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Multiphase feeding program for broilers can replace traditional system

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ABSTRACT: Broilers are traditionally managed with feeding programs that often consist of three or four phases. In this study we investigated whether a multiphase feeding program (14 phases) of broilers based on the optimal mix of two feeds could replace a traditional four phase system while maintaining broiler performance. To evaluate this prposed program we measured variables of performance, carcass yield, and nitrogen excretion. In addition, we determined if the multiphase feeding program (14 phases) would be equally effective regardless of bird gender. A total of 480 day-old Cobb chicks were used, with an average weight of 44.74 ± 0.16 g (females) and 44.71 ± 0.11 g (males). The birds were distributed in a completely randomized 2 × 2 factorial design. Each treatment consisted of six replicates with 20 animals per experimental unit. Results were analyzed separately in two periods (1–21 and 22–42 days) as determined by slaughter date, as well as for the entire growth period (1–42 days). The multiphase program led to improvements in final body weight and average daily weight gain, in addition to an increase in breast yield.

Keywords: Avinesp 1.0, precision nutrition, body composition, levels of lysine

Introduction

One aim in the formulation of diets in animal production systems is to adjust the diet to the decline in the animal's nutritional requirements over the course of growth. Currently, broilers are traditionally managed with feeding programs that often consist of three or four phases. As a consequence, during most of the growth period birds will, necessarily be provided with higher, or lower amounts of nutrients than their actual requirements (Buteri et al., 2009).

While feeding strategies that exceed nutritional requirements lead to high production costs and environmental impact due to increased nitrogen excretion levels (Nahm, 2007), suboptimal nutrient amounts impair performance. A way to integrate production, cost, and impact mitigation is to use mathematical models to predict nutritional requirements on a daily basis (Pesti and Miller, 1997). Multiphase feeding programs based on these models have indeed shown favorable results, and are emerging as an alternative to conventional feeding (Gutierrez et al., 2008).

Increasing the number of feeding phases is unfavorable to production logistics. A solution to these logistical challenges has been provided by the development of feeding systems that mix two diets automatically in real time, allowing the animal's requirements to be met throughout its growth. Therefore, ensuring that all requirements are properly met using only two feed formulations poses a problem requiring the use of multiple complex algorithms. This problem was partially solved by a modification of formulation algorithms that allowed for the determination of the optimum proportion of two diets for every growth period (Létourneau-Montminy et al., 2005).

Some researchers have investigated the effect of multiphase programs on the performance of broilers and environmental impact (Gutierrez et al., 2008; Pope and Emmert, 2001; Pope et al., 2002; Tolimir et al., 2010), but they did not consider the logistical shortcomings (only a two mixed feed in real time) associated with the need to formulate a diet for every feeding phase and a difference in nutrient requirements between male and female. In this study, we investigated whether a multiphase program of broilers based on the optimal mix of two feeds, could replace a traditional system while maintaining broiler performance and if it would be equally effective regardless of bird gender.

Materials and Methods

This study was conducted in Jaboticabal, in the state of São Paulo, Brazil (21°15'16" S; 48°19'19" W, altitude 607 m).

Animals and experimental design

480 day-old Cobb chicks were used, with an average weight of 44.74 ± 0.16 g (females) and 44.71 ± 0.11 g (males). Forty-eight chicks (six males and six females) nearest to the average body weight were slaughtered for initial body composition analyses (reference group). The remaining chicks were distributed in a completely randomized 2 × 2 factorial design (sex: male or female; feeding program: 4 or 14 phases).

Each treatment consisted of six replicates with 20 animals per experimental unit. During the experimental period, the birds were housed in pens with concrete floors and reused wood shavings, equipped with tubular feeders and nipple drinkers. Feed and water were provided *ad libitum* throughout the experimental period. Room temperature began at 33 °C from day one to three and was reduced gradually to reach 24 °C at the end of the experiment, and the relative humidity was around

60 %.The lighting program was in line with the recommendations given in the broiler management guide.

Nutritional requirements and diets

Daily lysine requirements were estimated with the aid of AVINESP 1.0, and the level of other nutrients used followed the recommendations of Rostagno et al. (2011) for broiler male and females of superior performance. Two premixed A and B diets were formulated to meet the requirements for the first and last day of the experimental period (Table 1), respectively, with reference to the lysine requirement. To obtain the average requirement of this amino acid in the various phases of each program, both diets were mixed in different proportions according to the formulation method developed by Létourneau-Montminy et al. (2005).

The traditional program supply (four phases) afforded four diets, each replaced at the start of each predetermined period (1 to 7, 8 to 21, 22 to 35, and 36 to 42 days old) and the same was done in the multiphase feeding program (14 phases), in which the diet was changed every three days, giving a total of 14 diets during the experimental period. The two premixed (A and B) for both groups of animals were weighed in a balance and after, mixed with a horizontal mixer.

Table 1 – Proximate and nutrient composition of diets used to compose the treatment of nutritional programs for males and females.

Ingredients (%)	Pre-mixtures			
	Male		Female	
	A	B	A	B
Corn	49.377	67.535	54.299	66.494
Soybean Meal (45 %)	42.558	26.637	37.246	22.500
Wheat Bran	0.000	0.000	0.000	5.100
Soy Oil	2.897	3.149	2.294	3.500
Dicalcium Phosphate	2.593	1.105	2.626	0.963
Limestone	0.797	0.738	1.597	0.702
Salt	0.400	0.395	0.400	0.400
Mineral Premix[1]	0.100	0.100	0.100	0.100
Vitamin Premix[2]	0.408	0.052	0.512	0.011
HCl-Lysine (78 %)	0.408	0.052	0.512	0.011
DL-Methionine	0.468	0.123	0.478	0.071
L-Treonine	0.236	0.000	0.2811	0.000
Choline Chloride (60 %)	0.067	0.067	0.067	0.067
Calculated Composition				
Crude Protein, %	24.00	17.60	22.15	16.41
ME, Mcal kg^{-1}	2,960	3,200	2,960	3,263
Calcium, %	1.100	0.663	1.400	0.632
Available Phosphorus, %	0.600	0.309	0.600	0.289
Sodium, %	0.203	0.195	0.201	0.204
Lysine, % Digestible	1.503	0.849	1.455	0.738
Methionine, % Digestible	0.757	0.358	0.746	0.299
Met+Cys, % Digestible	1.082	0.620	1.048	0.548
Threonine, % Digestible	0.977	0.55	0.946	0.515
Tryptophan, % Digestible	0.281	0.198	0.252	0.182

[1]Guarantee levels per kg: Copper (min) 8.000 mg kg^{-1} Iron (min) 50 g kg^{-1} Manganese (min) 70 g kg^{-1} Zinc (min) 50 g kg^{-1} Iodine (min) 1.200 mg kg^{-1}, selenium 200 mg kg^{-1}. [2] Guarantee levels per kg: Vitamin A (min) 7,000,000 IU kg^{-1}, Vitamin D3 (min) 2,200,000 IU kg^{-1} Vitamin E (min) 11,000 IU kg^{-1}, Vitamin K3 (min) 1,600 mg kg^{-1}, vitamin B1 (min) 2.000 mg kg^{-1} vitamin B2 (min) 5.000 mg kg^{-1}, vitamin B6 (min) 3.000 mg kg^{-1} vitamin B12 (min) 12 000 mcg kg^{-1} Niacin (min) 35 g kg^{-1} acid pantothenic (minimum) 13 g kg^{-1} folic acid (minimum) to 800 mg kg^{-1}.

Experimental measurements

The performance was evaluated at 1–21, 22–42, and 1–42 days of age through body weight, average daily feed intake, protein intake, daily weight gain, feed conversion, and protein and fat deposition. Two chicks from each pen nearest to the pen average body weight (± 10 %) were selected every 21 days from 0 to 42 days of age and slaughtered by asphyxiation with CO_2. They were placed in individual plastic bags and kept deep frozen at −20 °C prior to body composition analysis. On day 42, two more chicks from each pen nearest to the pen average body weight (± 10 %) were selected and slaughtered by asphyxiation with CO_2 to determine yield rating (%) of carcass, breast, wing, thighs, and drumsticks. The yield of the eviscerated carcass without head, neck, and feet was calculated according to body weight after fasting, while the yields from the cuts were calculated relative to the absolute weight of the carcass.

Prior to analysis, the frozen birds were then cut with a bandsaw and milled in an industrial meat grinder, homogenized, and aliquots removed for storage in Petri dishes and frozen again (-20 °C). The samples were then lyophilized, weighed again and later tested for total amount of dry matter, protein, and fat. Fat content of the carcass was obtained by extraction with petroleum ether in an Ancon unit and total nitrogen content in the degreased samples was quantified by the Kjeldahl method (AOAC, 2005).

Results from chemical analyses were used to estimate the protein and fat deposition in each period. The total deposition of protein or fat in the body weight was calculated for each pen on the basis of difference between the amounts at the beginning of the period and on the day of slaughter. The amounts at the beginning of the period were estimated from the initial BW-weight and BW composition of the reference group. The reference group for the first period (one day) consisted of 14 male and 14 female broilers slaughtered on the first day.

The reference groups for the second and last periods (21 and 42 days) consisted of two birds per pen from the first and last periods, respectively. Deposition rates for each period were calculated on the basis of total deposition divided by the length of the period (21 days). Nitrogen excretion was obtained from the difference between protein consumed (CP_{cons}) and body protein (BP_{body}) according to the equation: (CP_{cons} - *BPbody*/*period*).

Statistical analysis

Data were analyzed according to a 2 × 2 factorial arrangement using the GLM procedure from SAS (Statistical Analysis System, version 9.3). The main characteristics included gender, feed program, and their interaction. For all response criteria, the pen served as the experimental unit. Variability in the data was expressed as the pooled SE, and a $p < 0.10$ was considered to be statistically significant.

Results

Results were analyzed separately in two periods (1–21 and 22–42 days) as determined by slaughter date, as well as for the entire growth period (1–42 days). In the first period (Table 2), feeding programs influenced only body fat ($p < 0.07$), with a deposition 11 % higher in the multiphase program (14 phases). All other variables were not influenced by the programs ($p > 0.10$), only by bird gender ($p < 0.01$). The effect of the program, however, on these variables did not depend on bird gender ($p > 0.10$).

In the second period (Table 3) final body weight was 3 % higher ($p < 0.03$) in the multiphase program. The ADFI of multiphase program broilers was different (4 % higher) from that of broilers in the program with four phases ($p < 0.05$). The programs had no effect on ADG ($p > 0.10$). Feed conversion was 1 % worse in the multiphase program ($p < 0.07$). Similarly, protein intake was 4 % higher for the multiphase program ($p < 0.095$). The programs had no effect on protein deposition, fat deposition, body protein, or body fat in this phase ($p > 0.10$). Gender affected ($p < 0.01$) all variables except fat deposition and body fat ($p > 0.10$), and there was no interaction between gender and the feeding programs.

When the total period was analyzed (Table 4), final body weight ($p < 0.05$), ADFI ($p < 0.10$), and ADG ($p < 0.05$) were 2 % higher in the multiphase program. The programs had no effect on the remaining variables in this phase ($p > 0.10$). Table 5 also shows the analysis of cut yields. Total carcass yield was not influenced by the feeding program. Breast yield was 3 % higher in the multiphase program ($p < 0.05$).

Discussion

The multiphase program led to improvements in final body weight, in addition to an increase in breast yield. Specifically, the use of the mixing method proposed by Létourneau-Montminy et al. (2005) can en-

Table 2 – Mean performance of male and female broilers fed with a multiphase program (14 phases) or traditional four phase program for the period 1–21 days.

1–21 days of age	Feeding Program				P-value			SEM
	Four phases		Multiphase		Sex	Pr.[a]	Int.[b]	
	Male	Female	Male	Female				
Final body weight, g	988.82	864.72	976.22	883.60	0.00	0.79	0.20	27.49
Daily feed intake, g d^{-1}	59.48	55.70	59.14	56.74	0.00	0.53	0.23	1.21
Body weight gain, g d^{-1}	44.95	39.02	44.34	39.93	0.00	0.79	0.19	1.30
Feed conversion	1.32	1.45	1.33	1.43	0.00	0.36	0.14	0.02
Feed protein, g d^{-1}	12.18	10.69	12.14	10.65	0.00	0.77	0.97	0.32
Protein deposition, g d^{-1}	5.92	5.32	6.92	5.55	0.00	0.10	0.79	0.29
Fat deposition, g d^{-1}	2.87	3.76	2.88	3.91	0.00	0.77	0.78	0.53
Body protein, g (total)	130.25	117.30	136.69	122.05	0.00	0.10	0.79	6.20
Body fat, g (total)	62.79	80.59	66.48	92.11	0.00	0.06	0.30	6.78

[a]Pr. = program; [b]Int. = interaction; SEM = Standard error of mean; F test with 90 % confidence interval (analysis of variance-covariance).

Table 3 – Mean performance of male and female broilers fed with a multiphase program (14 phases) or traditional four phase program for the period 22–42 days.

22–42 days of age	Feeding Program				P-value			SEM
	Four phases		Multiphase		Sex	Pr.[a]	Int.[b]	
	Male	Female	Male	Female				
Final body weight, g	3004.44	2440.04	3107.13	2513.07	0.00	0.03	0.69	85.36
Daily feed intake, g d^{-1}	170.84	147.67	177.95	152.43	0.00	0.09	0.73	7.90
Body weight gain, g d^{-1}	99.14	75.86	100.83	77.88	0.00	0.27	0.99	3.54
Feed conversion	1.75	1.91	1.76	1.94	0.00	0.05	0.28	0.02
Feed protein, g d^{-1}	30.37	24.71	31.58	25.48	0.00	0.095	0.70	1.35
Protein deposition, g d^{-1}	16.47	10.54	15.10	10.95	0.00	0.46	0.18	1.26
Fat deposition, g d^{-1}	11.28	12.17	13.06	12.25	0.97	0.44	0.48	2.33
Body protein, g (total)	459.46	336.89	455.95	352.00	0.00	0.61	0.42	27.12
Body fat, g (total)	314.29	325.71	337.30	341.23	0.65	0.26	0.82	40.97

[a]Pr. = program; [b]Int. = interaction; SEM = Standard error of mean; F test with 90 % confidence interval.

Table 4 – Mean performance of male and female broilers obtained by analysis of variance-covariance, fed multiphase program (14 phases) or four phases program, for the total period of growth.

1–42 days of age	Feeding Program				P-value			SEM
	Four phases		Multiphase		Sex	Pr.[a]	Int.[b]	
	Male	Female	Male	Female				
Final body weight, g	3031.25	2440.04	3107.92	2480.34	0.00	0.043	0.50	55.36
Daily feed intake, g d–1	115.18	100.04	118.85	101.70	0.00	0.08	0.49	3.13
Body weight gain, g d–1	71.12	57.04	72.92	57.98	0.00	0.04	0.50	1.31
Feed conversion	1.63	1.76	1.63	1.77	0.00	0.41	0.32	0.02
Feed protein, g d–1	21.58	17.64	21.57	16.63	0.00	0.23	0.24	1.01
Protein deposition, g d–1	10.80	7.93	10.71	8.25	0.00	0.72	0.54	0.59
Fat deposition, g d–1	7.25	7.97	8.17	8.08	0.54	0.33	0.45	1.02
Body protein, g (total)	447.09	336.84	455.91	351.96	0.00	0.27	0.77	26.67
Body fat, g (total)	314.16	325.71	337.26	341.25	0.65	0.26	0.82	40.85
N excretion	0.76	0.56	0.57	0.48	0.31	0.31	0.68	0.27

[a]Pr. = program; [b]Int. = interaction; SEM = Standard error of mean; F test with 90 % confidence interval.

Table 5 – Average yield of carcass and commercial cuts of male and female broilers obtained by analysis of covariance, fed with a multiphase program (14 phases) or a traditional 4-phase program, at 42 days of age.

Yield	Feeding Program				P-value			SEM
	Four phases		Multiphase		Sex	Pr.[a]	Int.[b]	
	Male	Female	Male	Female				
Carcass (%)	75.41	74.47	75.75	74.87	0.05	0.42	0.95	1.46
Breast (%)	40.06	39.37	40.75	41.16	0.75	0.01	0.21	1.35
Thigh+drumstick (%)	27.68	27.66	27.23	27.26	0.99	0.10	0.92	0.77
Wing (%)	10.13	9.98	9.78	9.95	0.90	0.14	0.20	0.38

[a]Pr. = program; [b]Int. = interaction; SEM = Standard error of mean; F test with 90 % confidence interval.

hance performance of broilers, even when compared with traditional four phase programs based on an average level of nutrient requirements for each phase. The applicability of logistic shortcomings was not our objective because this has already been examined by another study (Gutierrez et al., 2008). The important aspect for us was to evaluate broiler responses when fed with a multiphase program using a specific mixing method that follows nutrient requirements.

With the exception of body fat content, which was lower in the four phase program, there were no differences in performance and carcass yield between the feeding programs in the initial (1–21 days) growth phase. Pesti and Fletcher (1984) observed that feed conversion efficiency improves during the week following a period with inadequate protein intake, leading to an increase in the proportion of abdominal fat even though there is a decrease in total body fat content. This corroborates the observation that in the traditional program based on average nutrient requirements within a phase, birds experience a likely deficit in protein intake in the first half of each phase. Therefore, the lower body fat content in the traditional program could be a by-product of this mechanism.

Final body weight and feed intake were greater in the multiphase program in the second period (21–42 days), although feed conversion was more efficient in the traditional program. This is consistent with the previously mentioned notion that early protein restriction and lower fat content may subsequently improve feed efficiency (Gous et al., 2012; Moran, 1979; Pesti and Fletcher, 1984). However, no difference in carcass yield between programs was observed, which might be explained by a compensatory gain in the four phase program (Eits et al., 2003).

When the entire 42-day period is considered, there is an overall increase in final body weight and average daily gain in the multiphase program, which could be justified by the higher feed intake. Another aspect is that the differences in nutrient levels in the feed between programs may have also affected the results. While the multiphase program follows the bird's requirements, traditional programs based on average requirements necessarily provide lower or greater amounts of nutrients than those needed.

An increase in breast yield was also observed. This finding is in line with the proposition that for optimized breast yield, a constant protein intake, and thus protein input adjustment, is necessary during the entire growth period (Eits et al., 2003). Therefore, the compensatory growth observed in the traditional program was, in all likelyhood insufficient to generate an increase in breast yield, particularly in light of the adverse effects of the lower crude protein intake early in this phase.

In this study, we simulated a real situation in the traditional program where supplies are expensive and used the factorial method to define nutritional level in diets by considering the mean requirement of the population and the feed phase. When this method is employed in traditional feed programs (few phases), generally the average requirement for a period of time is used to minimize production costs (Hauschild et al., 2010). This implies a constant adjustment between nutritional input and requirements. Results indicate that such adjustment was accomplished in both programs, as nitrogen excretion was not affected by the program when the entire period was considered. We cannot rule out, however, the possibility that the differences observed in performance and carcass yield between feeding programs would have been even greater had we adjusted the traditional program (four phases) by the nutritional requirements based on the first and not the average day of each phase. Therefore, this study illustrates the need to better take into account the dynamic nature of nutrient requirements before making strategic nutritional decisions.

Overall, the mixing method proposed by Létourneau-Montminy et al. (2005) and previously used only in pigs (Pomar et al., 2007) can also be applied to the poultry industry to generate improvements in broiler performance, making possible the use of multiphase programs to adjust nutrient input in all phases of broiler growth. Therefore, this feeding program allows one to reach a precision feeding design that can contribute to the reduction and optimization of broiler farms, and ensure their economic viability.

Conclusion

The multiphase feeding program based on the mixing method allows for improving broilers' performance, in addition to increasing breast yield, as compared to a traditional program (four feeding phases).

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