



Annual Report

01 September 2020 – 31 August 2021

Submitted to the Egg Producers Federation (EPF)

Dr Reza Abdollahi
Senior Poultry Scientist
Monogastric Research Centre
School of Agriculture and Environment
Massey University
Palmerston North 4442

TABLE OF CONTENTS

Page

Scope of Work	3
Research Activities, 2020/2021	4
Teaching, Training and Extension Activities	7
Proposed Activities, 2021/2022	10
Publication List	12

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, 2020/21

Apparent metabolisable energy of cereal grains for broiler chickens is influenced by age

The present study was conducted to investigate 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). Four experimental diets with the same inclusion (962 g/kg) of each grain were developed and fed to groups of broiler chickens aged 1-7, 8-14, 15-21, 22-28, 29-35 or 36-42 d post-hatch. Each diet, in pellet form, was randomly allocated to 6 replicate cages in each age group. Except for the 0-7 d age group, the birds were fed a starter (d 0-21) and/or a finisher (d 21-35) diet before the introduction of experimental diets. The number of birds per cage were 10 (d 1-7) and 8 (d 8-42). Excreta were collected over the last 4 d of each age period. The AME and AMEn of the grains were determined by the total excreta collection.

Bird age influenced ($P < 0.001$) the AME and AMEn of all cereal grains. The AMEn of wheat declined quadratically ($P < 0.01$) with advancing age, from 3,461 kcal/kg in week 1 to 3,219 kcal/kg in week 2 and then plateaued. The AMEn of sorghum grain declined linearly ($P < 0.001$) with advancing age, from 3,762 kcal/kg in week 1 to 3,614 kcal/kg in week 2, plateaued to week 5 and then declined to 3,556 kcal/kg in week 6. A quadratic ($P < 0.001$) reduction in the AMEn of barley was observed as birds grew older, with the AMEn decreasing between week 1 (3,285 kcal/kg) and week 2 (2,988 kcal/kg), increasing in week 3 (3,117 kcal/kg) and then plateauing. The AMEn of maize declined quadratically ($P < 0.05$) with advancing broiler age; the highest AMEn was observed in weeks 1 and 5, the lowest AMEn in week 2, with the other weeks being intermediate. In conclusion, the present results showed that broiler age has a substantial impact on the AME and AMEn of cereal grains and the effect varied depending on the cereal grain. These data suggest that age dependent AME and AMEn values may need to be considered when formulating broiler diets to improve the precision of feed formulation and production efficiency.

An investigation into the influence of age on the standardised amino acid digestibility of wheat and sorghum in broilers

The present study was conducted to determine the standardised ileal digestibility coefficients (SIDC) of nitrogen (N) and amino acids (AA) in wheat and sorghum at six different ages (d 7, 14, 21, 28, 35, and 42) of broilers. Two assay diets were formulated to contain 938 g/kg of each grain as the sole source of AA in the diet. Titanium dioxide (5 g/kg) was added as an indigestible marker. Each assay diet was fed to six replicate cages housing 14

(d 7), 12 (d 14), 10 (d 21), 8 (d 28), 8 (d 35), and 6 (d 42) birds per cage for four days prior to digesta collection from the lower half of the ileum. The apparent ileal digestibility coefficients (AIDC) were calculated and standardised by using the age-appropriate basal endogenous AA losses determined in a previous study (Chapter 5).

In the case of wheat, AIDC of N and all AA increased (linear or quadratic, $P < 0.05-0.001$) with advancing age. No age effect was noticed on the SIDC of N, average of indispensable (IAA) and dispensable AA (DAA), though the average of total AA tended (linear, $P = 0.09$) to increase by age. In sorghum, the AIDC of N, average of IAA and DDA were unaffected ($P > 0.05$) by age. The AIDC of Met, Trp, Cys, Asp increased ($P < 0.05$) linearly as the birds grew older. The SIDC of N, average SIDC of indispensable, dispensable and total AA were higher at d 7, reduced at d 14 and then plateaued. Among the IAA, the SIDC of Arg, His, Thr and Val decreased (quadratic, $P < 0.05$ to 0.01) with age. A linear decrease ($P < 0.05$ to 0.001) was observed for the SIDC of Ile, Leu, Lys and average of IAA with higher values determined at d 7. The SIDC of all individual DAA (except Cys) and the average of DAA decreased with age (linear or quadratic, $P < 0.05$ to 0.001) with higher values at d 7. Overall, the SIDC of AA increased in wheat and decreased in sorghum with advancing age. The current findings suggest that broiler age influenced the AIDC and SIDC of most AA in wheat and sorghum, and that the age effect may need be considered in practical feed formulations. The age effect was variable depending on the grain type and specific AA.

Comparison of the apparent ileal calcium digestibility of limestone in broilers and layers

The apparent ileal calcium (Ca) digestibility coefficients of two limestone sources in growing broilers and layers were determined in two separate experiments. In each experiment, two maize-based diets were developed with one of the two limestone sources (A, experiment 1 and B, experiment 2) to contain either 8.0 g/kg Ca for broilers or 40 g/kg Ca for layers. The two sources differed inter alia in particle size, with limestone A being finer and limestone B being coarser. Titanium dioxide was included in all diets as an indigestible indicator. Each experimental diet was randomly allotted to six replicate cages (six birds per cage for broilers or five birds per cage for layers) and offered for three days from 19 to 21-day post-hatch to broilers and during 40 weeks of age to layers. The total tract Ca retention was also measured using the indicator ratios in the diet and excreta.

In both experiments, the apparent ileal Ca digestibility, gizzard pH and gizzard Ca concentration were higher ($P < 0.05$) in layers than in broilers. The apparent ileal digestibility coefficient of limestone A for broilers and layers were 0.50 and 0.62, respectively. The corresponding values for limestone B were 0.43 and 0.70, respectively. The apparent total tract retention of Ca was similar ($P > 0.05$) between broilers and layers in both experiments, and between the two sources. The present data showed that the layers are more efficient in absorbing Ca from limestone than broilers.

Requirement of digestible calcium at different dietary concentrations of digestible phosphorus for broiler chickens during day 1 to 10 post-hatch

An experiment was conducted to determine the digestible calcium (Ca) and digestible phosphorous (P) requirements of 10-day-old broiler chickens. Fifteen maize-soybean meal-based diets containing 3.3, 3.9, 4.4, 5.0 and 5.5 g/kg standardised ileal digestible Ca (SID Ca) and 4.0, 5.0 and 6.0 g/kg standardised ileal digestible P (SID P) were fed to broilers from days 1 to 10. Each experimental diet was randomly allocated to six replicate cages (12 birds per cage). Body weight and feed intake were recorded at the start and end of experiment and the feed conversion ratio was calculated. On day 10, birds were euthanised to collect ileal digesta, toes and tibia for the determination of digestible Ca and P, toe ash concentration and the concentrations of ash, Ca and P in tibia. Titanium dioxide (5 g/kg) was included in all diets as an indigestible indicator for apparent ileal digestibility measurements. Total excreta were collected from day 1 to 10 for the measurement of total tract retention of Ca and P.

The growth performance, bone mineralisation and mineral utilisation of broiler starters were found to be optimised at 5 g/kg SID P concentration. Required SID Ca for maximum weight gain and bone mineralisation were determined to be 3.32 and 4.36-4.78 g/kg, respectively, at 5 g/kg SID P concentration, which correspond to SID Ca to SID P ratios of 0.66 and 0.87-0.96, respectively. The estimated SID Ca requirement for weight gain is lower than the current Ca recommendation (9.6 g/kg total Ca or 4.7 g/kg SID Ca) for broiler starters. However, bone mineralisation is maximised around the current total Ca recommendation at 8.9-9.8 g/kg (4.36-4.78 g/kg SID Ca), indicating that bone mineralisation requires more Ca than growth performance.

Nutrient analysis, metabolisable energy and standardised ileal amino acid digestibility of canola meals and canola seed for broiler chickens

Nutrient composition, nitrogen-corrected apparent metabolisable energy (AMEn) and ileal amino acid (AA) digestibility of two canola meals (CM1 and CM2) and one canola seed (CS) sample were evaluated using laboratory analyses and animal studies. The AME assay was conducted with broilers using the classical total excreta collection between day 18 and 25 post-hatch. A maize-soybean meal basal diet was formulated and a test diet, containing CM or CS, was developed by replacing (w/w) 30% of the basal diet with CM or CS. The AME of CM and CS was calculated based on the difference between the AME values of basal and test diets. Ileal protein and amino acid (AA) digestibility of CM and CS were determined using direct method. In this method, the assay diets were formulated with the CM or CS serving as the sole source of AA. All diets contained titanium dioxide as an indigestible marker.

The crude protein of CM1, CM2 and CS were determined to be 411, 393 and 235 g/kg (as received basis), respectively. Differences ($P < 0.05$) were observed in the AMEn value of CM and CS. The AMEn content of CM1, CM2 and CS were 7.22 and 6.78 and 10.29 MJ/kg, respectively. A tendency ($P = 0.052$) was observed for effect of dietary treatment on standardised ileal digestibility coefficient of protein and AA. The CS had highest ($P < 0.05$) digestibility compared to both CM samples, and no differences ($P > 0.05$) were observed between the two CM samples. In conclusion, the present study showed that the nutrient composition, AMEn, and standardised ileal digestibility of protein and AA vary between CM and CS samples. Canola meal and CS are attractive feed ingredients for poultry and can be used as a partial replacement for soybean meal in poultry diets.

Contract research and feed evaluation

These commitments continued during the reporting period. The total value of feed evaluation services and commercial contracts during 2020/21 was around \$120,000.

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, 2020/21

Postgraduate Research Supervision

Professor Ravi Ravindran, Dr Reza Abdollahi & Dr Fifi Zaefarian

PhD candidates

Perera, W. Nipuna U., Title: Influence of feed processing and enzyme supplementation on performance, nutrient utilisation and gut morphology of poultry fed barley-based diets. Completed in October 2020.

David, L.S., Title: Studies on the measurement of calcium digestibility in raw materials for poultry. Thesis submitted in July 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.

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

Michelle Taylor, Title: 'Gut microflora and bee health' (Co-supervisor: Ravindran). Thesis completed, December 2020.

Amira Elsayed Abdalla Mahmoud. Title: 'Optimising the use of black soldier fly *Hermetia 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

Gayatri Vinod Bhaskare. Title: Metabolisable energy and digestible amino acids of canola meals and canola seed for broilers. Completed February 2021.

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). Ongoing.

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

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). Ongoing.

Mohammad Javad Fasihi. Title: Influence of feed form and pellet quality on growth performance and digestive tract developments in broiler chickens. (Co-supervisor: Abdollahi). Animal Science Department, Agriculture College, Isfahan University of Technology, Isfahan, Iran. Completed March 2021.

Post-doctoral scientist

Dr Fifi Zaefarian appointment as a post-doctoral scientist (from March 2019 to February 2022) was changed to Senior Lecturer in 2020. This position is being supported by overseas industry funding.

Other activities

- The Biennial New Zealand Poultry Industry Conference to be held in Nelson in 5th and 6th October 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

- Poultry Science Annual Meeting (USA)- July 19-22, 2021. Feed Quality/Feed Manufacture Symposium. (**Virtual Meeting**). Invited speaker (**Abdollahi**) to present a paper on "The quest for optimal pellets, with an emphasis on nutritional value".
- IRAN Poultry Feed Technology Seminar, 10th June 2021 (**Virtual Webinar**). Invited speaker (**Abdollahi**) to present a paper on "Maximising the benefits of pelleting diets for modern broilers".
- USSEC-Turkey Feed Formulation Workshop, 4-5th May 2021 (**Virtual Webinar**). Invited speaker (**Abdollahi**) to present two papers on "Pelleting Broiler Feed: Implications for Efficiency, Digestion and Gut Development" and "Towards a Digestible Phosphorus and Calcium System in Poultry" at USSEC regional technical Seminar.
- University of Sydney Seminar Series, 27 May 2021. (**Virtual Webinar**). Invited speaker (**Abdollahi**) to present a talk on "Overview of Poultry Research at Massey University: Expertise and Research Interests".
- Arkansas Nutrition Conference, Roger, Arkansas, USA (Virtual meeting), September 2020 (**Ravindran**), 'Update of digestible calcium in poultry'

- USSEC **Virtual Workshop**: Recent Advances in feed evaluation for poultry, September 3rd and 4th, 2020 (**Ravindran, Abdollahi, Zaefarian**).
- Kemin Animal Nutrition and Health, Indonesia (**Virtual Conference**). Invited speaker (**Zaefarian**) to present a paper on “Fat Digestion in Poultry – Limitations and Strategies to Improve Fat Utilisation” 15th October 2020.
- Enzyme Transformation Virtual Summit- Kemin Animal Nutrition and Health, Asia Pacific (**Virtual Summit**). Invited speaker (**Zaefarian**) to present a paper on Nutrient digestion in poultry: The need for emulsification” 28th May 2021.

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 Technology* (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*
- Section Editor, *Animal*

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

- Associate Editor, *Animals*

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

- 2021 New Zealand Poultry Industry Conference, Nelson, October 2021.
- Seventh International Broiler Nutritionists’ Conference (Poultry Beyond 2025). (**Postponed due to COVID-19**)

PROJECTED ACTIVITIES SEPTEMBER 2021 – AUGUST 2022

Research Activities

Digestible calcium assessment in poultry

These studies will form part of the PhD programme of Ms. Laura David.

Influence of age of broilers on protein digestibility in different grains and protein sources

These studies will form part of the PhD programme of Mrs. Mukti Barua

Influence of age of broilers on metabolisable energy

These studies will form part of the PhD programme of Mr. Mahmoud Khalil

Influence of drying treatments on the metabolisable energy and, ileal digestibility of amino acids and starch in maize

This study will form part of the MSc programme of Mr. Elly Solomon Kambiam.

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. October 2021.
- Advancing Poultry Production 2022, 22nd Massey/Industry Conference' to be held in Palmerston North. May 2022.
- Poultry Beyond 2025, Seventh International Broiler Nutritionists' Conference to be held in New Zealand. **(Postponed due to COVID-19- The date has not been confirmed yet)**

Overseas Linkages

- 2021 Broiler Feed Quality Conference (**Virtual Workshop**): Alternative feed ingredients for poultry, October 2021 (**Ravindran, Abdollahi**)
- Sydney, Australia to present papers at the Australian Poultry Science Symposium, February 2022 (**Abdollahi & Zaefarian**)
- Queenstown, New Zealand, to attend and present invited papers at the Seventh International Broiler Nutritionists' Conference (The date has not been confirmed yet) (**Ravindran, Abdollahi & Zaefarian**)
- Paris, France, to attend and present a paper at World Poultry Conference, August 2022 (**Abdollahi & Zaefarian**)

PUBLICATION LIST, 2020/2021

Book Chapter

Ravindran, V. 2021. *Getting the Real Value of Soybean Meal: Variability vs. Consistency*. Technical Bulletin. United States Soybean Export Council, Singapore.

Ravindran, V. 2021. Feed additives for poultry. In: *The Encyclopedia of Farm Animal Nutrition* (Ed. R. Blair), CAB International, Wallingford, U.K. (in press).

Ravindran, V. 2021. Millets. In: *The Encyclopedia of Farm Animal Nutrition* (Ed. R. Blair), CAB International, Wallingford, U.K. (in press).

Ravindran, V. 2021. Egg formation. In: *The Encyclopedia of Farm Animal Nutrition* (Ed. R. Blair), CAB International, Wallingford, U.K. (in press).

Journal Articles

Abdollahi, M. R., Wiltafsky-Martin, M., **Ravindran, V.** (2021) Application of apparent metabolisable energy versus nitrogen-corrected apparent metabolisable energy in poultry feed formulations: A continuing conundrum. *Animals* 11: 2174.

Khalil, M. M., **Abdollahi, M. R.**, **Zaefarian, F.**, Chrystal, P. V., **Ravindran, V.** (2021) Apparent metabolizable energy of cereal grains for broiler chickens is influenced by age. *Poultry Science* 100:101288.

Barua, M., **Abdollahi, M. R.**, **Zaefarian, F.**, Wester, T. J., Girish, C. K., Chrystal, P.V., **Ravindran, V.** (2021) Basal ileal endogenous amino acid flow in broiler chickens as influenced by age. *Poultry Science* 100:101269.

Perera, W. N. U., **Abdollahi, M. R.**, **Zaefarian, F.**, Wester, T. J., **Ravindran, V.** (2021) High steam-conditioning temperature during the pelleting process impairs growth performance and nutrient utilization in broiler starters fed barley-based diets, regardless of carbohydrase supplementation. *Poultry Science* 100:101166.

Moradi, A., Moradi, S., Atabaigi Elmi, V., **Abdollahi, M. R.** (2021) Interactive effect of corn particle size and insoluble fiber source on performance, nutrient utilization and intestine morphology in broilers fed pelleted diets. *Journal of Animal Physiology and Animal Nutrition*. (Published Online)

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*. (Published Online)

David, L. S., **Abdollahi, M. R.**, Bedford, M. R., **Ravindran, V.** (2021) True ileal calcium digestibility in soybean meal and canola meal, and true ileal phosphorous digestibility in maize-soybean meal and maize-canola meal diets, without and with microbial phytase, for broiler growers and finishers. *British Poultry Science* 62 (2): 293-303.

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* 7: 268-281.

Khalil, M. M., **Abdollahi, M. R.**, **Zaefarian, F.**, **Ravindran, V.** (2020) Measurement of ileal endogenous energy losses and true ileal digestible energy of cereal grains for broiler chickens. *Poultry Science* 99: 6809-6817.

Barua, M., **Abdollahi, M. R.**, **Zaefarian, F.**, Wester, T. J., Girish, C. K., **Ravindran, V.** (2020) Standardized ileal amino acid digestibility of protein sources for broiler chickens is influenced by feed form. *Poultry Science* 99: 6925-6934.

Khalil, M. M., **Abdollahi, M. R.**, **Zaefarian, F.**, **Ravindran, V.** (2021) Influence of feed form on the apparent metabolisable energy of feed ingredients for broiler chickens. *Animal Feed Science and Technology* 271 (2021) 114754.

Barua, M., **Abdollahi, M. R.**, **Zaefarian, F.**, Wester, T. J., Girish, C. K., **Ravindran, V.** (2021) Influence of feed form on the standardised ileal amino acid digestibility of common grains for broiler chickens. *Animal Feed Science and Technology* 272 (2021) 114743.

van der Poel, A. F. B., **Abdollahi, M. R.**, Cheng, H., Colovic, R., den Hartog, L.A., Miladinovic, D., Page, G., Sijssens, K., Smillie, J. F., Thomas, M., Wang, W., Yu, P., Hendriks, W. H. (2020). Future directions of animal feed technology research to meet the challenges of a changing world. *Animal Feed Science and Technology* 270 (2020) 114692. (Invited multi-authored review for Special Issue).

Nalle, C.L. and **Ravindran, V.** 2021. Comparison of methodologies to determine the apparent ileal amino acid digestibility of maize, wheat, lupins, and peas for broiler chickens. *Journal of Applied Animal Nutrition*. (in press)

Ravindran, V. 2021. Progress in ileal endogenous amino acid flow research in poultry. *Journal of Animal Science and Biotechnology*. 12:5.

Anwar, M.N. and **Ravindran, V.** 2020. Measurement of ileal endogenous calcium losses in broiler chickens. *Journal of Applied Animal Research*. 48: 264-267.

Mutucumarana, R.K. and **Ravindran, V.** 2021. Measurement of endogenous phosphorus losses in broiler chickens. *Journal of Poultry Science*. 58: 58-63.

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

Conference Papers

Perera, W. N. U., **Abdollahi, M. R., Zaefarian, F., Wester, T. J., Ravindran, V.** (2021) Barley in pelleted broiler starter diets: Effects of carbohydrase supplementation and steam-conditioning temperature. Proceedings of the Australian Poultry Science Symposium 32: 117-120. Sydney, Australia.

Khalil, M. M., **Abdollahi, M. R., Zaefarian, F., Chrystal, P. V., Ravindran, V.** (2021) Apparent metabolisable energy of common cereal grains for broiler chickens is influenced by bird age. Proceedings of the Australian Poultry Science Symposium 32: 83-86. Sydney, Australia.

David, L. S., **Abdollahi, M. R., Bedford, M. R., Ravindran, V.** (2021) True ileal calcium digestibility in soybean meal and canola meal, without and with microbial phytase, for broiler starters and finishers. Proceedings of the Australian Poultry Science Symposium 32: 87. Sydney, Australia.