under these grazing conditions to inform adoption. The present study aimed at quantifying the enteric CH_4 mitigation effect of supplementing increasing levels of *Asparagopsis taxiformis* in the diet of grazing sheep.

Merino hoggets (n=80, initial live weight: 54.5 kg) were used in a completely randomised experimental design conducted at the Smart Farm, University of New England. Initially, 120 sheep were trained to use Green Feeds (GF; C-Lock, South Dakota, USA) for three weeks. This device was used during the experiment to deliver supplementary pellets treated with Asparagopsis taxiformis extract to the sheep and measure enteric CH_4 emissions. Out of the 120 sheep, the best 80 were selected based on the frequency of visits to the GFs and assigned into four animal groups balanced for frequency of visits to the GFs and live weight. The animal groups were then randomly assigned to four treatment levels consisting of increasing bromoform concentrations in the total diet (pasture + pellets): 0 (control), 8 (T1), 16 (T2) and 24 (T3) mg/ kg feed intake. Each animal group was assigned to one of the four paddocks measuring 2.1 ha and installed with a GF.

The paddocks were dominated by native unimproved pastures, and the animal groups rotated among them weekly. The supplementary pellets were constituted postprocessing, by mixing all-purpose ruminant pellets (Mort and Co. Stockfeeds, Guyra, NSW) in a concrete mixer with either pure canola oil (control) or canola oil infused with Asparagopsis taxiformis extract.

The constituted supplementary pellets had the following bromoform concentrations: control: 0 mg/ kg; T1: 159 mg/kg; T2: 319 mg/kg and T3: 478 mg/kg. Each sheep had a maximum daily allowance of 150 g of the respective pellets, split over eight equal meals over 24 h. The sheep were assumed to have a total feed intake of 2.5% of their live weight. The bromoform concentration in the pellets was analysed pre- and post-feeding and corrected for volatilisation losses. The animals were adapted to the dietary treatments for 14 d followed by a 28 d measurements period. A regression analysis between dietary bromoform intake and CH_4 mitigation achieved was fitted in Ms Excel.

The present finding shows a linear (R^2=0.99) increase in enteric CH_4 mitigation over the bromoform intake levels achieved (Table 1). On average, the sheep visited the GFs four times a day, with 79% of the initial flock trained successfully.

It can be concluded from the present findings that the inclusion of *Asparagopsis taxiformis* in the diet of grazing sheep results in a significant reduction in enteric CH_4 with the magnitude achieved dependent on the dose. Further studies are needed to establish the optimal supplementation dose and frequency for optimal enteric CH_4 abatement. Suitable supplement delivery systems need to be developed for use in grazing systems.

	Treatment			
Parameter	Control	TI	T2	T3
Average daily bromoform intake (mg)	0	15.7	37.0	40
Average daily weight gain (g)	201	183	202	224
Average daily CH_4 production (g)	38.7	29.9	25.1	14.5
CH_4 Abatement (% of the control)	_	30%	46%	64%

Table1: Effect of increasing the concentration of *Asparagopsis taxiformis* extract on enteric methane production in grazing sheep

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A multi-component protease improved growth performance and feed cost savings on nutrient-reduced growing-finishing diets containing highly diversified ingredients.

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The use of exogenous proteases is a valuable strategy to improve nutrient utilization in pigs, particularly in young piglets. However in mature animals, its efficacy is less explored due to their more developed digestive system and higher capacity to degrade complex nutrients. Moreover, its effectiveness is associated with the type of feed ingredients used in diet formulations.

A study was conducted to evaluate the effects of a multi-component protease on growth performance and economic benefits when supplemented on nutrient-reduced growing-finishing diets containing highly diversified feed ingredients of vegetable- and animal-based origins. A total of 264 growing pigs with initial body weight of 33.5 kg were assigned to three treatments: 1) Positive control (PC, standard diet containing highly diversified feed ingredients, 2) Negative control (NC, 5% reduction in crude protein and digestible amino acids from the standard diet), 3) NC + 250 g/t protease (NC+PRO).

The multi-component protease was supplemented twice higher than the standard commercial recommendation taking into account the 5% matrix reduction, and the highly diversified and more complex nature of the experimental diets than typical corn-soybean meal-based feeds. Each treatment consisted of 8 replicates with 11 pigs per replicate pen. All pigs were provided feed and water *ad libitum* for 56 days. Growth performance data was determined at d 0, 35, and 56.

Data were subjected to ANOVA with an unbalanced treatment structure and treatment means were separated using Tukey's test with $P<0.05$ considered as significant, while $P\leq0.10$ considered as a trend. At d 56, pigs fed NC+PRO tended ($P=0.07$) to have a higher body weight compared to those fed NC diet (87.5 kg vs. 84.8 kg), but was similar to PC. The overall average daily gain of NC+PRO was similar to PC, and was significantly higher ($P<0.04$) than NC (966 g vs. 917 g). Overall feed intake of pigs fed PC was higher ($P<0.04$) than NC (2250 g vs. 2150 g), but both treatments had similar feed intake to those fed NC+PRO.

Overall feed conversion ratio was not different among treatments ($P>0.05$). In terms of economic analysis, the feed cost of NC+PRO was intermediate between PC and NC. Pigs fed NC+PRO diet obtained the highest return over feed cost per pig (US$ 127.0) compared to those fed PC (US$ 125.9) and NC (US$ 123.7). Overall, the results of the study indicated that the supplementation of a multi-component protease in a nutrient-reduced, highly diversified diets offered improvements on the overall growth performance of pigs, resulting to better economic returns for pork producers.

The use of on-animal sensors to assess individual intake of supplements in beef cattle.

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The use of supplements is a strategy employed by beef cattle producers to provide nutrients that may be deficient in the pasture and minimize production losses. This strategy is based on the assumption that cattle consume the target amount of supplements. The current method of estimating supplement intake is done at the herd level, failing to account for individual intake. It is necessary to develop new methods to account for the individual intake of supplements. Dixon *et al*. (2016) reported that the variation in consumption ranged between 78% and 135% of the targeted intake and 10-30% of the herd may not consume any supplement. The objective of this experiment was to investigate the use of a Bluetooth ear-tag to monitor individual supplement intake using visual assessments to validate the ear-tag data.

An experiment was conducted at the University of Queensland, Gatton, QLD, 4343, from September to December 2022. Approval was granted by the University of Queensland Animal Ethics Committee. Fourteen Droughtmaster heifers (268 ±32.7 kg) fitted with an on-animal sensor in the form of Bluetooth ear-tags (WelfareTag™) were allocated to a 10ha paddock. The heifers were fed with low-quality native pasture (6.5% crude protein) and supplemented with two protein supplements for 12 weeks. During the first 6 weeks, a low intake (300g/head/day) supplement was offered, and during the remaining period, a high intake supplement (1000g/head/day) was offered.
The time spent at the supplement trough and frequency of supplement intake events were recorded by visual observation supported by a camera and a Bluetooth receiver, which recorded the presence and received signal strength indicator (RSSI) of Bluetooth ear-tag every 30 seconds; both devices were installed on the roof of the supplement trough. To estimate the distance between the ear-tag and the receiver device, RSSI values ranged between 0 to -100 dBm. This value is decreased with increasing distance between the transmitting and the receiving devices. Therefore, this system can detect the presence of the animal at the feed trough and the time spent at that location.

The data analysis was made by matching the time-stamped observations from the videos with the RSSI data from the ear-tag. Differences between the coefficients of correlation were compared using linear and multiple mixed models' packages using R and RStudio, version 4.2.1. There was good agreement between the time spent at the feed trough, measured by the video observations, and ear-tag RSSI (P=0.05, R^2=0.56). The most appropriate RSSI values to account for the individual supplement intake (Figure 1) were values under -45dBm (P=0.05, r= 0.72), followed by values under -50dBm (P=0.05, r= 0.69) and values under -55dBm (P=0.05, r= 0.64). However, there is a trade-off using values below -45dBm, as some intake events may not be accounted for. The coefficient of correlation weakens for values between -60dBm (P=0.05, r= 0.48) and -65dBm (P=0.05, r=0.28), which is expected as the animals may be walking in the direction of the supplement trough.

We found that the ear tag RSSI was provided with an accurate representation of time spent at the feed trough when compared with the video data. This has been found to have a strong relationship with supplement intake. The RSSI results suggested the estimated individual intake varied from 21 to 1239 ± 226 g/day for the low intake supplement and 21 to 2169 ± 524 g/d for the high intake supplement, indicating high variability within the herd on the daily intake of supplements. Thus, assessing supplement intake using on-animal sensors may provide a new tool for estimating individual supplement intake.

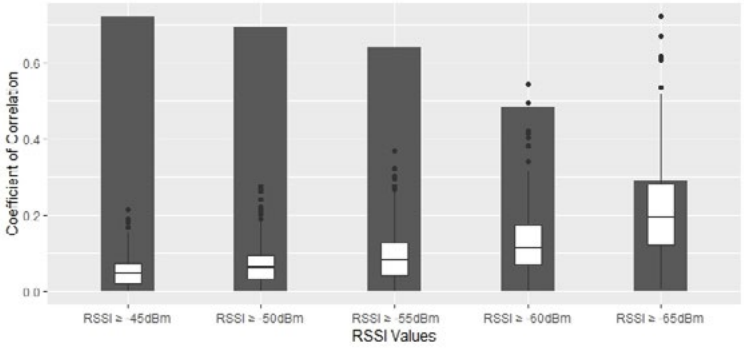

Figure 1. Coefficients of correlation between RSSI and video observations for daily supplement intake of fourteen heifers over 12 weeks. The coefficients of correlation are represented by the dark bars. White boxplots show the distribution of the sum of individual visits at the feed trough measured by the sum of video observations in different ranges of RSSI.

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Impacts of feeding lauric acid on performance of late-finishing, Improvac-treated male pigs

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The ability to optimise production in the late-finishing phase, where pigs consume a proportionally greater amount of feed and grow fastest, is a desirable outcome for the pork industry. Preliminary research by Pluske *et al*. (2015) showed that feeding 25 or 50 g/kg of the medium-chain fatty acid (MCFA) lauric acid (LA; dodecanoic acid; $C_{12}H_{24}O_2$) to late-finishing pigs improved aspects of production. Feeding MCFA may also augment the gastrointestinal tract microbiome (Jackman *et al*., 2020). The aim of this study was to first, examine the effects of feeding a broad range of LA to late-finishing pigs, and second, to ascertain whether feeding LA could modify selected bacterial populations.

A randomised complete block design experiment comprising 6 dietary treatments (0, 5, 10, 15, 20 and 25 g/kg LA, in substitution for tallow), with pen as the experimental unit, was conducted using 420 Improvac-treated pigs (~ 68 kg body weight (BW) at entry), with 10 pens per treatment and 7 pigs/pen. Pigs were acclimatised (0 g/kg LA) for 7 days and then fed the treatment diets ad libitum for 28 days. Performance data (average daily gain, ADG; average daily feed intake; ADFI) were collected, and at ~ 113 kg BW, pigs were harvested at a commercial abattoir, and carcase assessments and meat quality traits measured. Faeces were collected for assessment of bacterial populations. Linear mixed-model methodology was used to fit a statistical model to each variable. All models were fitted using *asreml* (Butler, 2009) within R (R Core Team, 2018). Where statistically significant, the initial statistical model for a trait was modelled as a second or third order polynomial to establish the optimum dose of LA for the variable. Statistical significance was accepted at $p < 0.05$. Bacterial data were analysed using Stata SE v.13 binomial logistic regression functions.

For pig BW, there were significant polynomial effects ($p < 0.05$) of feeding LA at days 14, 21, 28 and 35 of the experiment, with the optimal dosage of LA being 11.9 g/kg, 10.8 g/kg, 12.3 g/kg and 13.1 g/kg for an average pig BW of 84.4 kg, 94.4 kg, 104.1 kg and 114.6 kg, respectively. Pigs fed diet LA 20 had a higher ADG than pigs fed LA0 and LA25 ($p < 0.05$) in the first 7 days after experimental diets commenced, but there were no other differences in ADG in that period or at any other time interval. Pigs fed diets LA5, LA10, LA15 and LA20 had a higher ADFI ($p < 0.05$) during days 14-21 and in the overall period, days 7-28, than pigs fed LA0 or LA25. Pigs fed diets LA15 and LA20 had a better feed conversion ratio ($p < 0.05$) during days 7-14 of the experiment. Polynomial regression analyses showed that feeding 11.8-13.5 g/kg LA generated positive responses in BW and ADG, especially initially, as well as in overall ADFI, although there were no beneficial effects of feed conversion ratio.

There were no statistically significant effects of LA for any carcase or meat quality traits. There were no significant differences in the proportion of Gram-positive, Gram-negative, or the ratio of Gram-positive:Gram-negative organisms, in the faeces of pigs sampled in the late-finishing period.

These data suggest there is potential to improve some production variables in late-finishing, Improvac-treated male pigs by feeding a lower concentration of added LA.

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Towards the use of more sustainable protein source – investigating the nutrient content and amino acid digestibility of soybean meals from various origins in broilers

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Industry is moving towards more sustainable poultry production with minimal impact on productivity and efficiency. Feed has been estimated to contribute up to 91% of the life-cycle greenhouse gas emissions from poultry production (Benavides *et al*., 2020). Sustainability in feed can be achieved by producing feed with a lower environmental footprint and higher utilization of nutrients. Feed with a low carbon emission footprint can be produced from locally sourced ingredients or ingredients imported from areas free of deforestation.

Soybean meal (SBM) is the most common protein source in broiler diets worldwide. In Australia, SBM is mostly imported from South America. SBM imported from South America is linked to deforestation areas and thus contributes to the environmental footprint of poultry production. United States (US), Argentina (AR) and Brazil (BR) are three major producers of SBM. The crude protein (CP) and amino acid (AA) content of SBM are influenced by cultivar, agronomic and soil conditions and climatic conditions where soybeans are grown to produce meals (Goerke et al., 2012). Further, soybean storage and handling during and after harvest affects the structure of storage proteins. Hou and Chang (2004) found storage above 84% humidity and 30°C for more than seven months resulted in a decrease of free sulfhydryl groups and an increase in the glycoprotein content of glycinin.

The changes would be expected to reduce AA digestibility in SBM made from such beans. The aim of this experiment was to compare the nutrient value of SBM from various origins in broilers.

Nineteen samples of SBM were collected from commercial locations in Southeast Asia and identified to be from US (n = 5), AR (n = 10) and BR (n = 4) origins. Aliquots were analysed for proximate composition, carbohydrate, AA, reactive lysine, KOH protein solubility (KOH-PS), trypsin inhibitor activity (TIA), protein dispersibility index (PDI), and standardized ileal digestible (SID) AA coefficients and values in broilers. The CP was higher in BR (47.3%) as compared to US (46.0%) or AR (46.1%) SBM ($P < 0.05$). Sucrose content of the meals were ranked as US > AR > BR and different for each meal ($P < 0.001$). Sucrose was negatively correlated to CP ($R2 = 0.23$; $P < 0.05$). The SID lysine content was higher in US (2.55%) and AR (2.52%) than BR (2.25%) SBM ($P < 0.05$). US SBM had higher coefficients of SID methionine, cystine, threonine, valine, tryptophan, glycine and serine as compared to BR SBM ($P < 0.05$). Reactive lysine in SBM was positively correlated to KOH-PS ($R^2 = 0.39$; $P < 0.01$) and PDI ($R^2 = 0.22$; $P < 0.05$) but not TIA ($P > 0.05$).

The findings from this study suggest that SBM quality is affected by the origin of the meal. The SBM from the US was found to have a lower value for CP and higher values for sucrose and most of the digestible amino acids. The higher utilization of nutrients together with a lower environmental footprint of production make SBM from the US more sustainable to be used in feed for poultry.

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Does the falling-number value impact the adjusted digestible energy content of weather-damaged wheats for pigs?

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For cereals where the quantity of starch has been reduced, for example, in weather-damaged grains (van Barneveld *et al*. 2001), the accuracy of digestible energy (DE) as a measure of available energy in the growing pig is potentially less reliable. To account for possible differences in energy contributions along the gastrointestinal tract with such grains, an 'adjusted' DE value that simultaneously considers ileal and faecal digestibility can be used (van Barneveld *et al*., 2018). Traditionally, the Hagberg falling-number method (Hagberg, 1960), which provides an indirect measure of α-amylase activity in grains (lower values are indicative of sprouted grain), and (or) the test weight, have been used to assess the value of weather-damaged grains.

The 2021-22 harvest in NSW resulted in ~ 40-45% of wheat being downgraded due to pre-harvest germination (sprouting) (Grain Central 2022). With such a large quantity of germinated grain available, it is important to understand the effect of pre-harvest sprouting on the energy value of wheats fed to pigs. The objective of this study was to determine whether the degree of sprouting, as indicated by the falling-number method and test weight, is relevant to the nutrient value of wheats as assessed using the 'adjusted' DE method determined using AusScan Online.

A total of 23 samples of wheat were collected during the 2021-22 NSW harvest, in which ripe grain remained unharvested for many days longer than normal due to prolonged wet weather. Grain samples were analysed for falling number (Hagberg, 1960), test weight (International Organisation of Standards method ISO 7971-1:2009 for cereal grains), and pig ileal and faecal DE (AusScan Online). Standard regression analyses were used to analyse the grain variables.

Grain sample test weight ranged from 72.6 to 80.4 kg/hL. The lower test weight values were associated with low falling-number values, but the correlation between test weight and falling number value was weak (R^2 = 0.36, p = 0.002). The ileal and faecal ingredient DE values were used to calculate an 'adjusted' DE value to provide a more accurate measure of nutritional value. A correlation between adjusted DE and falling number was found (R^2 = 0.54, p = 0.001) indicating that higher adjusted DE values were associated with higher falling number values (Figure1). Of the 23 samples tested only 2 samples had falling number values greater than 300 seconds, and 21 samples (91%) were less than 200 seconds of which more than half the samples recorded 62 seconds. A total of 21 samples were classified as sprouted grain and would have been downgraded to feed wheat.

The sprouted wheat samples in this study have a similar nutritional value to normal wheat possibly because starch concentrations have not been significantly reduced, and ileal DE: faecal DE ratios were consistent with normal wheats (> 0.84). The results of this study indicate the relationship between falling number value and adjusted DE would only be of practical significance for values > 200 seconds. The majority of falling number values were between 62 and 200 seconds and the difference in adjusted DE was calculated to be only 0.14 MJ / Kg which is within the error of the estimated DE value. These data were based on a sample group with limited variation and the conclusions require further investigation with a larger sample number.

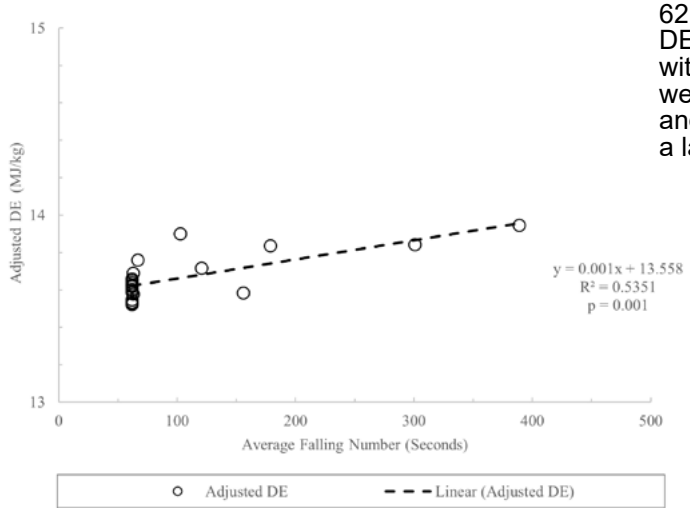

Figure 1. The calculated Adjusted DE[1] (○, MJ/kg) with a range of Falling Number values (seconds) for 23 sprouted wheat samples. [1]Adjusted DE = (ileal : faecal DE × DE) + ((DE – (ileal : faecal DE × DE)) × 0.75)

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Acidification of sheep urine using negative dietary cation anion difference (DCAD) and different levels of crude protein (CP) in live export diets

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Air ammonia in live export operations is mainly volatilised from urea in the urine. It is a pH-dependent process that can be reduced by lowering urinary pH (Tudor *et al*. 2003). Ruminants' urine pH is alkaline (pH 7.4 to 8.4) and is highly influenced by diet (Parrah *et al*. 2013). It is well-accepted that using anionic salts to reduce dietary cation-anion difference (DCAD) is associated with urinary pH reduction (Luebbe *et al*. 2011).

Meanwhile, a low crude protein (CP) diet is mainly fed to ruminants to reduce urinary nitrogen excretion. However, combining low DCAD with a low crude protein (CP) diet to lower urine pH has yet to be examined.

This experiment aimed to investigate the inclusion effects of low DCAD in conjunction with low CP in the diet of sheep on urinary pH. It was hypothesised that offering low DCAD in the diet with low CP would decrease urinary pH.

A 2x2 factorial experiment was applied on thirty-two Merino wethers [liveweight 46 ± 2.6 kg (mean ± SD)] randomly assigned into four dietary treatments across two runs (16 sheep per run). The treatments combined two levels of DCAD (high and low) and CP (high and low) iso-energetic. Magnesium sulphate [$MgSO_4$ (1.58% and 1.40%)] and magnesium chloride [$MgCl_2$ (0.96% and 1.09%)] were added to one of the high and low CP diets to vary the DCAD content. The commercial shipper pellets were used as the base diet with varying barley and protein levels to lower the CP content.

The animals were given restricted diets at 3% of liveweights as a total mixed ration. After adapting to the diets, the wethers were kept in metabolism crates for six days to collect total urine and faeces. Fresh urine pH was measured in the morning using an electronic pH meter (EC-PH6-02K, Eutech Instruments Pte Ltd., Singapore).

The content of CP in the diet did not influence urinary pH (Table 1). On the other hand, urinary pH was affected by DCAD levels, where decreasing DCAD using anionic salts in the diet resulted in lower urinary pH (pH < 7). The interaction between CP and DCAD levels did not affect urinary pH. Therefore, it is concluded that the use of DCAD is potentially effective in minimising NH_3 volatilisation by reducing urine pH without considering the CP level in the diet.

Table 1. Means (± SD) for urinary pH in experimental diets combining 2 levels of CP with 2 levels of DCAD

	High CP (11.50%)	**High CP** (11.45%)	**Low CP** (10.01%)	**Low CP** (9.82%)	***P*-value**		
	High DCAD (5.8 meq/kg)	**Low DCAD** (-336.25 meq/kg)	**High DCAD** (31.72 meq/kg)	**Low DCAD** (-346.17 meq/kg)	CP	DCAD	CP × DCAD
Urine pH	7.63 ± 1.15	6.12 ± 0.839	7.07 ± 1.36	6.21 ± 0.773	0.176	< 0.001	0.193

CP = Crude protein; DCAD = dietary cation-anion difference

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4. Special thanks to LiveCorp and Meat and Livestock Australia (MLA) for funding this work

Session 7

Revisiting tropical pasture intake – what's changed in 50 years?

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The measurement and prediction of pasture intake in extensive grazing systems, typical of northern Australia remains elusive after 50 years of research. The aim of this paper is to review research conducted over the last 50 years, highlight advances in understanding, discuss remaining challenges and consider future developments with digital technologies.

While the fundamental components of voluntary intake are well understood, their measurement is difficult particularly in extensive grazing systems which has limited the development of predictive models that adequately address the interplay of factors influencing intake from the bite to the landscape scale.

Ongoing research by the authors is used as an example to highlight the potential application of digital technologies to overcome limitations in measurement and prediction. Digital technologies offer the opportunity for monitoring factors that control voluntary pasture intake at scale and under commercial conditions. However, our ability to ground-truth novel indices of intake remain limited without ongoing development of physical methods. This will limit the accuracy and precision of predictive models incorporating digital technologies that can be applied to the extensive grazing conditions of northern Australia. The advent of precision livestock management for extensive cattle production is essential if the industry is to remain viable in a future where production is transparent, ethically sound and environmentally defensible as well as profitable.

Full manuscript available at: https://www.publish.csiro.au/an/pdf/AN23045

Multispecies forages in the dairy feedbase: what is the biological business case?

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This review considers the potential role of multispecies swards in de-risking Australian dairy systems that currently rely heavily on monocultures of perennial ryegrass and high rates of inorganic nitrogen application to be productive. Recent trends in increasing inorganic nitrogen fertiliser prices, societal pressure for increased environmental sustainability of farming practices, coupled with variable and extreme weather events have renewed interest for functionally diverse pasture mixtures.

Evidence from the latest international studies either for or against the purported benefits of multispecies swards (e.g. productive, resilient, and environmentally positive) are examined. There is an ever-growing body of evidence confirming that species richness can promote high levels of productivity at low or zero rates of nitrogen fertiliser application, often with increasingly positive effects as species richness increases. However, results within and between different levels of species richness are not always consistent, suggesting that not all multispecies swards will perform alike even at a constant level of functional diversity. A multitude of other factors are presented that interact to determine the success of one multispecies sward over another.

These include soil type and fertility, species choice, functional group proportions, sward management under either grazing or cutting, fertiliser regimes, and grazing management practices. It was concluded that this complexity gives rise to a need for further research into the biological mechanisms behind multispecies mixtures to determine the factors, other than simply species richness, that will guarantee success as more farmers inevitably search for alternatives to perennial ryegrass pasture in the Australian dairy farming industry.

Session 8

Importance of circadian rhythms in dairy nutrition

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Biological rhythms are repeating patterns that are driven by time-keeping mechanisms within the animal and are adaptive as they coordinate physiology and metabolism with the external environment. The dairy cow has a well-recognized natural daily pattern of feed intake and milk synthesis, but regulation of these rhythms has not been well described in the literature or well considered in current dairy management.

Recent discoveries have clearly described circadian time-keeping mechanisms in peripheral tissues that are responsive to the timing of food availability. Some management strategies on dairy farms may desynchronize the interactions between central and mammary circadian timekeepers resulting in reduced milk yield and efficiency. Feeding a total mixed ration is commonly assumed to create constant ruminal conditions, but the large variation in the rate of feed intake across the day causes large fluctuations in rumen fermentation and absorbed nutrients.

Milk composition also differs across the day due to both dynamics in nutrient absorption and biological regulation attempting to match milk yield and composition with calf requirements across the day. Recent work has shown that milk synthesis varies over the day and is modified by the timing of feed intake and nutrient absorption. These rhythms have also been shown to be impacted by the timing of feed delivery. We expect that maximal milk yield and efficiency are achieved when we have more consistent rumen fermentation and match the timing of nutrient absorption and mammary capacity for milk synthesis.

Managing feeding times provides the opportunity to modify feed intake across the day, but behavior responses are complex. Appreciating the impact of circadian rhythms provides the foundation to develop nutrition and management strategies considering circadian dynamics of intake and milk synthesis and provides opportunities for new gains in cow efficiency, welfare, and health.

Interactions of diet and circadian rhythm to achieve precision nutrition of poultry

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Precision nutrition regimes currently rely on the assumption that broilers will grow in a steady and predictable way on a daily basis, with the continuous deposition of nutrients into muscle or, in the case of laying hens, into an egg. However, it has been observed that this is not the case for egg production, with Ca requirements being aligned with eggshell formation.

Recent research has suggested that muscle is also deposited at differing rates over a 24-h cycle. The circadian rhythm synchronises various biological processes to oscillate within a 24-h cycle. Thus, the cyclic nature of body systems should be explored, to determine whether consideration of the circadian rhythm is required for precision nutrition programs, achieving peak efficiency of performance and accurate nutrient requirement recommendations.

Recent advances in nutrition have demonstrated the powerful effect of the circadian rhythm on human health and animal growth and production. Therefore, this review discusses recent circadian-rhythm research with relevance to poultry. Specific focus is given to the interaction of the circadian rhythm with diet and dietary nutrients, for the precision nutrition of poultry and optimising production.

Full manuscript available at: https://www.publish.csiro.au/an/pdf/AN23075

POSTER PRESENTATIONS

Evaluation of the effects of medium-term (57-day) omeprazole administration and of omeprazole discontinuation on serum gastrin and serum chromogranin A levels in the horse.

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The reoccurrence of gastric disease and symptoms following the discontinuation of proton pump inhibitors (PPI), caused by rebound gastric hyperacidity (RGH) is a growing concern in human and equine medicine (Helgadottir and Bjornsson, 2019; Pagan *et al*., 2020; Sykes, 2021). Acid suppression by PPI's, causes a loss of negative feedback on gastrin, increasing gastrin production and resulting in hypergastrinemia (Helgadóttir *et al*., 2019). Gastrin has a trophic effect on Enterochromaffin-Like (ECL) cell density, responsible for histamine release (Brenna and Waldum, 1992; Waldum, 1996). Histamine and ECL cells have roles in the stimulation of acid secretion by gastrin, and hypergastrinemia coupled with increased ECL cell density, increases the acid secretory capacity of the stomach (Helgadottir and Bjornsson, 2019). Elevated serum gastrin and chromogranin A (CgA) have been observed in rats and humans during PPI treatment, indicating the occurrence of hypergastrinemia and ECL cell hyperplasia (Klinkenberg-Knol *et al*., 1994; Lamberts *et al*., 1993; Sanduleanu *et al*., 2001; Waldum, 1996).

Rebound gastric hyperacidity has been reported to result in the rapid reoccurrence of acid related symptoms in human patients (Helgadottir and Bjornsson, 2019; Reimer *et al*., 2009). Serum gastrin levels have been reported to double within 14 days of omeprazole treatment in the horse (Pagan *et al*., 2020). The clinical significance of this finding is unclear, but a recent study comparing withdrawal periods for omeprazole treatments in Thoroughbreds, reported an equine squamous gastric disease (ESGD) prevalence of 83% of horses following '2 clear days' recommended withholding period (RWP) for omeprazole; this was an increase from 25% of horses with ESGD before the RWP (unpublished data). Suggesting RGH might contribute to the rapid reoccurrence of disease (Sykes, 2021).

The aim of this study was to evaluate changes in serum gastrin and chromogranin A (CgA) concentrations in response to medium-term (57-day) omeprazole treatment and following omeprazole discontinuation.

Fourteen mature Thoroughbred racehorses in simulated race training, received 2.28 grams of oral omeprazole once daily for 57 days within a 61 day period. Serum samples were collected on day 0 prior to omeprazole treatment, on day 1 of each week of the treatment period, and for a further five weeks post-discontinuation of treatment. Serum gastrin and CgA concentrations were analysed using radioimmunoassay (RIA) analysis and ELISA, respectively. The Kruskal Wallis test for multiple comparisons was used to assess treatment effect over time, in comparison to baseline measurements.

Median serum gastrin concentrations (pg/mL [IQR]) had a 2.5-fold increase from baseline measurements on day 0 (20.5 [13]) to day 7 (52.5 [18.25]) ($p < 0.001$). Gastrin remained elevated at each sample time from day 7 (52.5 [18.25]) until day 56 (64.5 [38]) ($p < 0.001$).. The last dose of omeprazole was administered on day 59 (n=7) or day 61 (n=7) and median serum gastrin concentrations returned to baseline (20.5 [13]) by day 63 (25 [7.25]) ($p = 0.74$). Median serum CgA concentrations did not change from baseline measurements on day 0 (77.18 [26.10]) during the omeprazole treatment period ($p>.0005$).

The current study demonstrated the development of hypergastrinemia within 7 days in Thoroughbreds treated with omeprazole and the return of serum gastrin concentrations to baseline within 2-4 days of discontinuation, consistent with previous studies (Pagan *et al*., 2020). No effect of omeprazole treatment on CgA concentrations was observed, contrasting with previous human studies (Sanduleanu *et al*., 2001), however accuracy of the CgA results is limited. These findings do not support tapering of omeprazole treatment following medium-term administration but suggest that management practices targeted at reducing ESGD risk should be optimised in the 2-4 days following discontinuation of omeprazole treatment.

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Effect of microalgae on *in vitro* rumen fermentation, gas and methane production

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In Australia, ruminant livestock contribute the vast majority of methane (CH_4) emissions from agriculture. In addition to being a potent greenhouse gas (GHG), enteric CH_4 emissions can equate to a loss of 8-12% of the total gross energy intake of ruminants (Johnson and Johnson, 1995). Reducing CH_4 production in ruminants without impacting ruminal fermentation is desirable (Grainger and Beauchemin, 2011). There are reports that microalgae have anti-methanogenic effects (Meehan *et al*., 2021; Kholif *et al*., 2023); however, as with *in vivo* trials, many of the *in vitro* studies reported conflicting results on the effects of microalgae on rumen fermentation and methanogenesis.

Therefore, this study aimed to investigate the *in vitro* effects of different doses (0%, 0.5% and 1% DM) of *Chlorella vulgaris* microalgae (Genesis Co. Pty Limited, Bowen, Australia) incubated with a mixture of barley hay and lamb feedlot pellet (Riverina Pty Limited, Australia) in a ratio of 41:59 (as basal substrate) on rumen CH_4 and gas production after 6 and 24 h, and on volatile fatty acids (VFA) after 24h. A total of 0.5 g of the basal substrate (ground to pass through a 1 mm screen) was incubated with liquid microalgae and 25 mL of 2:1 mixture of rumen fluid: buffer saturated with CO_2. Each level of inclusion was replicated 3 times in 3 separate runs, in addition to 3 blank bottles. All bottles were incubated under

anaerobic conditions at 39°C. Gas production and concentration of methane were measured at 6 and 24 h, while pH and proportions of volatile fatty acids were determined at 24 h.

Results showed that supplementation with microalgae up to 1% DM had no effect on total methane production (P = 0.53) or gas production (P = 0.91) compared to the control. The inclusion of microalgae had no effect on in vitro ruminal pH (averaged 5.86; P = 0.48). Similarly, no effect was observed on the total VFA (mM; P = 0.61) or the two main VFAs, acetate (P = 0.59) and propionate (P = 0.64). This is not surprising given the lack of effect on methane production during the 6 and 24 h incubation.

In line with previous studies (Meehan *et al*., 2021; Kholif *et al*., 2023), microalgae did not alter rumen fermentation; however, further in vitro testing at different doses is recommended.

Table 1. Chemical composition of feed substrates

Parameters	Barley Hay	Pellets
Dry matter (DM), %	90.00	89.07
Crude Protein, % DM	13.20	16.00
Ether Extract, % DM	2.00	2.89
ADF, % DM	38.20	7.00
NDF, % DM	57.70	19.13

ADF = Acid detergent fibre; NDF = neutral detergent fibre

Table 2. *In vitro* fermentation characteristics of lamb feedlot diets supplemented with microalgae

Parameters	Control (0%)	Medium (0.5%)	High (1%)	SEM	*P*-value
pH	5.94	5.82	5.82	0.07	0.48
Gas production 6h, mL	27.22	24.33	25.43	2.87	0.64
Gas production 24h, mL	23.59	25.15	24.64	4.54	0.43
Total gas production, mL/g Digested DM	50.89	49.48	50.08	2.97	0.91
CH_4 production 6h, mL	12.21	12.04	11.84	0.51	0.89
CH_4 production 24h, mL	17.32	20.33	19.64	5.70	0.47
Total CH_4 production 24h, mL/g Digested DM	29.51	32.37	31.49	5.98	0.53
Total VFA, mM	143.05	143.93	148.22	3.83	0.61
Individual VFA, as a percentage of total VFAs					
Acetate (A)	90.18	89.95	93.04	3.19	0.59
Propionate (P)	29.79	30.15	30.99	0.89	0.64
Butyrate	17.77	18.37	18.71	0.39	0.30
Isobutyrate	1.00	1.01	1.02	0.07	0.79
Valerate	2.51	2.60	2.62	0.06	0.48
Isovalerate	1.50	1.55	1.53	0.07	0.41
Caproate	0.30	0.31	0.31	0.04	0.70
Branched-chain VFA	2.49	2.56	2.55	0.14	0.59
Ratio A:P	3.03	2.98	3.01	0.12	0.62

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Estimation of methane abatement by *Asparagopsis* supplementation of grazing cattle

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Inclusion of *Asparagopsis* species in cattle diets has been shown to substantially reduce the daily methane production (DMP; g/d) and methane yield (MY; gCH_4/kg DMI) of cattle when fed as a freeze-dried product (Roque *et al* 2021) or an oil-extract of the plant (Avarez-Hess *et al* 2023). Most studies have been undertaken in a controlled feeding environment, with the *Asparagopsis* (ASP) mixed into the entire ration, so that ASP is ingested in every mouthful consumed. Little data is available on methane mitigation arising from sporadic intake of ASP containing feed supplements by grazing cattle. This study was undertaken to quantify the mitigation from offering an ASP containing supplement pellet in place of an ASP-free pellet. Angus steers (mean 440kg, SD 23.4 kg liveweight) were allocated to the control (n=8) and ASP supplements (n=9) by stratified randomisation on liveweight.

Control pellets were prepared daily by mixing commercial pellets with 5% by weight of canola oil. ASP pellets were prepared daily by mixing commercial pellets with 5% by weight of an Asparagopsis extract in canola oil (SEAFEED™). The canola oil used in both supplements was from the same source. An average pellet intake of 2 kg/head/d was targeted to provide an estimated 30 mg $CHBr_3$ /kg of DMI, assuming a mean intake of 10 kg of DM/head/d. DMI intake was subsequently estimated from CO_2 production (Caetano *et al* 2017).

Pellets were delivered from, and daily methane production (DMP) and CO_2 production were measured by, 2 Greenfeed emission monitors (C-Lock Inc. SD), with one unit delivering control and one ASP pellets. The 2 units were adjacent in a single paddock in which all steers grazed a low-quality summer pasture supplemented with pasture hay. The supplements were offered for 45 days with the study moved to a second paddock on day 20 due to heavy mud and pugging, splitting the data into phase 1 (day 1-19) and phase 2 (day 29-45).

In phase 1 average pellet intake of ASP cattle was numerically less than control cattle (1290 v 1827 g/d; P=0.11) and their lower CO_2 production (6322 v 5374 g/d; P<0.05) suggested total ME intake and so DMI was 21% less than controls, and was responsible for a reduction in DMP, also of 21%.

In phase 2, there was no treatment difference in estimated DMI, but daily methane production was more substantially reduced (96 v 197 g/d; P<0.01) and estimated MY was reduced by 51% (11.4 v 23.1 g/kg DMI; P<0.05). Equipment failure limited collection of data but up to 67% mitigation was observed over one 4 day period. Overall, there was a linear relationship between ASP pellet intake and DMP across the study (Figure 1).

The study was effective in demonstrating the efficacy of ASP in mitigation of enteric methane from grazing beef cattle by using Greenfeed units to deliver supplement and measure emissions. The observed mitigation of up to 67% suggests that ASP can have application as a mitigation technology for grazing cattle as well as cattle fed total mixed rations.

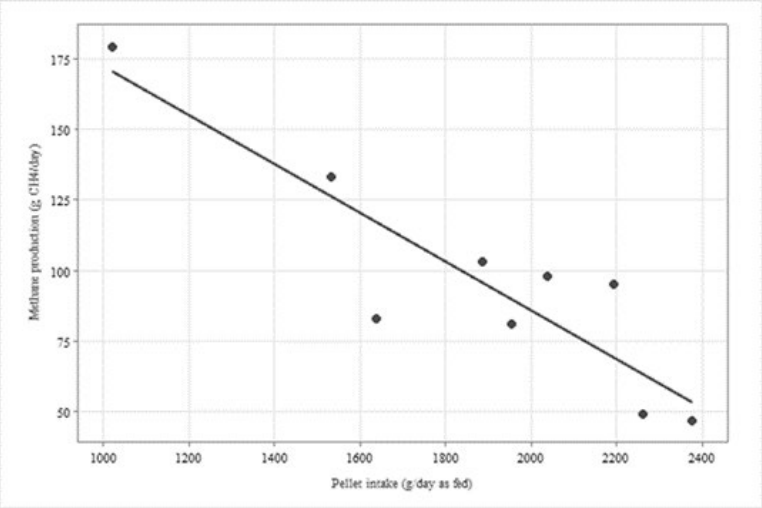

Figure 1. Regression between intake of ASP pellets by 9 individual cattle and their average daily methane production over this period [g CH_4/d = 259 – 0.0865* g pellet intake. r^2 = 0.78]

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Early gut colonisation of *Bacillus* probiotics in broilers in a leaky gut model

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The poultry industry has been continuously challenged by various diseases and pathogens. The application of antibiotics in broiler production is a prominent solution in combating infectious pathologies and improving production performance. Yet, in 2006, European Union (EU) imposed a ban in antibiotics as a growth promoter (AGP) because of emerging antimicrobial resistance pathogens in poultry production. Various substitutes for AGPs, such as probiotics, prebiotics, symbiotics, organic acids and enzymes have been extensively studied, and *Bacillus* probiotics were selected as a potential substitute for AGP in broilers. Some of probiotics mode of action includes modification of microbial population, competitive exclusion, production of specific compounds (bacteriocins, metabolites) and modifications of intestinal epithelium. The first 3-4 days offers a crucial period for permanent gut colonisation in broilers kept for short period (35-42 days). Therefore, improving gut health via manipulation by *Bacillus* probiotics is important. In the present paper broilers (ROSS 308) at Central Queensland University (CQU) were challenged by Dexamethasone (DEX). DEX induces a leaky gut model, which injures gut lining, causing poor intestinal permeability for pathogen growth. Eggs (n=256) of mixed sex were incubated and hatched. The hatchlings were individually weighed, and birds of a similar body weight (BW) (±2 g) were assigned in 4 groups (CTR; Control, NTP; Probiotic, CTR.DEX; Control and DEX, NTP.DEX; Probiotic and DEX). The CTR group was fed a basalwheat-soybean diet with no medication, NTP feed was supplemented in a probiotic mixture of *Bacillus* bacteria, consisting of BPR-11, BPR-16 and BPR-17 (Table 1).

The DEX challenge started on day 28 and ended on day 35. The BW, average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) were collected on a weekly basis for 28 days, and gut microbiota were collected on day 35. The production performance data is shown in Table 2 and gut microbiota analysis is shown in Figure 1.

The *Bacillus* probiotic group, NTP showed a better BW, ADG and FCR (day 0-28). Mean BW was increased by 33 g ($p = 0.12$), ADG by 1.17 g ($p = 0.12$) and FCR by 2 points ($p < 0.05$). NTP group also had decreased mortality (1.56% vs 3.13% in CTR). The gut microbiota collected from litter were analysed by Anosim multivariate analysis, showing differences in bacterial abundances and memberships. Anosim multivariate analysis shows a drop in sample-to-sample distance post-DEX supplementation. NTP. DEX was less affected by DEX induced changed ($p < 0.01$). This study confirms NTP benefits in production performance and in achieving better gut health during challenging conditions.

Probiotic Strains	Specification
Bacillus amyloliquefaciens (BPR-11)	2×10^8 CFU*/g
Bacillus amyloliquefaciens (BPR-16)	2×10^8 CFU*/g
Bacillus amyloliquefaciens (BPR-17)	2×10^8 CFU*/g

* CFU – Colony Forming Units.

Table 1. *Bacillus* strains and specifications in F1 probiotics.

	CTR	NTP	*p*-Value
BW 0 (g)	42.38 ± 0.26	42.97 ± 0.27	0.11
BW 7 (g)	152.30 ± 1.57	155.91 ± 1.74	0.14
BW 14 (g)	416.54 ± 4.38	420.24 ± 4.59	0.53
BW 21 (g)	885.46 ± 9.47	910.57 ± 9.02	0.04
BW 28 (g)	1573.27 ± 13.43	1606.12 ± 15.64	0.12
ADG 0-7 (g)	15.70 ± 0.23	16.14 ± 0.24	0.23
ADG 7-14 (g)	37.75 ± 0.58	37.76 ± 0.73	0.99
ADG 14-21 (g)	66.99 ± 0.75	70.05 ± 0.66	0.005
ADG 21-28 (g)	98.26 ± 1.55	99.36 ± 1.15	0.57
ADG 0-28 (g)	56.19 ± 1.94	57.36 ± 2.14	0.12
ADFI 0-7 (g)	16.47 ± 0.29	16.52 ± 0.21	0.90
ADFI 7-14 (g)	46.50 ± 0.59	46.78 ± 0.61	0.74
ADFI 14-21 (g)	83.49 ± 0.70	87.58 ± 0.80	0.00061
ADFI 21-28 (g)	138.12 ± 1.67	138.69 ± 1.57	0.80
ADFI 0-28 (g)	71.95 ± 2.00	72.47 ± 2.68	0.63
FCR 0-7	0.76 ± 0.01	0.74 ± 0.00	0.17
FCR 7-14	1.23 ± 0.01	1.24 ± 0.01	0.58
FCR 14-21	1.25 ± 0.01	1.25 ± 0.00	0.70
FCR 21-28	1.41 ± 0.01	1.40 ± 0.01	0.29
FCR 0-28	1.28 ± 0.00	1.26 ± 0.00	0.01
Mortality (%)	3.13	1.56	

* Statistically significant difference *p*-value < 0.05

Table 2. Production performance of NTP on performance parameters of broiler chickens (day 0-28)

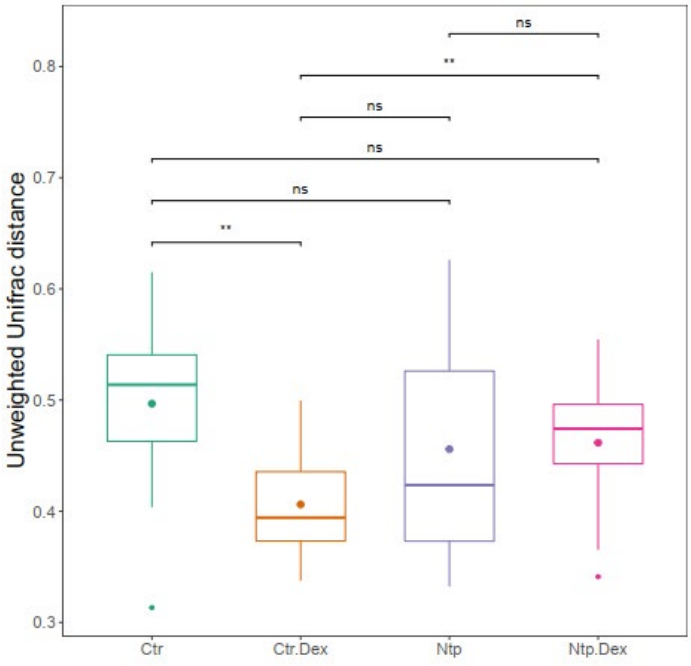

Figure 1. Anosim multivariate analysis (Unweighted Unifrac) between 4 groups.

Modelling the consequences of individual animal selection in commercial livestock farming systems.

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Genetic gain can be enhanced beyond sire selection alone through on-farm selection decisions. The economic implications of animal selection decisions are complicated by environmental constraints and the farm's current level of performance relative to the industry average (Enns *et al*. 2010). This paper outlines the rationale for an approach to assess different individual animal selection strategies on enterprise productivity. The approach requires animal genetic potential within a livestock production model to be informed by an individual animal model used to predict changes to traits over time. The findings will be used in a decision support context to explore the interaction between animal genotype and phenotype.

Current livestock production models do not allow the representation of genetic diversity within populations and as such it is difficult to assess the value of selection decisions. Important parameters (such as growth rate) can be adjusted for cohorts but cannot be varied for individuals. This does not allow an accurate assessment of the rate of change of enterprise productivity achievable through selection. In contrast, for the prediction of genetic merit, individual animal phenotypes are corrected for known environmental effects and contemporary group membership whereas, in a production system, we want to predict uncorrected phenotypes (Kinghorn 2012).

Decision support systems have been developed to match selection decisions to specific production environments by restricting the expression of genetic merit through constrained nutrition (Walmsley *et al*. 2013). The methods used may not be precise enough for widespread use in on-farm decision making (Bourdon 1998). Individual-based animal models have been developed to explore the effects of genetic diversity within populations, and it has been identified that mature weight and milk production have the most substantial impact on economic outcomes (Schafer *et al*. 2007). However, this did not include the retention of replacements and targeted selection of animals limiting the exploration of the cumulative effects over generations.

The proposed research will utilise an existing livestock production model (AusFarm, Hermann *et al*. 2015) to explore the consequences of incremental changes to traits in the context of selection decisions over time. This approach will investigate changes to specific traits and combinations of highly correlated traits within cohorts. The model will also be used to assess the impact of these changes in diverse Australian farming environments.

An individual-based livestock model (CLEM, CSIRO 2023) will be used to predict the outcomes of generations of selection. The individual-based animal model will incorporate variation in heritability of traits and predict genetic progress. The analysis will include several selection strategies such as selecting animals based on age, utilising only sire selection, and the targeted selection of animals for specific traits. Additionally, variation in the intensity of selection, through increased rates of culling, will be used to simulate the effects of drought. The outputs from the individual-based animal model will not predict production outcomes but will inform the livestock production model of potential changes to traits achievable from various selection strategies over time.

The combination of models removes some of the complexity that is encountered when attempting to incorporate individual animal variability and the inheritance of traits into a single simulation. This approach will then be used to better inform commercial producers of the potential value of individual animal selection decisions, which is likely to be especially important when they are faced with major culling events associated with drought. This will include which economically relevant traits have the most substantial impact, which environments they are most likely to exist in, and will allow producers to assess the cost to benefit ratio of collecting and analysing the necessary data.

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A short-term broiler digestibility bioassay for calcium and phosphorus

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Calcium digestibility can vary dramatically depending on the Ca source, limestone solubility, source of phytate and addition of phytase (Li *et al*., 2021). However, there is no agreement on the most appropriate method for determining Ca digestibility (Li *et al*., 2017). In the current study, the apparent ileal Ca and P digestibility was determined in diets varying in Ca content, with and without phytase supplementation, based on the short-term protocol described by Kim *et al*. (2019). This procedure avoids some of the difficulties when determining digestibility, namely the physiological adaptation of the bird to P deficient or Ca and P imbalanced diets when longer feeding periods are used.

Day old, Ross 308, male chicks were fed a wheat-sorghum-soybean meal broiler diet. The diet contained 0.65% Ca and 0.25% ileal digestible P with supplemental phytase at 500 FTU (AXTRA® PHY TPT 10,000) and a mixture of carbohydrases (AXTRA® XB 201 TPT). On day 20, the birds were weighed and allocated by stratified randomisation into cages, with 8 birds per cage and 8 replicates per treatment. There were 4 dietary treatments. The control birds were fed the mash basal diet (Diet 1) containing low Ca maize and soybean meal diet (Ca = 0.15 %), with an added indigestible marker, celite, at 20 g/kg.

Diet 2 consisted of the basal diet, plus phytase at 1000 FTU/kg. Diet 3 consisted of the basal diet to which was added limestone (PureCal 12-40) to increase the dietary Ca concentration to 0.65%. Diet 4 was prepared by supplementing Diet 3 with phytase (1000 FTU/kg). After 36 hrs of feeding, the contents of the distal half of the ileum were collected, pooled per replicate, freeze dried and ground. Feed and digesta were analysed in duplicate for Ca and P. Ileal digestibility coefficients were calculated and are shown in the Table.

The results show the impact that both dietary concentrations of Ca and phytase can have on Ca and P digestibility. These relationships have been described in the literature (Li *et al*., 2017) and in the present study they demonstrate that this bioassay is appropriate for determining Ca and P digestibility. This short-term feeding procedure avoids some of the difficulties when determining digestibility that occur when longer feeding periods are used.
The results demonstrate that an ileal digestibility assay using 22-day old broilers that have been fed the bioassay diet for 36 hours is suitable for determining Ca digestibility. The results indicate that the method could be used to rank dietary Ca sources based on Ca digestibility.

	Diet 1	**Diet 2**	**Diet 3**	**Diet 4**
	- LS - phytase	**- LS + phytase**	**+ LS - phytase**	**+ LS + phytase**
Ca digestibility	56.32[a]	72.41[a]	47.01[d]	67.35[b]
SEM	0.67	1.13	1.53	1.08
P digestibility	70.06[a]	88.93[a]	31.77[d]	79.92[b]
SEM	0.69	0.55	1.57	1.82

[a,b,c,d,] means within the rows with different superscripts differ (P<0.05)

Table. Apparent ileal Ca an P digestibility (%) of limestone (LS) with or without phytase

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Dose and the efficacy of probotic Bacillus amyloliquefaciens strain H57

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The effect of probiotics on animal performance is not consistent and may be impacted by multiple factors, such as dose, route of administration, disease stress, and management (Shini and Bryden, 2022). We have previously examined the efficacy of *Bacillus amyloliquefaciens* strain H57 (H57) in a disease stress model with subclinical necrotic enteritis (NE) (Shini *et al*., 2020); in the study only one dose of H57 (10^8 CFU/g feed) was used. The purpose of present study was to evaluate if the effect of H57 on performance and gut health of broiler chicks challenged with subclinical NE is dose dependent.

Day-old, male, Ross 308 broiler chicks were assigned to 48 cages by stratified randomization with 10 chicks per cage in an environment-controlled room. The day-old chicks were fed a wheat/soybean basal diet that was also supplemented with graded doses of H57 at 0, 10^6, 10^7, and 10^8 CFU/g feed, respectively; Treatments 1, 2, 3 and 4. Treatments 5-8 replicated Treatments 1-4, but were challenged by NE. Each treatment diet was fed to 6 cages and the procedure to induce NE, as detailed by Shini *et al.* (2020) was followed. Briefly, at 9-days of age, the birds were challenged with an *Eimeria spp*. vaccine strain administered in drinking water at 20 times the manufacturer's recommended dose. At 14-days of age, Clostridium perfringens inoculated broth was mixed into the diets. Body weight and feed intake were recorded weekly. The experiment ended on day 21 when samples were collected from two birds per replicate, including liver, spleen, bursal of Fabricius, pooled ileal digesta (pH), and ileal tissue for histomorphology. At the end of the experiment and after euthanasia, NE gut lesions in the birds were visually scored.

Body weight was not significantly different ($P>0.05$) between birds fed graded levels of H57 (Treatments1-4). However, the body weight of NE-birds treated with H57 at 10^7 CFU/g was the highest ($P < 0.05$) compared with other challenged groups. H57 improved the FCR of both non-challenged and challenged birds. Challenged birds fed H57 at 10^8 CFU/g had a similar FCR to the control group. The ratio of villi height and crypt depth of NE-birds supplied with 10^7 CFU/g H57 was significantly ($P < 0.05$) lower than NE-only birds. NE-birds supplied with H57 at 10^8 CFU/g had the lowest gut lesion score amongst challenged groups and were not significantly different to the non-challenged groups. Digesta pH of challenged groups was significantly ($P < 0.05$) lower than the non-challenge groups. Digesta pH of the NE birds fed H57 at 10^7 CFU/g and 10^8 CFU/g. was not significantly different ($P > 0.05$) compared with non-NE birds.

The results of this study demonstrate that the probiotic H57 reduces the impact of NE in broilers by the maintenance of gut integrity and of growth performance. The data showed that there was a dose effect with the dietary addition of H57 with respect to the parameters measured. However, birds receiving the highest dose (10^8 CFU/g) did not always out perform the birds receiving 10^7 CFU/g feed. The effects of H57 appear to be like other probiotics, the mode(s) of action is complex (Shini and Bryden, 2022). Therefore, when deciding on the dose to be added to feed in the feed, prevailing production conditions need to be considered along with the cost of the probiotic. As shown in this study, the highest dose does not always produce superior performance.

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Effects of dietary supplementation of pure benzoic acid and resinated benzoic acid (Benzocal-50®) on growth performance in Ross 708 broilers

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The use of antibiotics as growth promoters evolved and grew with the commercial poultry industry to fulfill the growing demand for meat and eggs as both per capita consumption and total populations increased across the globe (Suresh et al., 2018; Chen *et al*., 2018; Sharma *et al*., 2022). The loss of antibiotic growth promoters (AGPs) has stimulated research institutes and organizations to invest resources to develop alternatives to AGPs in recent decades (Sharma *et al*., 2022). Benzoic acid has been reported to improve the growth performance and gastro-intestinal function of both broilers and turkeys (Józefiak *et al*., 2010; Giannenas *et al*., 2014). The objective of this study was to investigate the effects of pure benzoic acid and resinated benzoic acid on the growth performance of Ross 708 broilers.

A total of 1680 1-day-old male Ross 708 broiler chickens (BW: 39.0 ± 1.00 g) were assigned to 4 treatments (12 replicate pens of 35 broilers per pen) in a completely randomized design. Broilers were fed 3 dietary phases over the 42-day period (Starter, d 1 to d 14; Grower, d 15 to d 28; Finisher, d 29 to d 42). Treatments were 1) NC: basal diet without feed additive; 2) PC: NC + 50 mg/kg bacitracin methylene disalicylate; 3) PBA: NC + 1000 mg/kg of pure benzoic acid; 4) RBA: NC + 330 mg/kg of resinated benzoic acid (Benzocal-50®). Average daily feed intake (ADFI), body weight, average daily gain (ADG) and feed conversion ratio (FCR) were measured for each phase. Data were analyzed using one-way ANOVA with the least significant difference test of SPSS and significance was accepted at P = 0.050.

In the starter phase, the PC increased (P < 0.05) ADFI and FCR in comparison with the NC, whereas PBA and RBA showed no differences (P > 0.05) in ADFI, ADG, and FCR. Over the grower phase, PC, PBA, and RBA increased (P < 0.05) ADFI and decreased (P < 0.05) the FCR compared with the NC. During the finisher phase, RBA showed the highest ADG and was improved in comparison to NC and PBA(P < 0.05) but was not different than the PC. PC increased the ADFI (P < 0.05) compared to NC and PBA in the finisher phases and resulted in the worst (P < 0.05) FCR among all treatments.

In the finisher phase, RBA resulted in the lowest (most efficient) FCR in comparison to PC and RBA (P < 0.05) and similar to the NC. Over the entire 42-d experiment, PC and RBA (P < 0.05) increased ADG and final body weight compared with NC and PBA. PC shows a higher (P < 0.05) ADFI compared with other groups. RBA had the lowest (most efficient) (P < 0.05) FCR among all treatments.

Table1. Effects of the basal diet (NC), bacitracin methylene disalicylate (PC), pure benzoic acid (PBA), and resinated benzoic acid (RBA) on average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) of male Ross 708 chickens on day 42 (12 replicates/treatment; 35 birds/replicate

Items	**NC**	**PC**	**RBA**	**PBA**	***P*-value**
Initial body weights, g	39.3±0.98	39.3±0.87	38.8±1.06	38.6±1.00	0.129
Overall (Day 1 to 42)					
Final body weights, g	2559±77.8^{b}	2660±116.4^{a}	2680±104.9^{a}	2576±74.1^{b}	0.006
ADG, g	61.0±1.85^{b}	63.3±2.77^{a}	63.8±2.50^{a}	61.3±1.76^{b}	0.038
ADFI, g	99.5±2.62^{b}	103.9±4.21^{a}	100.9±3.86^{b}	101.4±3.51^{ab}	<0.001
FCR, g/g	1.67±0.03^{a}	1.67±0.05^{a}	1.61±0.03^{b}	1.69±0.04^{a}	0.006

^{abc}Means within rows with common superscripts are not significantly different (P >0.05).

In conclusion, the supplementation of resinated benzoic acid could bring beneficial effects and be used as an alternative to AGPs.

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Performance of broilers fed diets, containing graded inclusion of feather meal, formulated on the basis of total or digestible amino acids

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Feather meal (FM) is an abundant and alternative protein source with a high protein content (86-94%, unpublished data). However, as it has poor amino acid (AA) digestibility (59-70%, unpublished data) it is rarely included in poultry diets. It is well known that diets formulated with digestible amino acid (DAA) values result in superior performance of chickens to the diets formulated with total amino acids (TAA) and permit higher inclusion levels of poor quality proteins (Bryden and Li, 2010). As part of a project that examined the poor digestibility of FM, the present study was designed to investigate the effect of formulating sorghum-soybean-based diets on the basis of TAA or DAA when diets had varying inclusion levels of FM.

A total of 160, day-old, Ross 308, male broiler chicks were obtained from a local hatchery. Broiler starter diets were formulated according to the results of our previous digestibility study (data not shown). All diets were formulated to contain similar protein concentrations (~27%) and 3000 Kcal/kg of metabolisable energy. In the TAA and DAA based diets, the commercial feather meal was included at 0, 2, 4, or 8% of the diets. The birds were weighed and randomly allocated into 32 cages of 5 birds each, with 4 cages per diet/treatment. All birds were reared to 21 days of age. Bird body weights and feed intake were recorded by cage on days 0, 7, 14, and 21. Mortality was recorded and dead birds were weighed to adjust the feed conversion ratio (FCR). All data were analysed using the General Linear Model (Minitab 18). The results appear in Table 1.

The body weight gain and feed intake of broilers were numerically higher in the DAA diets than the TAA diets, but the differences were not statistically significant ($P > 0.05$). FCR was similar ($P > 0.05$) for all diets. Moreover, the inclusion level of FM had no significant effect on broiler growth performance. However, the mean body weight gain and feed intake response to increasing inclusion level of FM decreased numerically, and the mean FCR response to increasing inclusion level of FM increased numerically ($P > 0.05$).

These results show that FM can be used in broiler diets as a partial sorghum-soybean meal substitute during the starter phase at 8% of the diet, which is about double industry practice (Okonkwo et al. 2016). However, higher inclusion levels (from 3 to 10%) of FM have been reported, but in these studies, diets were supplemented with methionine, lysine, histidine, and tryptophan to overcome the AA imbalance of FM (Cabel *et al.* 1987; Ochetim 1993).

In conclusion, the results of this study show that FM is an acceptable protein ingredient for broilers and can be incorporated at 8% into diets, especially diets formulated on a DAA basis, without negatively affecting growth performance. However, further studies are required to determine the upper limit for FM inclusion in broiler diets.

	Treatments									
	TAA0%	DAA0%	TAA2%	DAA2%	TAA4%	DAA4%	TAA8%	DAA8%	SEM	P-Value
BWG	42.9	47.0	40.3	46.6	40.7	43.3	41.7	42.5	4.21	0.062
FI	50.6	53.0	49.8	49.5	48.4	49.4	49.4	49.1	4.66	0.298
FCR	1.19	1.13	1.24	1.11	1.19	1.14	1.19	1.16	0.10	0.113

TAA = total amino acid; DAA = digestible amino acid; % = inclusion level of FM in diet; BWG = body weight gain (g/bird/day); FI = feed intake (g/bird/day); Each mean represents an average of 4 replicate cages (5 birds per cage).

Table1. Growth performance of broilers fed diets formulated on a TAA or DAA basis with graded inclusion of feather meal (FM) from 0-21 days of age

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Bacillus probiotics: A promising alternative for improving animal health and productivity

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The emergence of antibiotic-resistant bacteria has driven the search for an effective and safer alternative such as probiotics from the genus *Bacillus*. These *Bacillus* probiotics are live microorganisms that contain a unique protective outer shell, allowing them to resist the harsh conditions of the upper gastrointestinal system, and germinate in the gut where they confer health benefits to the host. In this study, we investigated six *Bacillus* strains (BPR-11, BPR-12, BPR-13, BPR-14, BPR-16 and BPR-17), which have been previously reported for their general safe for consumption (GRAS) status.

Each *Bacillus* strain was fermented in Tryptic Soy Broth (1L) for 8 hours at 37°C, 300 rpm, pH 7, with O2 levels at 300 ppm. Subsequently, this culture was sonicated, centrifuged at -4°C at 8000rpm and was separated with EtOAc three times at 37°C, to obtain an EtoAc extract. The antimicrobial experiments of these EtOAc extractions showed that four *Bacillus* strains (BPR-11, BPR-14, BPR-16 and BPR-17) expressed antimicrobial activity against pathogenic strains *Clostridium perfringens, Escherichia coli* and *Staphylococcus aureus*, with BPR-16 and BPR-17 also able to inhibit *Pseudomonas aeruginosa* and *Salmonella enterica*. Further chemical isolation of the EtoAc extract of BPR-17 led to the identification of eight metabolites, namely C16, C15, C14, C13 Surfactin C, maculosin, maculosine 2, genistein and daidzein, which were able to inhibit all tested pathogens with MIC values ranging from 6.25 to 50 µg/ml.

Further animal trials were conducted to test the effects of probiotic supplement in broiler chicken. Broiler eggs of mixed sex (n = 256) were randomly selected and incubated at 37.5°C and 55% relative humidity for 21 days. Hatchings were individually weighed and birds that had a similar weight were randomly assigned to either a control or probiotic group. The control group was fed a basal, medicated free wheat-soybean diet, whilst the probiotic group's feed was supplemented with a mixture of *Bacillus* strains (F1) at 2 × 108 CFU/g to the basal diet and thoroughly mixed. The broiler chickens were reared in floor pens and had ad libitum access to feed and water for 28 days.

The data collection over the experiment showed small and sometimes significant increases in the measured indicators in birds supplemented with the *Bacillus* probiotic mixture. While some of the indicators indicated significant improvements at day 21 (Table 1), these became non significant trends by day 28. Specific comparisons included mean body weight (1573 g to 1606 g; p = 0.12), average body gain (98.2 g to 99.4 g; p=0.57), feed intake (138.1 g to 138.7 g; p=0.80), FCR from 1.41 to 1.40 (Table 1) and mortality from 3.13% to 1.56%.

The presence of surfactin C analogues were further confirmed in the gut following mass spectroscopy analysis and targeted metabolomics. Currently, we are looking into the small metabolite differences within the gut and blood between probiotic and control poultry and understand how they work *in vivo*. Once done, we will optimize the probiotic feeding strategies to establish a stable protocol for commercial use.

Table1. Effect of Bacillus mixture (F1) on performance parameters of broiler chickens from day 1 to 28 (n = 256)

	Treatment group (n = 128)		
	Control	**Probiotic**	**P value**
BW0 (g)	42.6 ± 0.26	42.8 ± 0.27	0.11
BW7 (g)	152.3 ± 1.57	155.9 ±1.74	0.14
BW14 (g)	416.5 ± 4.38	420.2 ± 4.59	0.53
BW21 (g)	885 ± 9.47	911 ± 9.02	0.04
BW28 (g)	1573 ± 13.43	1606 ± 15.64	0.12
ADG0-7 (g)	21.8 ± 0.23	22.3 ± 0.24	0.13
ADG7-14 (g)	37.8 ± 0.58	37.8 ± 0.73	0.99
ADG14-21 (g)	67.0 ± 0.75	70.0 ± 0.66	0.005
ADG21-28 (g)	98.2 ± 1.55	99.4 ± 1.15	0.57
ADFI0-7 (g)	16.5 ± 0.29	16.5 ± 0.21	0.90
ADFI7-14 (g)	46.5 ± 0.59	46.8 ± 0.61	0.74
ADFI14-21 (g)	83.5 ± 0.70	87.6 ± 0.80	>0.0006
ADFI21-28 (g)	138.1 ± 1.67	138.7 ± 1.57	0.80
FCR0-7 (g/g)	0.76 ± 0.01	0.74 ± 0.00	0.17
FCR7-14 (g/g)	1.23 ± 0.01	1.24 ± 0.01	0.58
FCR14-21 (g/g)	1.25 ± 0.01	1.25 ± 0.00	0.70
FCR21-28 (g/g)	1.41 ± 0.01	1.40 ± 0.01	0.29
Mortality (%)	3.13	1.56	

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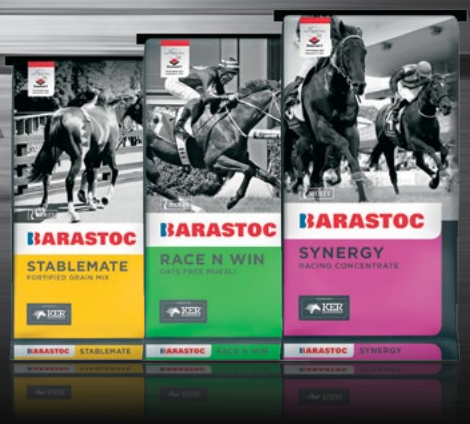

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