Annual Report
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Submitted to the Poultry Industry Association of New Zealand (PIANZ)

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SCOPE OF WORK

Funding of $ 10,000 p.a. is provided by the Poultry Industry Association of New Zealand (PIANZ) for the retention of Poultry Research and Teaching capabilities at Massey University

Terms of reference for the poultry scientists will be to:

- Assist in the strategic direction of poultry research and the preparation of Research and Development submissions for the School of Agriculture and Environment,

- Attract, conduct and/or oversee contract or publicly funded research projects in poultry on behalf of the School of Agriculture and Environment,

- Assist with the development and implementation of liaison groups, facilitating communication about poultry issues between the School of Agriculture and Environment, and

- Involve in poultry teaching programmes of the School of Agriculture and Environment where required but not to the detriment of his research programme.

RESEARCH ACTIVITIES, 2021/22

Influence of broiler age on the apparent metabolisable energy of cereal grains determined using the substitution method

The present study investigated the influence of broiler age on the apparent metabolisable energy (AME) and nitrogen-corrected AME (AMEn) of four common cereal grains (wheat, sorghum, barley and maize) using the substitution method. A maize-soybean meal basal diet was formulated, and the test diets were developed by replacing (w/w) 300 g/kg of the basal diet with wheat, sorghum, barley or maize. Six groups of broiler chickens, aged 1-7, 8-14, 15-21, 22-28, 29-35 or 36-42 d post-hatch, were utilised. Each diet, in pellet form, was randomly allocated to six replicate cages in each age group. Except for the 1-7 d age group, birds were fed a starter (d 1-21) and/or a finisher (d 21-35) diet prior to the introduction of experimental diets. The number of birds per cage were 10 (d 1-7), 8 (d 8-14) and 6 (d 15-42). The AME and AMEn of the grains were determined by total excreta collection. Data for each grain were subjected to orthogonal polynomial contrasts using the General Linear Models procedure.

The retention of dry matter (DM) and nitrogen linearly decreased ($P < 0.001$) with advancing broiler age in all cereals. Bird age influenced ($P < 0.001$) the AMEn of wheat and sorghum but had no effect ($P > 0.05$) on those of barley and maize. The AMEn of wheat increased with age ($P < 0.001$) from 12.53 MJ/kg DM in week 1 to 14.55 MJ/kg DM in week 2, then declined for following weeks, but no linear or quadratic responses were observed. The AMEn of sorghum demonstrated a quadratic response ($P < 0.05$), increasing from 12.84 MJ/kg DM in week 1 to 13.95 MJ/kg DM in week 2, and then plateauing to week 6. Overall, the present results suggest that the effect of broiler age on the AMEn of cereal grains varies depending on the grain type. The current study demonstrated that the application of age dependent AME or AMEn values of grains in diet formulations is conditional on the type of grain.

Influence of age on the apparent metabolisable energy of soybean meal and canola meal for broilers

The present study investigated the influence of broiler age on the apparent metabolisable energy (AME) and nitrogen-corrected AME (AMEn) of soybean meal (SBM) and canola meal (CM). A maize-soybean meal basal diet was formulated and the test diets were developed by replacing (w/w) 300 g/kg of the basal diet with SBM or CM. Six groups of broiler chickens, aged 1-7, 8-14, 15-21, 22-28, 29-35 or 36-42 d post-hatch, were utilised. Each diet, in pellet form, was randomly allocated to six replicate cages in each age group. Except for the 1-7 d age group, birds were fed a starter (d 1-21) and/or a finisher (d 21-35) diet prior to the introduction of experimental diets. The number of birds per cage were 10 (d 1-7), 8 (d 8-14) and 6 (d 15-42). The AME and AMEn of the protein source ingredients were determined by total excreta collection. Data for each protein source were subjected to orthogonal polynomial contrasts using the General Linear Models procedure. Bird age decreased the retention of dry matter quadratically ($P < 0.001$) for both SBM and CM. The retention of nitrogen decreased linearly ($P < 0.001$) with the advancing age of broilers for SBM and CM. The AMEn of SBM and CM decreased quadratically ($P < 0.001$) as birds grew older. The highest AMEn was observed during week 1 for both SBM and CM, then declined until week 3, followed by increases thereafter. The current results showed that the age of broiler chickens influenced the AMEn of SBM and CM. These findings support the need to consider the age-dependent AMEn of feed ingredients in diet formulations.

Influence of age on the standardised ileal amino acid digestibility of maize and barley in broilers

The aim of this study was to determine the standardised ileal digestibility coefficients (SIDC) of nitrogen (N) and amino acids (AA) in maize and barley. Titanium dioxide (5 g/kg) was added as an indigestible marker. Each assay diet, in pelleted form, was offered to birds for four days during the six periods namely d 3-7, 10-14, 17-21, 24-28 and 38-42. The ileal digesta were collected on d 7 (14 birds per cage), 14 (12 birds per cage), 21 (10 birds per cage), 28 (8 birds per cage), 35 (8 birds per cage) and 42 (6 birds per cage), respectively. The apparent AA digestibility coefficients were corrected using age-appropriate basal endogenous AA losses. No age effect ($P > 0.05$) was noted for the SIDC of N in maize. The average SIDC of indispensable AA (IAA) and total AA (TAA) was influenced in a quadratic manner ($P < 0.05$) with the values being higher at day 7 then decreased at day 14 and increased from day 14 to 21 and plateaued between days 21 to 35 with a further decrease at day 42. The average SIDC of dispensable AA (DAA) was influenced linearly ($P < 0.05$). In barley, the SIDC of N, average IAA, DAA and TAA was affected (quadratic; $P < 0.001$) by age. The digestibility increased from days 7 to 21, and then plateaued up to day 42. The present findings confirm that the SIDC of AA in maize and barley are influenced by broiler age and that the age effect on AA digestibility may need to be considered for precise feed formulation.

Influence of age on the standardised ileal amino acid digestibility of soybean meal and canola meal in broilers

The influence of broiler age on the standardised ileal digestibility coefficients (SIDC) of nitrogen (N) and amino acids (AA) in two protein sources (PS) [soybean meal (SBM) and canola meal (CM)] was investigated. Six age groups (d 7, 14, 21, 28, 35, and 42) were utilised. Two assay diets were formulated to contain either SBM (413 g/kg) or CM (553 g/kg), as the sole source of dietary AA. Titanium dioxide (5 g/kg) was added as an indigestible marker. Each assay diet, in pelleted form, was offered to birds for four days during the six periods namely d 3-7, 10-14, 17-21, 24-28 and 38-42. The ileal digesta were collected on d 7 (14 birds per cage), 14 (12 birds per cage), 21 (10 birds per cage), 28 (8 birds per cage), 35 (8 birds per cage) and 42 (6 birds per cage), respectively. The apparent ileal digestibility coefficients (AIDC) were standardised using previously determined age-appropriate basal endogenous AA (EAA) flows. In the SBM, the AIDC of N, average AIDC of indispensable (IAA), dispensable (DAA) and total AA (TAA) increased linearly ($P < 0.01$) with broiler age. The AIDC of all individual AA, except Leu, Asp and Glu ($P > 0.05$), was influenced (linear or quadratic; $P < 0.05$-0.001) by age. Though the SIDC of N tended to be influenced (quadratic; $P = 0.075$) by age, the average SIDC of IAA and TAA were unaffected ($P > 0.05$). An age effect (quadratic; $P < 0.05$) was observed in the average SIDC of DAA in SBM with the highest value at d 7, followed by a decrease from d 14 to 28, then increased beyond d 35. The SIDC of some individual AA (Arg, Thr, Trp, Cys, Pro) were affected ($P < 0.05$-0.001) in a quadratic manner by age. In the CM, the AIDC of N (quadratic; $P < 0.05$), average AIDC of IAA (linear; $P < 0.001$), DAA and TAA (quadratic; $P < 0.05$), were low between d 7 to 28 and increased thereafter. The SIDC of N, average SIDC of IAA, DAA and TAA in CM were influenced (quadratic; $P < 0.05$ to 0.001) by age. The SIDC of N and average SIDC of DAA and TAA were higher from d 7 to 14, declined at d 21 and then increased beyond d 28. The average SIDC of IAA was low between d 7 and 28, and increased thereafter. The SIDC of individual AA were affected (linear or quadratic; $P < 0.05$ to 0.001) by different magnitudes by the age. In general, the AIDC AA in SBM and CM increased with advancing age. The age influence on the SIDC of AA was variable, depending on the PS and AA. The results demonstrate that age-appropriate SIDC ofAA data might need consideration in broiler feed formulations.

Requirement of digestible calcium at different dietary concentrations of digestible phosphorus for broiler chickens. 2. Broiler growers (d 11 to 24 post-hatch)

An experiment was conducted to determine the digestible calcium (Ca) and digestible phosphorous (P) requirements of 11-24 d old broiler chickens. Eighteen maize-soybean meal-based diets containing 1.80, 2.35, 2.90, 3.45, 4.00 and 4.55 g/kg standardised ileal digestible (SID) Ca and 3.5, 4.5 and 5.5 g/kg SID P were fed to broilers from d 11 to 24. Each experimental diet was randomly allocated to six replicate cages (8 birds per cage). Body weight and feed amount were recorded at the start and end of the experiment and the feed conversion ratio was calculated. On d 24, birds were euthanised to collect ileal digesta, tibia and carcass for the determination of digestible Ca and P, the concentration of ash, Ca and P in tibia and the retention of Ca and P in the carcass. Titanium dioxide (5 g/kg) was included in all diets as an indigestible indicator for apparent ileal digestibility measurement. Total excreta output was measured during the last 4 d of the experimental period for the measurement of apparent total tract retention of Ca and P. Fixed effects of the experiment were dietary concentrations of SID Ca and SID P and their interaction. If the interaction or main effects were significant ($P < 0.05$), the parameter estimates for second-order response surface model were determined using General Linear Model procedure of SAS. The weight gain of broiler growers was optimised at the SID P concentration of 3.5 g/kg and SID Ca concentrations between 2.35 to 4.00 g/kg. At 3.5 g/kg SID P concentration, the required SID Ca for maximum weight gain was determined to be 3.05 g/kg, which corresponded to SID Ca to SID P ratios of 0.87. The concentration of SID Ca that maximised tibia ash at 3.5 g/kg SID P was 3.69 g/kg, which corresponded to SID Ca to SID P ratio of 1.05. Maximizing bone ash requires more Ca than maximising weight gain. Carcass Ca and P retention were reflective of total tract Ca and P retention values. The estimated SID Ca requirements (at 3.5 g/kg SID P) for both maximised weight gain (3.05 g/kg or 6.11 g/kg total Ca) and bone ash (3.69 g/kg or 7.28 g/kg total Ca) are lower than the current Ca recommendation (8.70 g/kg total Ca equivalent to 4.03 g/kg SID Ca; Ross, 2019) for broiler growers, indicating possible oversupply of Ca in diets formulated based on the current recommendation.

Influence of age and dietary cellulose levels on ileal endogenous energy losses in broiler chickens

Two experiments were conducted to determine the ileal endogenous energy losses (IEEL) and, AMEn and true ileal digestible energy (TIDE) of four cereal grains (maize, sorghum, wheat and barley) for broilers. In experiment 1, a glucose-based purified diet was used to determine the IEEL for correcting the apparent ileal digestible energy (AIDE) values to TIDE. The diet was randomly allocated to 6 replicates (6 birds per replicate) of male broilers and fed from 18 to 21 days post-hatch. The jejunal and ileal digesta were collected on day

21. In experiment 2, 4 experimental diets with similar inclusion (957 g/kg) of grains were developed to determine AMEn, AIDE and TIDE. Titanium dioxide (5.0 g/kg) was added to all diets as an indigestible marker. Each diet was randomly allotted to 6 replicates (8 birds per replicate) and fed from 14 to 21 days post-hatch and the ileal digesta were collected on day 21. Jejunal and ileal EEL were determined to be 648 ± 127.2 and 347 ± 29.4 kcal/kg DM intake, respectively. The TIDE was higher ($P < 0.05$) than both AMEn and AIDE for all cereals, with no differences between the AMEn and AIDE. The highest ($P < 0.05$) AIDE and TIDE values were observed for maize, followed by sorghum, wheat and barley. The highest and lowest coefficients of apparent ileal digestibility (CAID) for nitrogen and starch were obtained with maize and barley, respectively, with sorghum and wheat being intermediate. The CAID of DM, nitrogen and starch were positively correlated ($P < 0.001$) with TIDE ($r = 0.990$, 0.703 and 0.705, respectively) than the AMEn ($r = 0.873$, 0.483 and 0.656, respectively). In conclusion, IEEL can be quantified in the ileal digesta of birds by feeding a glucose-based purified diet. Overall, TIDE values were higher than AMEn and AIDE, and showed strong correlations with ileal digestibility of nutrients. Further studies are warranted to investigate the application of TIDE as potential available energy system for poultry.

Metabolisable energy and standardised ileal amino acid digestibility of full-fat soybeans for broilers are influenced by wet-heating, expansion temperature and autoclaving time

The influence of wet-heating (WH) and expansion temperature (ET), and autoclaving time (AT) on the nitrogen-corrected apparent metabolisable energy (AMEn) and standardised ileal digestibility (SID) of AA in full-fat soybeans (FFSB) for broilers was examined in two experiments. The AMEn and SID AA of FFSB were determined by the difference and direct methods, respectively. In Experiment 1, raw FFSB (K0) were either treated by WH at 80°C for 1 min and expanded at 115°C (K1-115) or 125°C (K1-125), WH at 100°C for 6 min and expanded at 115°C (K2-115) or 125°C (K2-125), or WH at 100°C for 16 min and expanded at 115°C (K3-115) or 125°C (K3-125). Wet-heating and ET significantly ($P < 0.001$) increased the AMEn in FFSB. Among heat-treated FFSB, K1-115 and K1-125 resulted in the lowest and highest AMEn values, respectively, with all samples wet-heated at 100°C being intermediate. The K3-125 had AMEn values similar ($P > 0.05$) to K1-125. Among heat-treated FFSB, the highest average SID of AA was recorded for K3-125. In Experiment 2, K3-125 from experiment 1 was divided into 9 batches and autoclaved at 110 °C for 15 (Z1), 30 (Z2), 45 (Z3), 60 (Z4), 120 (Z5), 180 (Z6), 240 (Z7), 300 (Z8), and 360 (Z9) min. A quadratic ($P < 0.01$) pattern was observed for the effects of AT on AMEn. The AMEn was unaffected until 300 min AT and then declined at 360 min. The AT quadratically ($P < 0.001$) affected the average SID AA where the SID increased from K3-125 to Z1, plateaued to Z5, and then declined to Z9. In

conclusion, the results demonstrated that WH at 100°C for 16 min followed by expansion at 125°C are the most optimal wet-heating and expansion processing, associated with the highest SID AA. Autoclaving at 110°C for 30 min enhanced energy utilisation and AA digestibility in FFSB, suggesting that further advantages may be achieved by short-time autoclaving of previously wet-heated and expanded FFSB samples.

Influence of conditioning and expansion characteristics on the apparent metabolisable energy and standardised ileal amino acid digestibility of full-fat soybeans for broilers

This study investigated the influence of short-term and long-term conditioning and expansion on the nitrogen-corrected apparent metabolisable energy (AMEn) and standardised ileal digestibility (SID) of amino acids (AA) in full-fat soybeans (FFSB) for broilers. A batch of raw soybeans was used to manufacture 10 FFSB products (T0 to T9) by applying various combinations of conditioning and expansion. The AMEn and SID AA of FFSB were determined by difference and direct methods, respectively. All heat treatments increased ($P < 0.001$) the AMEn, compared to raw FFSB. The sample subjected to long-term conditioning at 100 °C for 6 min and expansion at 18 kWh/t (T5) supported 3.88 MJ/kg higher AMEn than the raw FFSB. Raw FFSB had the poorest ($P < 0.05$) AA digestibility. Among the heat-treated samples, the highest ($P < 0.05$) SID AA was recorded for T5. The results demonstrated that the long-term conditioning of FFSB at 100 °C for 6 min prior to expansion with 18 kWh/t specific energy input enhanced metabolisable energy and SID AA. Further increases in conditioning time from 6 to 9 min or expansion specific energy input from 18 to 28 kWh/t, did not yield additional benefits to energy utilisation and AA digestibility of FFSB.

Contract research and feed evaluation

These commitments continued during the reporting period. The total value of feed evaluation services and commercial contracts during 2021/22 was around $145,000.

The project “Effect of broiler age on energy utilisation and amino acid digestibility”, funded by Agrifutures, Australia in 2020, continues (2020-2023), supporting two PhD projects (Mr Mahmoud Khalil; Mrs Mukti Barua).

TEACHING, TRAINING AND EXTENSION ACTIVITIES, 2021/22

Postgraduate Research Supervision

Professor Ravi Ravindran, Dr Reza Abdollahi & Dr Fifi Zaefarian

PhD candidates

David, L.S., Title: Studies on the measurement of calcium digestibility in raw materials for poultry. Completed in December 2021.

Mahmoud Mohammad Khalil, Title: Influence of broiler age of energy utilisation. Ongoing. Funded by Agrifutures, Australia.

Mukti Barua, Title: Influence of broiler age on ileal nutrient digestibility. Ongoing. Funded by Agrifutures, Australia. Completed in August 2022.

S. Jananai Santhiralingam. Title: Factors affecting feed ingredients digestibility in pig and poultry. (Co-supervisors: Abdollahi and Zaefarian). On-going.

Amira Elsayed Abdalla Mahmoud. Title: 'Optimising the use of black soldier fly *Hermeta illucens* L. for animal feed' (Co-supervisor: Ravindran).

Alireza Jafari. Title: The effect of limestone particle size on performance, calcium digestibility and gene expression of calbindin in broiler chickens and pullets. (Co-supervisor: Abdollahi). On-going. Bu-Ali Sina University, Hamedan, Iran.

Priya Lal. Title: Wheat particle size and enzyme supplementation in egg type birds. (Co-supervisor: Abdollahi). On-going. USP, Samoa.

MSc candidates

Elly Solomon Kambiam. Title: Influence of drying treatments on the metabolisable energy and, ileal digestibility of amino acids and starch in maize. (Main-supervisor: Zaefarian; Co-supervisor: Abdollahi). Completed in March 2022.

Kshanada Ganraj. Title: Nutritive value of Fodder Beet for poultry. (Co-supervisors: Abdollahi and Zaefarian). Completed in September 2021.

Shola Gabriel Olumodeji. Title: Effect of dietary fibre affecting ad libitum feed intake and feeding behaviour of growing-finishing pigs fed a using single-spaced electronic feeders. (Co-supervisor: Zaefarian). Completed in 2021.

Post-doctoral scientist

Dr Laura David was appointed as a post-doctoral scientist (from March 2022 to February 2025). This position is being supported by Contract research funding.

Other activities

- The Biennial New Zealand Poultry Industry Conference was held virtual in March 2021. The meeting is jointly organised by the World's Poultry Science Association (NZ Branch) and Massey University.

Dr Fifi Zaefarian is involved in teaching the following papers:

- Teaching 'Poultry Production' (117.371) for Animal Science and Agriculture undergraduates.
- Teaching 'Monogastric Nutrition' (117.302) for Animal Science undergraduates.
- Paper coordinator of 'Animal Feed Science and Technology' paper (117.224) for Animal Science undergraduates.
- Teaching in 'Animal Feed Science and Technology' paper (117.224) for Animal Science undergraduates.
- Teaching 'Poultry Production' in 'Animal Production for Veterinarians II' paper (227.215) for Vet undergraduates.
- Teaching 'Poultry Science' in 'Animal Science' paper (117.202) for Animal Science undergraduates.
- Teaching 'Poultry Science' in 'Problem Solving in Animal Production' paper (117.381) for Animal Science and Agriculture undergraduates.
- Teaching 'Nutrient Metabolism' in 'Performance Animal Nutrition' paper (117.226) for Animal Science undergraduates.
- Teaching 'Avian Reproduction' in 'Animal Reproduction and Lactation in Livestock' paper (117.243) for Animal Science undergraduates.

Overseas Linkages

- World Poultry Congress, Paris, France. 7-11th August 2022 (In-person meeting).
- USSEC- Regional Poultry Management and Feed Formulation Workshop. Kathmandu, Nepal, 27-28th July 2022 (In-person meeting).
- USSEC- Regional Technical Seminar, 17th December 2021 (Virtual Webinar).
- Broiler Feed Quality Conferences (BFQC), November 2021 (Virtual Webinar).

Appointments

Member, Editorial Boards of the following International Journals (**Ravindran**)

- Associate Editor, *Animal Production Science* (published by the CSIRO, Australia)
- Section Editor (Poultry), *Animals*

- Senior Editor, *Animal Feed Science and Techno*logy (Elsevier, the Netherlands).
- Section Editor, *British Poultry Science* (Published by British Poultry Science Association)
- Editorial Board, *Journal of Applied Animal Nutrition* (Cambridge Press, UK).
- Editorial Board, *Asian-Australasian Journal of Animal Science* (Published by the Asian-Australasian Association of Animal Production)

Member, Editorial Board of the following International Journal (**Abdollahi**)

- Associate Editor, *Animal Nutrition*

Member, Editorial Board of the following International Journal (**Zaefarian**)

- Associate Editor, *Animals*

Organising committee of the following conferences (**Ravindran & Abdollahi**)

- 2022 New Zealand Poultry Industry Conference, Virtual, March 2022.
- 2023 New Zealand Poultry Industry Conference, Nelson, March 2023.
- Seventh International Broiler Nutritionists' Conference (Poultry Beyond 2025).

PROJECTED ACTIVITIES SEPTEMBER 2022 – AUGUST 2023

Research Activities

- **Digestible calcium assessment in poultry**

These studies will form part of the Postdoc of Ms. Laura David.

- **Influence of age of broilers on protein digestibility in meat and bone meal**
- **Influence of age of broilers on metabolisable energy of meat and bone meal**
- **Influence of drying treatments on the metabolisable energy and, ileal digestibility of amino acids and starch in maize**

Teaching, Training and Extension Activities

- Postgraduate supervision and training; teaching of undergraduates and postgraduates – poultry nutrition and production.
- Animal Science (117.202)
- Animal Feed Science and Technology (117.224)
- Animal Reproduction and Lactation in Livestock (117.243)
- Monogastric Nutrition (117.302)
- Animal Production (117.371)
- Problem Solving in Animal Production (117.381)
- Performance Animal Nutrition (117.226)

- Animal Production for Veterinarians II (227.215)
- Farm Animal Population Health and Production (227.311)

- New Zealand Poultry Industry Conference to be held in Nelson. March 2023.
- Advancing Poultry Production 2022, 22nd Massey/Industry Conference' to be held in Palmerston North. (Date not confirmed).
- Poultry Beyond 2025, Seventh International Broiler Nutritionists' Conference to be held in New Zealand in 2023/2024.

- Member of Scientific Committee to organize the 2nd International Feed Technology Congress (IFTC; Utrecht, the Netherlands, 2022).

Overseas Linkages

- Latin American Scientific Conference, October 2022, Paraná, Brazil. (**Abdollahi**)
- FeedExpo, January 2023, Tehran, Iran. (The date has not been confirmed yet) (**Abdollahi**)

PUBLICATION LIST, 2021/2022

Book Chapter

Journal Articles

Tancharoenrat, P., **Zaefarian, F., Ravindran V.** (2022) Composition of chicken gallbladder bile. British Poultry Science, https://doi.org/10.1080/00071668.2022.2044451

Sanaa Efranji, S., Sedghi, M., Mahdavi, A. H., **Abdollahi, M. R.** (2022) effects of feed physical form and insoluble fiber during different rearing periods on productive performance, immune response, behavior, tibia indices and gastrointestinal alterations of W-36 laying pullets. Poultry Science Journal 10(1): 111-127

Abdollahi, M. R., Wiltafsky-Martin, M., **Zaefarian, F., Ravindran, V.** (2022) Metabolizable energy and standardized ileal amino acid digestibility of full-fat soybeans for broilers are influenced by wet-heating, expansion temperature, and autoclaving time. Poultry Science 101:102016.

David, L. S., **Abdollahi, M. R.,** Bedford, M. R., **Ravindran, V.** (2022) Requirement of digestible calcium at different dietary concentrations of digestible phosphorus for broiler chickens. 2. Broiler growers (d 11 to 24 post-hatch). Poultry Science. (Accepted)

Khalil, M. M., **Abdollahi, M. R., Zaefarian, F.,** Chrystal, P. V., **Ravindran, V.** (2022) Influence of age and dietary cellulose levels on ileal endogenous energy losses in broiler chickens. Poultry Science 101:101948.

Abdollahi, M. R., Wiltafsky-Martin, M., **Zaefarian, F., Ravindran, V.** (2022) Influence of conditioning and expansion characteristics on the apparent metabolizable energy and standardized ileal amino acid digestibility of full-fat soybeans for broilers. Animals. 12, 1021.

Khalil, M. M., **Abdollahi, M. R., Zaefarian, F.,** Chrystal, P. V., **Ravindran, V.** (2022) Influence of broiler age on the apparent metabolizable energy of cereal grains determined using the substitution method. Animals 12, 183.

Dersjant-Li, Y., **Abdollahi, M. R.,** Bello, A., Waller, K., Marchal, L., **Ravindran, V.** (2022) Effects of a novel consensus bacterial 6-phytase variant on the apparent ileal digestibility of amino acids, total tract phosphorus retention and tibia ash in young broilers. Journal of Animal Science 100, 1-9.

Dersjant-Li, Y., Bello, A., Stormink, T., **Abdollahi, M. R., Ravindran, V.,** Babatunde, O. O., Adeola, O., Toghyani, M., Liu, S. Y., Selle, P. H., Marchal, L. (2022) Modeling improvements in ileal digestible amino acids by a novel consensus bacterial 6-phytase variant in broilers. Poultry Science 101:101666.

Tari, L. M., Perera, W. N. U., **Zaefarian, F., Abdollahi, M. R.,** Cowieson, A. J., **Ravindran, V.** (2022) Influence of barley inclusion method and protease supplementation on growth performance, nutrient utilisation, and gastrointestinal tract development in broiler starters. Animal Nutrition 8, 61-70.

David, L. S., **Abdollahi, M. R.,** Bedford, M. R., **Ravindran, V.** (2021) Comparison of the apparent ileal calcium digestibility of limestone in broilers and layers. British Poultry Science 62:6, 852-857.

Barua, M., **Abdollahi, M. R., Zaefarian, F.,** Wester, T. J., Girish, C. K., Chrystal, P. V., **Ravindran, V.** (2021) Influence of age on the standardized amino acid digestibility of corn and barley in broilers. Animals 2021, 11, 3575.

Ravindran, V., Abdollahi, M. R. (2021) Nutrition and digestive physiology of the broiler chick: State of the art and outlook. Animals 2021, 11, 2795. (As part of the Special Issue "The Relationship between Dietary Factors and Bacterial, Parasitic, or Fungal Challenges in Modern Poultry Production")

David, L. S., **Abdollahi, M. R.,** Bedford, M. R., **Ravindran, V.** (2021) Requirement of digestible calcium at different dietary concentrations of digestible phosphorus for broiler chickens. 1. Broiler starters (d 1 to 10 post-hatch). Poultry Science 100:101439.

Zaefarian, F., Cowieson, A. J., Pontoppidan, K., **Abdollahi, M. R., Ravindran, V.** (2021) Trends in feed evaluation for poultry, with emphasis on in vitro techniques. Animal Nutrition. Volume 7, Issue 2, Pages 268-281.

Pedersen, N. B., **Zaefarian, F.,** Storm, A. C., **Ravindran, V.,** Cowieson, A. J. (2021) Mathematical prediction of ileal energy and protein digestibility in broilers using multivariate data analysis. Poultry Science 100 (6):101106.

Pedersen, N. B., Hanigan, M., **Zaefarian, F.,** Cowieson, A. J., Nielsen, M. O., Storm, A. C. (2021) The influence of feed ingredients on CP and starch

disappearance rate in complex diets for broiler chickens. Poultry Science 100 (5):101068. doi: 10.1016/j.psj.2021.101068

Conference Papers

Perera, W. N. U., **Abdollahi, M. R., Zaefarian, F., Ravindran, V.** (2022) Influence of whole barley feeding and supplemental carbohydrases on performance and nutrient utilisation of broiler starters. Proceedings of the 2nd International Feed Technology Conference (IFTC) 2. Utrecht, the Netherlands.

Barua, M., **Abdollahi, M. R., Zaefarian, F.,** Wester, T. J., Girish, C.K., Chrystal, P. V., **Ravindran, V.** (2022) Influence of age on the standardised ileal amino acid digestibility of maize and barley in broilers. Proceedings of the Australian Poultry Science Symposium 33: 12-15. Sydney, Australia.

David, L. S., **Abdollahi, M. R.,** Ravindran, G., Bedford, M. R., **Ravindran, V.** (2022) Requirement of digestible calcium at different dietary concentrations of digestible phosphorus for broiler growers (Day 11-24 posthatch). Proceedings of the Australian Poultry Science Symposium 33: 39-42. Sydney, Australia.

Khalil, M. M., **Abdollahi, M. R., Zaefarian, F.,** Chrystal, P. V., **Ravindran, V.** (2022) Estimation of ileal endogenous energy losses at different ages and influence of dietary cellulose levels in broiler chickens. Proceedings of the Australian Poultry Science Symposium 33: 16. Sydney, Australia.

Abdollahi, M. R. (2021; Invited speaker). The quest for optimal pellets, with an emphasis on nutritional value. In Symposium: A comprehensive approach to maximize feed quality and meat bird potential through feed manufacture. ID: 492S. Poultry Science Association (PSA), Proceedings of 110th Annual Meeting, Virtual Annual Meeting.