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Editorial



Advancements in animal nutrition: The interplay of feed enzymes, gut health, and nutrient supply in poultry and pig production – A tribute to Professor Mingan Choct's 30-year scientific legacy

Animal production is a significant protein source for human consumption (Salter and Lopez-Viso, 2021). The production of monogastric animals has grown enormously in recent decades, particularly of poultry and swine (Rauw et al., 2020). Such growth is attributed to the progress in animal nutrition, disease control, and genetic improvement in response to the global demand for meat (Kumar et al., 2023) and, of course, the tireless efforts of scientists working in the area for the past decades. Among them is Professor Mingan Choct, a monogastric animal nutritionist at the University of New England. He has dedicated his entire academic career to the field, significantly contributing to monogastric animal research and industry. To honour his contribution and celebrate his retirement, we organized a special issue in *Animal Nutrition* with contributions from a group of prominent researchers in monogastric animal nutrition and health. In this special issue, we published reviews and research papers, 8 in total, with a focus on the nutrition and health of monogastric production animals.

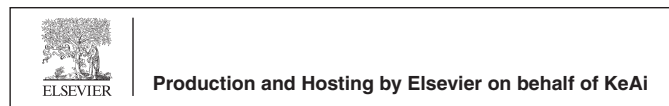
Professor Choct completed his PhD with elegant work pioneering the understanding of the roles of nonstarch polysaccharides (NSP) in poultry feed (Choct and Anison, 1990, 1992a, 1992b; Choct et al., 1992), which revolutionized the use of wheat as an ingredient in poultry diets with the aid of supplemental NSP-degrading enzymes (Choct, 2015; Choct et al., 1995; Svihus, 2011). In this special issue, three eminent researchers, Dr Michael Bedford, Research Director for AB Vista, England and Adjunct Professor at University of New England, Australia; Professor Birger Svihus at Norwegian University of Life Sciences, and Dr Aaron Cowieson, Senior Science Fellow of DSM, Netherlands, updated the understanding of the roles of dietary fibre in non-ruminant animal production, the capacity of exogenous carbohydrases to use dietary fibre as a focal substrate to generate lower molecular weight carbohydrates, and their interactions with the host in terms of gut development, microbiome modulation and metabolism. This review contends that the concentration and complexity of fibre in poultry diets of poultry will increase over time. This is because nutritionists will

be able to deploy highly targeted and efficacious carbohydrases to utilize locally sourced non-fibre-rich conventional raw materials and by-products in larger quantities in poultry diets whilst improving gut function, modulating the microbiome, and enhancing health and welfare.

Indeed, Prof. Choct's earlier work has alluded to the interaction between fibre and microflora (Choct and Anison, 1992a). Later, his review addressed the importance of gut microflora modulation on animal health and nutrition (Choct, 2009). In this special issue, we also have contributions from two outstanding scientists, Professors Richard Ducatelle and Filip Van Immerseel, at Ghent University, Belgium, on poultry gut health. They reiterate the critical importance of intestinal health for the digestion and absorption of nutrients and, hence, animal performance. They suggest that a shift in the microbiota composition in the intestinal tract, i.e., dysbiosis, elicits an inflammatory response and loss of integrity of the tight junctions between the epithelial cells, leading to gut leakage, which results in reduced nutrient absorption and an increased susceptibility to infections. More importantly, the review identified key factors determining intestinal health and important nutritional tools available to support intestinal health via the modulation of microbiome, i.e., enzymes, prebiotics, probiotics, synbiotics and postbiotics. They speculate that the next step is the nutritional steering of the microbial metabolome towards the production of beneficial 'interkingdom' signals, for example, endogenous microbial butyrate in the caeca of poultry (Onrust et al., 2015).

In line with the modulation of gut health, a profound understanding of gut microbiota dynamics is mandatory. This special issue also features the collaborative work of leading researchers, Professor Robert Moore at RMIT University, Professor Dragana Stanley at Central Queensland University and Professor Kapil Chousalkar at The University of Adelaide on faecal microbiota in commercial layer flocks. The paper presents their findings from a study where 16S rRNA sequencing was used to characterize the composition and temporal development of the gut microbiota in layers from four commercial flocks with a total of 1999 samples across a period from hatch to 70 weeks of age. To my knowledge, this study was unprecedented in scope and scale. The findings are, despite inter-flock differences, common patterns of microbiota development are present: Firmicutes and Proteobacteria are dominant at an early age in all flocks; the microbiota develop gradually during the rearing phase; richness and diversity increase after 42 d of age and then undergo significant changes in composition with Bacteroidota becoming more dominant in older birds. Such a

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large-scale and temporal characterization of faecal microbiota in layers is highly valuable as it is a big step forward for enriching the knowledge about microbiota development in layers to provide the basis for the modulation of gut health and, thus, improved egg production.

Poultry intestinal health is critical for growth performance and nutrient digestion, absorption and utilization. The mucous layer plays an essential role as the uttermost defence line of the gastrointestinal tract to maintain the gut health of animals. On the other hand, mucin produced by mucus can be lost as endogenous protein secretion, adding cost to digestion. In this special issue, a review authored by two renowned researchers, Professor Edwin Moran of Auburn University and Dr Michael Bedford of AB Vista, highlights the usefulness of endogenous loss in providing products that enhance overall large intestinal functioning in a comparison between swine and poultry as good representatives of mammals and the avian species with both consuming similar foods. The opportune use of endogenous mucins to sustain satisfactory operation for anaerobes is one of the examples. The authors elucidate that mucins throughout the upper gastrointestinal tract provide selective barrier functions between the lumen and mucosa as an intensive anaerobic population in the large intestine would require an extensive barrier that protects the host and provides a microbial environment for anaerobic bacteria to survive. Given its importance in gut health, the role of mucin in animal nutrition and health is also Professor Choct's research interest. His group extensively examined the intestinal microflora and mucin dynamics in response to the treatments of broilers by manno-oligosaccharides (Chee et al., 2010a,b,c). They revealed the modulating effects of manno-oligosaccharides on intestinal mucin dynamics, which may play a crucial role in how nutrients are digested in the lumen and absorbed across the mucosa.

The prevention of enteric diseases such as necrotic enteritis is another measure to maintain intestinal health. The outbreak of necrotic enteritis has become a pressing issue for the poultry industry due to the recent trend to remove antibiotics from animal feed, as has been enforced in the European Union since 2006 (Castanon, 2007). Professor Choct turned his attention to this issue and established a necrotic enteritis challenge model at the University of New England, one of few in the world to conduct broiler performance trials to tackle this disease with different nutritional measures (Ao et al., 2012; Mikkelsen et al., 2009; Rodgers et al., 2015; Wu et al., 2010). Thereafter, his group at the University of New England became a hub for assessing feed additives in relation to their effects on maintaining gut health and ameliorating necrotic enteritis in broilers. As a world-leading expert in the area, Professor Robert Moore at RMIT University reviews the production of broiler chickens under the pressure of necrotic enteritis resurgence and the worldwide removal of antibiotics in animal feed and the current challenges in testing and using alternative products in this special issue. Professor Moore focuses on the challenges and pitfalls in undertaking the experimental assessment of alternative necrotic enteritis treatments and translating laboratory research to real-world commercial production settings based on his experience, foresight, and analysis of the available information. The review covers discrepancies in understanding the causes of necrotic enteritis despite the confirmation that netB is the virulent toxin essential for the disease to occur, the progress in finding the alternatives to antibiotics and their tests with challenge models. Professor Moore insightfully brings attention to the fact that the alternatives controlling necrotic enteritis might also have wider impacts than just on pathogenic *Clostridium perfringens* strains, such as on beneficial groups of bacteria in the gut, and points out that it may be possible to select beneficial strains more efficiently, at an earlier stage in

screening and development in the case of probiotic screening in vitro, if a wider view is taken of the antimicrobial activity spectrum of products. The review concludes that products need to be tested in different production environments to determine their overall effectiveness. The vaccine might be the most effective solution if high-efficacy vaccines can be devised and built, and available management approaches and feed additive products may have important applications in the poultry industry beyond just the control of necrotic enteritis.

Another area that Professor Choct is passionate about is the application of a net energy system in poultry (Clements, 2010). He conceptualized the studies in establishing accurate prediction equations of net energy for poultry feed and ingredients performed at the University of New England (Barzegar et al., 2020; Wu et al., 2019). Currently, the realization of the use of net energy to replace metabolizable energy in poultry is progressing, and more studies have been done to fine-tune the prediction equation and assessments of ingredient net energy values (Liu et al., 2023; Ning et al., 2022; Sharma et al., 2021). A group of researchers from Charoen Pokphand Foods Public Company Limited (CPF), Thailand and Adisseo France S.A.S., France, led by Dr Jean Noblet, retired from INRA, France, a world-leading scientist in monogastric net energy, moved a step further in the prediction of net energy in broilers which is published in this special issue. The study used 23 diets with 13 major ingredients currently used in feed formulation and produced a prediction equation for broiler feed involving crude protein, fat and neutral detergent fiber as nutrient predictors in addition to the apparent metabolizable energy. The authors show that the ranking between complete feeds or between ingredients differs in the AME and NE evaluation systems according to their chemical composition and suggest combining the outcomes from recently published studies to propose a more general set of NE prediction equations. Indeed, Dr Noblet, in collaboration with a group of researchers from Charoen Pokphand Foods Public Company Limited (CPF), University of New England, and Adisseo France S.A.S., including Professor Choct has reanalyzed the data produced by the relevant institutes, reviewed the current status of net energy concepts and methodologies, assessed the merits and limits of the studies, and considered the current status of understanding and use of the net energy by industry and nutritionists, and finally proposed a practical application of consensus net energy prediction equations achieved through the orchestrated efforts of the researchers. The review concludes that the routine measurement of net energy values as an attempt to tabulate NE values for individual ingredients is fraught with difficulties and is of little reliability, which should be avoided. The best solution for evaluating the net energy of ingredients is to precisely quantify their apparent metabolizable energy content using a robust method so as to achieve net energy values accurately, and the industry is recommended to move to a net energy system to take advantage of its ability to offer a more accurate representation of dietary energy and better predict animal performance than the ME system.

As an animal nutritionist, Professor Choct puts great emphasis on the accuracy of feed formulation, whether on nutrients or energy. The studies he has performed are all about how to feed animals accurately to ensure their optimal performance, health, and welfare. In this regard, feed formulation is inevitably critical, requiring delicate skills and knowledge, which, in turn, relies on a correct measurement of feed nutrient contents and accurate determination of the nutritive value of ingredients. Gene Pesti, a retired professor from the University of Georgia, USA, and an Adjunct Professor at the University of New England, is a renowned poultry nutritionist worldwide. He has co-authored a paper on the future of feed formulation for poultry for this special issue with Professor

Choct. They highlight the features of the current linear, least-cost feed formulation and postulate the more profitable and complicated maximum-profit non-linear formulation. The review specifies that anything that affects the production function, bird genetics, feed quality, housing and environment should be considered for maximized profits. The profit-maximizing models of poultry firms improve with a move from metabolizable energy to net energy systems, consideration of the requirements for non-essential amino acids, and the use of dietary fiber (NSP plus lignin) instead of crude fiber as the measure of fiber in feed, for optimized use of exogenous enzymes. Such profit-maximizing production models will be evolving processes with field conditions and results being continually utilized to re-calibrate the technical models so that the management team can use cost and return projections to decide on the best choices of inputs and outputs. It concludes that future feed formulation will be part of management tools that resolve the conflicts between various aspects of poultry production, and the nutritionist will need to interact with other managers to maximize return to the firm. Furthermore, the pellet mill energy expenditures, nutritional effects on egg size, and the quantitative relationships (regressions) between all the inputs and outputs need to be known for the overall profitability of producers to be maximized, including the environmental costs and welfare concerns to move from linear least-cost models to non-linear profit maximizing models.

Overall, this special issue covers several important aspects of poultry production with swine production to a lesser extent, in line with Professor Mingan 'Choct's research journey. Good nutrition and gut health are the core of animal production. Precision feeding of appropriate nutrients to animals ensures their health, welfare and production and, at the same time, increases production efficiency, minimizes costs and environmental footprints, and eventually maximizes the profit for the farmers and the wellbeing of humankind. A good understanding of nutrient needs and utilization, gut microbiota and physiology related to intestinal health, the interaction between microbiota and host, and the control of diseases is paramount for animal industries. I hope this special issue will have an impact on these aspects, which have been the main contributions of Professor Choct. I wish Professor Choct a joyful and fulfilling retirement. However, I firmly believe that his dedication to sharing knowledge will persist as he continues to contribute his expertise to poultry and swine researchers as well as industry professionals.

Declaration of competing interest

To ensure editorial independence, the sponsors are not involved in the peer review process and do not influence what papers will be published. The peer review process for this special issue follow the same procedures as other special issues. Papers deemed suitable are sent to independent peer reviewers by the guest editor to assess the scientific quality. The editor-in-Chief Prof. Mingan Choct makes the final decision. For submissions from the editor-in-chief, the guest editor or authors who have conflicts of interest with them, we ensure that the paper is handled confidentially by a different editorial team member.

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