Final Report

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Evaluation of precision feeding to enhance broiler growth efficiency

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In submitting this report, the researcher has agreed to Poultry Hub Australia publishing this material in an edited form.

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Project Summary

Project Title	Evaluation of precision feeding to enhance broiler growth efficiency
Project No.	19-103
Date	Start: 01/10/19 End: 15/03/22
Project Leader(s)	Dr Amy Moss
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Project Aim	The aim of this project is to permit the daily mixing of a protein dense concentrate with an energy dense component to meet daily nutrient requirements, thereby improving efficiency and profits of the Australian chicken meat industry. This project uses a novel approach to precisely meet broiler nutrient requirements by utilising modern technologies in collaboration with industry.
Background	Chicken meat is the dominant animal protein consumed in Australia and production needs to improve to supply increasing consumption. Broiler chickens grow rapidly with nutrient requirements changing daily. However, they are fed 3–5 diet stages throughout their growth, meaning nutrients are under- and over-supplied throughout production (Kleyn 2013).
Research Outcome	It is apparent that birds offered precision nutrition grew faster than those offered conventional diets, particularly those on the precision nutrition adjusted treatment. There was also significant improvement in FCR from 14 to 21 days post-hatch and precision nutrition tended to improve FCR from 28 to 35 days. The precision nutrition adjusted treatment also demonstrated the greatest energy utilisation, which is in agreement with the performance results.
Impacts and Outcomes	The precision nutrition adjusted treatment numerically improved feed cost by 3.2 cents/kg live weight, representing a reduction in cost of 4.13%. Considering that the Australian chicken meat industry produces 1.3 million tonnes of chicken meat per year, this may save the Australian chicken meat industry $41.5 million annually. If it were to cost $50,000 per shed to upgrade to the precision nutrition equipment, then it would cost the industry an investment of $150 million to incorporate it into every broiler shed. Thus, it would take about 3.5 to 4 years for the savings generated by precision nutrition to cover the investment cost. Beyond this, the poultry industry would also benefit from a reduced CV (coefficient of variation; which may bring savings at the processing plant) and the ability to adjust the diet blends to tailor the diet to the growth (or intake or health status) of the chickens. More research to confirm these observations and to optimise precision nutrition programs is therefore warranted.
Publications	In preparation

Executive Summary

Broiler chickens grow rapidly with nutrient requirements changing daily. However, they are fed 3–5 diet stages throughout their growth, meaning nutrients are under- and over-supplied throughout production (Kleyn 2013). Thus, the aim of this project is to demonstrate that the daily mixing of a protein dense concentrate with an energy dense component to meet the daily nutrient requirements of broilers will improve efficiency and profits of the Australian chicken meat industry. This project uses a novel approach to precisely meet broiler nutrient requirements by utilising modern technologies in collaboration with industry.

Birds offered precision nutrition grew faster than those offered conventional diets, particularly those on the precision nutrition adjusted treatment. There was also significant improvement in FCR from 14 to 21 days post-hatch and precision nutrition tended to improve FCR from 28 to 35 days. The precision nutrition adjusted treatment also demonstrated the greatest energy utilisation, which is in agreement with the performance results.

Additionally, the precision nutrition adjusted treatment numerically improved feed cost by 3.2 cents/kg live weight, representing a reduction in cost of 4.13%. Considering that the Australian chicken meat industry produces 1.3 million tonnes of chicken meat per year, this may save the Australian chicken meat industry $41.5 million annually. If it were to cost $50,000 per shed to upgrade to the precision nutrition equipment, then it would cost the industry an investment of $150 million to incorporate it into every broiler shed. Thus, it would take about 3.5 to 4 years for the savings generated by precision nutrition to cover the investment cost. Beyond this, the poultry industry would also benefit from a reduced CV (which may bring savings at the processing plant) and the ability to adjust the diet blends to tailor the diet to the growth (or intake or health status) of the chickens. More research to confirm these observations and to optimise precision nutrition programs is therefore warranted.

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Introduction

Chicken meat is the dominant animal protein consumed in Australia and production needs to improve to supply increasing consumption. Broiler chickens grow rapidly with nutrient requirements changing daily. However, they are fed 3–5 diet stages throughout their growth, meaning nutrients are under- and over-supplied throughout production (Kleyn 2013). Additionally, Kleyn (2013) presented a cost comparison that demonstrates that a 3-phase diet reduces feed cost by 3.72% compared to a 2-phase diet, as nutrients are used more efficiently. Furthermore, Warren and Emmert (2000) compared broilers fed on a 3-phase regime to those fed a single NRC (National Research Council) recommendation between 40 to 61 days. Feeding broilers on the 3-phase regime improved gain:digestible lysine intake by 6.5% (50.9 versus 54.2; $P < 0.05$) and subsequently reduced feed cost/bird. Thus, it stands to reason that blending a ration on a daily basis to meet the daily energy and lysine requirements will reduce feed costs even further. While increasing the number of feed phases is more efficient; pelleting, transporting and storing 4 or more individual diets is often impractical. However, modern feed delivery systems have the capacity to be programmed to automatically blend dietary components together on a daily basis to achieve the desired nutrient profile. Thus, broilers may be fed to a daily target by creating a protein and mineral dense concentrate diet for day old broiler chicks, which may then be subsequently diluted with a low protein and mineral but energy dense component. As only two dietary components are used in the process, the profitability of this regime won't be hindered by the practicalities of feed transportation and storage. Sharma et al. (2014) demonstrated that broilers offered a nutrient dense starter diet that is diluted with whole wheat by increasing increments every 4 days up to 40 days post-hatch do not exhibit a significantly different weight gain or carcass composition than broilers offered standard starter and grower phases. Feed conversion ratio was compromised; however, this study unfortunately did not balance the whole wheat dilution with the birds' nutrient requirement –a design flaw that explains the compromised efficiency. Therefore, this project will explore the development and implementation of a precision feeding program which blends two dietary components to meet daily broiler nutrient requirements via modern feeding technology. The outcomes of this project are of great potential benefit to the efficiency and profitability of the Australian chicken meat industry.

Objectives

The aim of this project is to permit the daily mixing of a protein dense concentrate with an energy dense component to meet daily nutrient requirements, thereby improving efficiency and profits of the Australian chicken meat industry. This project uses a novel approach to precisely meet broiler nutrient requirements by utilising modern technologies in collaboration with industry.

Methodology

Experimental design

Four dietary treatments were offered to ten replicates of 11 birds over 11–42 days post-hatch. The treatments consisted of a standard commercial diet as the control (with starter, grower, finisher and withdrawal phases), a precision nutrition diet, a precision nutrition diet with the blends adjusted based on weekly bird weight, and a precision nutrition diet made up of blending the standard commercial diets (Tables 1 and 2). The precision nutrition blends comprised a high protein low energy concentrate, and a low protein high energy concentrate. The daily nutrient requirements of the broilers was modelled via EFG Software (2019) Broiler Growth Model growth curves (Figure 1). From this information, protein dense concentrate and an energy dense concentrate were formulated and a linear reduction of the protein concentrate for the energy concentrate calculated. Birds on the precision nutrition adjusted treatment had the diet blends adjusted based on their weekly weights, where they were moved forward on the feeding schedule to match the requirement of their current weight (not age). Diets were wheat-soy based (Tables 3 and 4) and the nutrient composition of feed ingredients was analysed by NIR (Near Infra-red Spectroscopy) prior to formulation. Feed Logic (Feedworks Pty Ltd) feed blending technology was used to accurately mix and deliver the components on a daily basis.

Poultry trial

The study was approved by the University of New England's Animal Ethics Committee (AEC20-106) and met the requirements of the Australian code of practice for care and use of animals for scientific purposes (NHMRC, 2013). Upon arrival, chicks had unlimited access to feed and water under a '23-h-on-1-h-off' lighting regime for the first 3 days, followed by '20-h-on-4-h-off' to 7 days and finally, '18-h-on-6-h-off' for the remainder of the study in an environmentally controlled facility. An initial room temperature of 32 ± 1°C was maintained for the first week, which was gradually decreased to 21 ± 1°C by the end of the third week, and maintained at this temperature until the end of the study. At 11 days, the chicks were weighed and randomly allocated to dietary treatments on the basis of bodyweight. Any dead or culled birds were removed on a daily basis and their bodyweights recorded and used to adjust FCR calculations. Birds and feed were weighed weekly starting on day 14 to calculate weekly weight gain and feed intake, from which the feed conversion ratio (FCR) was calculated.

A total of four birds per pen were moved to metabolic cages on day 21 to determine apparent metabolisable energy (AME). A four-day adaptation period was allowed, and feed intake and excreta output was measured from 25–27 days post-hatch in order to calculate AME. During the 21 to 27 day period, each treatment continued on their daily blends. Thus, there were differences in the AME of each diet at the point of excreta collection for AME; where T1 AME = 13.27 MJ and CP = 20.8%; T2 AME = 13.30 MJ and CP = 21.0%; T3 AME = 13.33 MJ and CP = 20.8%; and T4 AME = 13.32 MJ and CP = 20.7%. These birds were euthanised via electrical stunning followed by cervical dislocation and sampled on day 28 to determine their fat pad weights and collect digesta for digestibility analysis. The small intestine was removed and the jejunum was demarcated by the end of the duodenal loop to Meckel's diverticulum. The ileum was demarcated by Meckel's diverticulum and the ileo-caecal junction. Digesta were collected from the distal 2/3rd of the jejunal and ileal segments. Digesta samples were pooled by cage, homogenised and freeze dried. On day 42, a total of 4 birds were euthanised via electrical stunning followed by cervical dislocation and sampled to determine fat pad weight and breast, thigh and drumstick weights. The sex of the birds was also determined and the sex of any remaining un-sampled birds was determined via their phenotypic characteristics, which were pronounced at this age.

Laboratory analysis

Excreta were dried for 24 h at 80˚C in an air-forced oven. The GE (gross energy) of diets and excreta were determined via bomb calorimetry using an adiabatic calorimeter (Parr 1281 bomb calorimeter, Parr Instruments Co., Moline, IL). AME (MJ/kg) and calculated by the following equation:

$$AME_{diet} = ((\text{Feed intake} \times GE_{diet}) - (\text{Excreta output} \times GE_{excreta})) / (\text{Feed intake})$$

N-corrected AME values were calculated by correcting to zero N retention, using the factor of 36.54 kJ/g.

N retention was calculated by the following equation:

$$\text{Retention (\%)} = ((\text{Feed intake} \times \text{Nutrient}_{diet}) - (\text{Excreta output} \times \text{Nutrient}_{excreta})) / (\text{Feed intake} \times \text{Nutrient}_{diet}) \times 100$$

Concentrations of starch in diets and ileal digesta were determined by methods as described in Mahasukhonthachat et al. (2010). Nitrogen concentrations were determined as outlined in Siriwan et al. (1993).

Toe bone samples were collected from all birds by severing the middle toe through the joint between the 2nd and 3rd tarsal bones from the distal end. Toes from each cage were pooled and the composite samples dried to a constant weight at 100˚C and then ashed in a muffle furnace at 550˚C for 16 h for the assessment of bone mineralisation as described by Potter (1988).

Dry matter digestibility (%) =

$$100 - [(TiO_2\ \text{diet} * \text{Dry matter digesta/excreta}) / (TiO_2\ \text{digesta/excreta} * \text{Dry matter diet})] * 100$$

Diets and digesta were analysed for titanium dioxide (TiO_2) concentrations in quadruplicate and duplicate replicates, respectively, by the method described by Short et al. (1996).

Statistical analysis

Experimental data were analysed via an ANOVA. Pen was considered as the experimental unit. Statistical significance was established at $P \leq 0.05$.

Discussion of results

Performance

The weight gain, feed intake and feed conversion ratio of dietary treatments are reported in Tables 5, 6 and 7. There was no significant effect of dietary treatments on weight gain and feed intake. However, the numerical differences in both weight gain and feed intake generated a significant improvement in FCR from 14 to 21 days post-hatch and tended to improve FCR from 28 to 35 days. It is interesting that an effect was shown over these specific dates because these periods immediately followed diet changes (starter to grower diets and grower to finisher diets, respectively), which is the time that we would expect to see the greatest response. Relative fat pad weights at days 28 and 42 as well as relative breast, thigh and drumstick weights at day 42 are given in Table 8. Day 28 fat pad weights as well as day 42 breast, thigh and drumstick weights were not significantly different. Day 42 fat pad weights tended (P = 0.055) to be reduced with precision nutrition. Bodyweight at day 42 (Table 8) was significantly greater for birds offered precision nutrition diets than the control or blended standard diets. When corrected for weight gain (correction factor = 3.2), the corrected FCR of treatments 1 to 4 are: 2.50, 2.50, 2.29 and 2.51, respectively.

It is interesting that blending the standard starter, grower, finisher and withdrawal diets to more closely meet nutrient requirements and reduce the shock of sudden diet changes did show some benefit in FCR, but not in fat pad weight or final body weight. It is also interesting that birds that had their precision nutrition diet adjusted to their actual body weights obtained the lightest fat pads and were the heaviest birds at day 42.

The effect of precision nutrition on coefficient of variation (CV; of the individual weights of birds within a pen) at 14, 21, 28, 35 and 42 d post-hatch is given in Table 9, where precision nutrition treatments significantly reduced CV at almost all time points. The feed cost per kilo of live weight gain is also given in Table 9, for both 2020 and 2022 costings. The trial was completed in 2020 and thus the calculated returns are based from this period. Precision nutrition adjusted treatment numerically improved feed cost by 3.2 cents/kg live weight. While not significant, this is a reduction in cost of 4.13%. With the rising price of SBM (soybean meal) in late 2022, feed costs were recalculated with a SBM price of $1000/tonne. The precision nutrition adjusted treatment still numerically improved feed cost but the price differential was less due to the high protein concentrate requiring a slightly higher amount of SBM. Thus, this cost could be reduced with cheaper SBM alternatives.

Laboratory Analysis

The effects of dietary treatments on dry matter, N and starch ileal digestibility coefficients (%) at 28 days post-hatch are shown in Table 10. There was not a significant effect of dietary treatments on dry matter and N (nitrogen) digestibility. However, there was a significant influence of dietary treatment on the digestibility of starch, where the blended standard diets significantly reduced starch digestibility compared to the control and precision fed birds. While not significant, the dry matter and N digestibility was numerically lower within the blended standard diets treatment than the precision nutrition or control treatments.

The effects of dietary treatments on apparent metabolisable energy (AME; MJ/kg DM; dry matter), N corrected AME (AMEn; MJ/kg DM) and excreta moisture (%) from 25–27 days post-hatch are shown in Table 11. Dietary treatments had a significant influence on both AME and AMEn, where the precision nutrition adjusted treatment demonstrated the greatest energy utilisation. This was expected as the precision nutrition adjusted blend had the greatest AME at the point of excreta collection, however the extent of improvement in AME is much greater than the formulated increase. Conversely, the blended standard diets treatment numerically had the poorest energy utilisation. Excreta moisture was not significantly influenced by dietary treatment.

The effects of dietary treatments on toe ash (%) at 28 and 42 days post-hatch are shown in Table 12. There was no significant influence of dietary treatments on toe ash at 28 or 42 days. However, it is notable that the blended standard diet treatment had a numerically reduced toe ash compared to the precision nutrition and control treatments at 28 days, which is consistent with the nutrient utilisation and digestibility results.

Implications

The precision nutrition adjusted treatment numerically improved feed cost by 3.2 cents/kg live weight, representing a reduction in cost of 4.13%. Considering that the Australian chicken meat industry produces 1.3 million tonnes of chicken meat per year, this may save the Australian chicken meat industry $41.5 million annually. With 678 million chickens produced a year, and on average 220,000 chicks produced per shed annually (Australian Chicken Meat Federation, 2022), we estimated that there are approximately just over 3,000 broiler sheds in Australia. If it were to cost $28,000 per shed to upgrade to the precision nutrition equipment, then it would cost the industry an investment of approximately $84 million to incorporate it into every broiler shed. Thus, it would take about 2 years for the savings generated by precision nutrition to cover the investment cost. Beyond the economic benefits, the poultry industry would also benefit from a reduced CV (which may bring savings at the processing plant) and the ability to adjust the diet blends to tailor the diet to the growth (or intake or health status) of the chickens. Finally, in industry there is currently an issue of new diets being added to a silo directly on top of the old diet; thus new batches of chicks may be consuming withdrawal feed for a period of time. Blending two dietary concentrates would eliminate this issue.

Recommendations

Precision nutrition is showing great promise to save money and produce other benefits for industry. It was a concern of industry that the cost of investment may outweigh the benefits. With a 2 year term to pay off the investment, precision nutrition would bring real profits to industry within a relatively short amount of time. More research to confirm these observations and to optimise precision nutrition programs is therefore warranted.

Acknowledgments

The authors would like to acknowledge and thank Feedworks for the donation of the precision feeding equipment to this trial, and Poultry Hub Australian for funding this trial and their ongoing support.

Media and Publications

A manuscript is in preparation. Additionally, the following abstracts have been presented at national and international conferences:

Moss AF, Chrystal PV, Cadogan DJ (2021) Precision feeding: The future face of Australian chicken-meat production? 33rd Australian Association of Animal Sciences, 1-3 February 2021.

Moss AF, Chrystal PV, Cadogan DJ (2020) Precision feeding enhances feed efficiency and carcass yield compared to broilers offered standard feeding programs. International Production and Processing Expo Scientific Forum, Atlanta, Georgia, USA, Jan 27-28 2020.

An article will also be published in Australian Feed Magazine in 2022. Finally, a related review was also published:

Moss AF, Chrystal PV, Cadogan DJ, Wilkinson SJ, Crowley TM and Choct M (2021) Precision feeding and precision nutrition: A paradigm shift in broiler feed formulation? *Animal Bioscience* 34(3), 354-362.

Intellectual Property Arising

There is not any IP arising from this project.

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Appendices – tables and figures

Table 1 Schedule of dietary treatments

Treatment	Description
1	Control (4 phases)
2	Precision nutrition
3	Precision nutrition adjusted
4	Blended standard diets

Table 2 Record of dietary blends offered from days 11 to 42 post-hatch

Day	T1 Control	T2 Precision Nutrition				T3 Precision Nutrition Adjusted				T4 Blended Standard			
		Blend 1	%	Blend 2	%	Blend 1	%	Blend 2	%	Blend 1	%	Blend 2	%
11	Starter	Hi Pro	100	Lo Pro	0	Hi Pro	100	Lo Pro	0	Starter	100	Grower	0
12	Starter	Hi Pro	94	Lo Pro	6	Hi Pro	94	Lo Pro	6	Starter	66	Grower	34
13	Starter	Hi Pro	88	Lo Pro	12	Hi Pro	88	Lo Pro	12	Starter	33	Grower	67
14	Grower	Hi Pro	82	Lo Pro	18	Hi Pro	82	Lo Pro	18	Grower	100	Finisher	0
15	Grower	Hi Pro	76	Lo Pro	24	Hi Pro	71	Lo Pro	29	Grower	91	Finisher	9
16	Grower	Hi Pro	71	Lo Pro	29	Hi Pro	65	Lo Pro	35	Grower	82	Finisher	18
17	Grower	Hi Pro	65	Lo Pro	35	Hi Pro	60	Lo Pro	40	Grower	73	Finisher	27
18	Grower	Hi Pro	60	Lo Pro	40	Hi Pro	56	Lo Pro	44	Grower	64	Finisher	36
19	Grower	Hi Pro	56	Lo Pro	44	Hi Pro	51	Lo Pro	49	Grower	55	Finisher	45
20	Grower	Hi Pro	51	Lo Pro	49	Hi Pro	47	Lo Pro	53	Grower	46	Finisher	54
21	Grower	Hi Pro	47	Lo Pro	53	Hi Pro	42	Lo Pro	58	Grower	37	Finisher	63
22	Grower	Hi Pro	42	Lo Pro	58	Hi Pro	38	Lo Pro	62	Grower	28	Finisher	72
23	Grower	Hi Pro	38	Lo Pro	62	Hi Pro	34	Lo Pro	66	Grower	19	Finisher	81
24	Grower	Hi Pro	34	Lo Pro	66	Hi Pro	31	Lo Pro	69	Grower	10	Finisher	90
25	Finisher	Hi Pro	31	Lo Pro	69	Hi Pro	27	Lo Pro	73	Finisher	100	Withdrawal	0
26	Finisher	Hi Pro	27	Lo Pro	73	Hi Pro	24	Lo Pro	76	Finisher	92.3	Withdrawal	7.7
27	Finisher	Hi Pro	24	Lo Pro	76	Hi Pro	21	Lo Pro	79	Finisher	84.6	Withdrawal	15.4
28	Finisher	Hi Pro	21	Lo Pro	79	Hi Pro	18	Lo Pro	82	Finisher	76.9	Withdrawal	23.1
29	Finisher	Hi Pro	18	Lo Pro	82	Hi Pro	13	Lo Pro	87	Finisher	69.2	Withdrawal	30.8
30	Finisher	Hi Pro	16	Lo Pro	84	Hi Pro	11	Lo Pro	89	Finisher	61.5	Withdrawal	38.5
31	Finisher	Hi Pro	13	Lo Pro	87	Hi Pro	9	Lo Pro	91	Finisher	53.8	Withdrawal	46.2
32	Finisher	Hi Pro	11	Lo Pro	89	Hi Pro	7	Lo Pro	93	Finisher	46.1	Withdrawal	53.9
33	Finisher	Hi Pro	9	Lo Pro	91	Hi Pro	6	Lo Pro	94	Finisher	38.4	Withdrawal	61.6
34	Finisher	Hi Pro	7	Lo Pro	93	Hi Pro	4	Lo Pro	96	Finisher	30.7	Withdrawal	69.3
35	Finisher	Hi Pro	6	Lo Pro	94	Hi Pro	3	Lo Pro	97	Finisher	23	Withdrawal	77
36	Finisher	Hi Pro	4	Lo Pro	96	Hi Pro	0	Lo Pro	100	Finisher	15.3	Withdrawal	84.7
37	Finisher	Hi Pro	3	Lo Pro	97	Hi Pro	0	Lo Pro	100	Finisher	7.6	Withdrawal	92.4
38	Withdrawal	Hi Pro	2	Lo Pro	98	Hi Pro	0	Lo Pro	100	Withdrawal	100	Withdrawal	0
39	Withdrawal	Hi Pro	1	Lo Pro	99	Hi Pro	0	Lo Pro	100	Withdrawal	100	Withdrawal	0
40	Withdrawal	Hi Pro	1	Lo Pro	99	Hi Pro	0	Lo Pro	100	Withdrawal	100	Withdrawal	0
41	Withdrawal	Hi Pro	0	Lo Pro	100	Hi Pro	0	Lo Pro	100	Withdrawal	100	Withdrawal	0
42	Withdrawal	Hi Pro	0%	Lo Pro	100%	Hi Pro	0	Lo Pro	100	Withdrawal	100	Withdrawal	0

Table 3 Formulation of experimental diets/concentrates (%)

Ingredient	Cost ($AUD)/tonne	Starter	Grower	Finisher	Withdrawal	High Protein/Low energy	Low protein/High energy
Soybean meal	510	34.0	27.8	21.9	22.3	34.3	22.5
Wheat	290	55.9	59.9	64.1	63.4	55.4	63.3
Canola seed	340	3.0	6.0	8.0	8.0	3.0	8.0
Limestone	115	1.341	1.198	1.062	0.811	1.341	0.811
Salt	245	0.192	0.175	0.177	0.161	0.192	0.161
Monodicalcium phosphate	975	0.843	0.666	0.488	0.289	0.842	0.288
Sodium bicarbonate	345	0.298	0.268	0.266	0.180	0.298	0.180
Vegetable oil	2500	2.695	2.688	2.794	3.781	2.900	3.757
Betaine 38%	1800	0.130	0.130	0.130	0.130	0.130	0.130
L-lysine Sulphate	2550	0.369	0.340	0.315	0.221	0.368	0.221
DL-methionine	3600	0.417	0.361	0.317	0.269	0.420	0.270
L-threonine	3650	0.139	0.111	0.085	0.066	0.140	0.067
L-Valine	6700	0.011				0.012	
choline chloride 75% L	450	0.025	0.025	0.020	0.020	0.025	0.020
Vitamin + mineral premix	8000	0.450	0.250	0.250	0.200	0.450	0.200
Xylanase	12000	0.025	0.025	0.025	0.025	0.025	0.025
Phytase	12000	0.030	0.030	0.030	0.030	0.030	0.030

Table 4 Formulated and analysed nutrient composition of experimental diets/concentrates (%, unless otherwise stated)

Nutrient	Starter	Grower	Finisher	Withdrawal	High Protein/Low energy	Low protein/High energy
Dry matter	90.56	90.54	90.54	90.55	90.579	90.552
AMEn, MJ/kg	12.55	12.97	13.39	13.70	12.589	13.690
Crude protein	23.43	21.58	19.70	19.73	23.508	19.772
Lysine[1]	1.280	1.150	1.020	0.980	1.285	0.983
Methionine[1]	0.707	0.634	0.572	0.526	0.711	0.528
Methionine + cysteine[1]	0.950	0.870	0.800	0.755	0.954	0.757
Threonine[1]	0.860	0.770	0.680	0.666	0.863	0.668
Tryptophan[1]	0.276	0.254	0.231	0.233	0.277	0.233
Isoleucine[1]	0.860	0.780	0.700	0.706	0.863	0.708
Leucine[1]	1.487	1.358	1.227	1.236	1.493	1.240
Valine[1]	0.960	0.873	0.795	0.801	0.964	0.803
Arginine[1]	1.397	1.256	1.114	1.124	1.404	1.128
Ca	0.960	0.870	0.780	0.647	0.960	0.647
Available P	0.480	0.435	0.390	0.350	0.480	0.350
Crude fibre	2.691	2.750	2.767	2.766	2.689	2.768
Sodium	0.195	0.180	0.180	0.150	0.195	0.150
Chloride	0.200	0.190	0.190	0.180	0.200	0.180
Potassium	0.992	0.902	0.814	0.820	0.995	0.822
Crude fat	5.507	6.574	7.394	8.366	5.705	8.343
Analysed						
Dry matter	88.1	86.7	87.0	87.3	87.6	87.9
Gross energy, cal/g	4096	4080	4153	4218	4067	4261
Protein (N x 6.25)	25.0	23.0	19.5	19.7	24.8	19.3
Starch	33.5	34.0	38.0	38.7	31.7	39.4

[1] Digestible basis

Table 5 Effects of dietary treatments on weekly and total (d11 to d42 post-hatch) weight gain (g/bird)

Treatment	Period (days post-hatch)						
	11 to 14	**14 to 21**	**21 to 28**	**28 to 35**	**35 to 42**	**11 to 28**	**28 to 42**
Control (4 phases)	197	543	718	741	655	1445	1396
Precision nutrition	195	568	771	775	710	1534	1486
Precision nutrition adjusted	196	569	742	783	751	1509	1541
Blended standard diets	194	568	724	744	671	1486	1414
SEM	2.43	13.61	21.87	23.28	43.48	30.78	49.71
Significance (P =)	0.781	0.516	0.353	0.478	0.417	0.228	0.184

Table 6 Effects of dietary treatments on weekly and total (d11 to d42 post-hatch) feed intake (g/bird)

Treatment	Period (days post-hatch)						
	11 to 14	**14 to 21**	**21 to 28**	**28 to 35**	**35 to 42**	**11 to 28**	**28 to 42**
Control (4 phases)	223	711	941	1213	1247	1902	3400
Precision nutrition	221	700	1033	1254	1364	1995	3691
Precision nutrition adjusted	219	720	969	1193	1350	1944	3564
Blended standard diets	216	738	1044	1184	1264	1999	3492
SEM	2.54	22.93	42.44	30.65	43.06	52.97	83.92
Significance (P =)	0.288	0.693	0.277	0.413	0.146	0.536	0.114

Table 7 Effects of dietary treatments on weekly and total (d11 to d42 post-hatch) feed conversion ratio (g/g)

Treatment	Period (days post-hatch)						
	11 to 14	**14 to 21**	**21 to 28**	**28 to 35**	**35 to 42**	**11 to 28**	**28 to 42**
Control (4 phases)	1.132	1.397a	1.409	1.623	1.803	1.320	2.480
Precision nutrition	1.132	1.203b	1.331	1.578	1.847	1.273	2.497
Precision nutrition adjusted	1.114	1.207b	1.359	1.526	1.766	1.289	2.315
Blended standard diets	1.117	1.255b	1.357	1.630	1.812	1.318	2.498
SEM	0.010	0.019	0.034	0.028	0.060	0.019	0.092
Significance (P =)	0.480	<0.001	0.358	0.058	0.845	0.292	0.478

[ab] Means within columns not sharing a common suffix are significantly different at the 5% level of probability.

Table 8 Effects of dietary treatments on relative fat pad weight (g/kg) at 28 and 42 days post-hatch, relative breast (g/kg), thigh (g/kg) and drumstick weights (g/kg) and body weight (g) at 42 days post-hatch

Treatment	D28 fat pad weight (g/kg)	D42 fat pad weight (g/kg)	D42 breast weight (g/kg)	D42 thigh weight (g/kg)	D42 drumstick weight (g/kg)	D42 bird body weight (g)
Control (4 phases)	7.29	10.63	100.75	51.1	43.22	3197a
Precision nutrition	7.06	9.80	98.95	51.2	42.52	3381b
Precision nutrition adjusted	6.96	8.70	96.40	50.6	42.19	3428ab
Blended standard diets	8.04	10.46	97.60	51.1	43.81	3315a
SEM	0.381	0.513	2.612	0.906	0.761	48.01
Significance (P =)	0.188	0.055	0.598	0.900	0.320	0.044

[ab] Means within columns not sharing a common suffix are significantly different at the 5% level of probability.

Table 9 Effect of precision feeding on coefficient of variation (CV; of the individual weights of birds within a pen) at 14, 21, 28, 35 and 42 d post-hatch, and feed cost ($AUD) per kilo live weight at d42

Treatment	14d	21d	28d	35d	42d	Feed cost ($AUD) (2020 prices)	Feed cost ($AUD) (2022 prices)
Control (4 phases)	8.85b	10.03	12.08a	14.02a	15.24a	0.774	0.935
Precision nutrition	8.96b	8.94	8.83b	9.19b	11.04b	0.771	0.920
Precision nutrition adjusted	6.71a	7.14	10.55ab	10.02b	9.26b	0.742	0.909
Blended standard diets	9.64b	8.37	8.86b	10.52b	12.29ab	0.771	0.930
SEM	0.569	0.96	0.67	1.11	1.25	0.011	0.014
Significance (P =)	0.012	0.222	0.006	0.026	0.019	0.209	0.581

[ab] Means within columns not sharing a common suffix are significantly different at the 5% level of probability.

Table 10 Effects of dietary treatments on dry matter, protein (N) and starch ileal digestibility coefficients (%) at 28 days post-hatch

Treatment	Dry matter	protein (N)	Starch
Control (4 phases)	67.96	79.45	95.65b
Precision nutrition	67.35	79.12	95.87b
Precision nutrition adjusted	68.49	80.58	95.70b
Blended standard diets	65.58	78.01	91.99a
SEM	0.767	0.818	1.024
Significance (P =)	0.081	0.234	0.037

[ab] Means within columns not sharing a common suffix are significantly different at the 5% level of probability.

Table 11 Effects of dietary treatments on apparent metabolisable energy (AME; MJ/kg DM), N corrected AME (AMEn; MJ/kg DM) and excreta moisture (%) from 25–27 days post-hatch

Treatment	AME (MJ/kg DM)	AMEn (MJ/kg DM)	Excreta moisture (%)
Control (4 phases)	12.34ab	11.62ab	79.9
Precision nutrition	12.56bc	11.75bc	80.9
Precision nutrition adjusted	12.62c	11.78bc	81.6
Blended standard diets	12.16a	11.40a	79.3
SEM	0.080	0.081	0.777
Significance (P =)	0.002	0.013	0.162

[abc] Means within columns not sharing a common suffix are significantly different at the 5% level of probability.

Table 12 Effects of dietary treatments on toe ash (%) at 28 and 42 days post-hatch

Treatment	Day 28	Day 42
Control (4 phases)	11.12	10.98
Precision nutrition	11.14	10.64
Precision nutrition adjusted	11.57	10.94
Blended standard diets	10.87	10.81
SEM	0.301	0.357
Significance (P =)	0.437	0.910

Figure 1 Daily nutrient requirements of digestible lysine and apparent metabolisable energy of the broiler, as modelled via EFG Software (2019) Broiler Growth Model growth curves