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ANIMAL SCIENCE

Productive and economic performance of broiler chickens fed diets with different nutritional levels

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Abstract: The present study evaluated the productive characteristics, nutrient digestibility, and economic indexes of broiler chickens submitted to diets containing different nutritional levels, and identified advantages for the commercialization of poultry in the griller-type whole chicken model. A total of 180 COBB 500 chicks ™ were distributed in a completely randomized design, in a 2x3 factorial scheme: sex (male and female) and nutritional level (nutritional requirements for male, female or mixed flock); with 6 repetitions of 5 birds each. It was observed effect of the sex factor in the performance and the economic analysis, in which the male chickens presented the highest feed costs, in spite of exhibiting the best feed conversion rates and gross marketability, resulting from greater body weight. Considering nutritional levels, the most outstanding diet was that formulated according to the demands of the females, which did not affect the performance or carcass characteristics of the birds, obtained the highest gross margins with good feeding costs, showed good retention of dry matter and gross energy, regardless of sex. The diet of nutritional requirements of the females provides promising results for the production of broiler chickens. The female birds present marketing advantages in the griller-type chicken model.

Key words: Carcass characteristics, digestibility, poultry, profitability.

INTRODUCTION

The modern broiler chicken is the result of scientific and technological contributions from different fields, highlighting genetic improvement, which has provided around 80% to 85% of the increment in performance, allowing to slaughter animals in a shorter period of time (Rutz et al. 2017); and nutrition, which has enabled producers to more accurately meet the nutritional requirements of these birds (Tavernari et al. 2014).

Studies on nutritional requirements concerning energy (Sakomura et al. 2004a, Ferreira et al. 2015), protein content (Costa et al. 2001), amino acids (Almeida et al. 2002) and the relationship between these nutrients (Kamran et al. 2008, Lima et al. 2008) have been conducted, aiming to obtain balanced diets with optimized nutritional levels. These assessments have provided adequate feeding programs that allow poultry to express their genetic potential, minimizing the costs of production.

In order to modify the nutritional levels of a given diet, factors such as production costs and the interference of sex must be taken into account. According to Embrapa's Poultry and Swine Intelligence Center (*Central de Inteligência de Aves e Suínos* – CIAS/EMBRAPA 2020), the cost of producing broiler chickens undergoes frequent oscillations. From the period between January 2018 to January 2019, production costs increased by 12.95%, of which 10.29% comprised the increment in corn and soybean prices.

The protein source is certainly becoming a constant concern for broiler producers since in three years the price of soybean has increased by an average of 8.0% (Cepea / ESALQ / USP 2020). In this sense, according to Saleh (2016) feeding broiler on low protein diets may reduce feed cost and allow for use of alternate feedstuffs and considered as one of the most important decisions for broiler nutritionists, because of the expense of providing sufficient protein to growing broilers. In addition, the ability to lower crude protein in the diet can result in decreased nitrogen excretion (Nahm 2002, Namroud et al. 2008, Silva et al. 2012), promoting economic and environmental benefits.

The observed differences in growth between male and female chickens indicate that nutritional requirements vary between sexes (Rutz et al. 1999). According to zootechnical indexes, female poultry undergo a decrease in productive performance as of the third week of age (20 days) (Leeson & Summers 2005), reducing body weight by 12.93% and 16.56% at 30 and 42 days of age, respectively, when compared to male chickens (Rostagno et al. 2017). This condition may interfere in the cost dynamics of the poultry industry since male chicken growth can be more favorable in comparison to female growth when considering the cost-benefit ratio.

In this scenario, the commercialization of female broiler chickens should be carried out in markets interested in smaller carcasses. The Middle East may be an alternative to commercialize chicken carcasses since it increased 4.21% the imports of griller-type whole chickens in the period from 2017 to 2018) (ABPA 2019). This type of chicken should present between 1.3 and 1.5 kg of live weight at 27-29 days of age, and feed conversion of 1.5 (Olivo 2006), ideal characteristics that adapt to the performance displayed by female poultry, rendering this bird an alternative for the production of griller-type whole chicken. Thus, the present study aimed to evaluate the productive and economic indexes and the digestibility of broiler chickens fed diets containing different nutritional levels, and that were reared in such a way as to analyze advantages for the commercialization of poultry in the griller-type whole chicken model.

MATERIALS AND METHODS

The present study was performed in accordance with Brazilian guidelines, based on Federal Law No. 11,794 of October 8th, 2008, and was approved by the Research Ethics Committee – CEP/FZEA/USP, under Process No. 3979011015.

Birds, installations, and diets

A total of 180 one-day-old Cobb 500™ chicks, including 90 males weighing 49.87 ± 1.07g and 90 females with an initial weight of 49.32 ± 1.74g, were housed in the Poultry Laboratory of the Faculty of Animal Science and Food Engineering of the University of São Paulo (FZEA/USP). The animals were vaccinated in the hatchery against Marek disease.

In the animal housing, the birds were allocated in 36 galvanized wire cages (90cm x 70cm x 50cm) equipped with excreta collection trays, nipple-type drinkers, and infant and gutter-type feeders. A light program of 23h light:1h dark was established, except during the first week (24 hours of light). The thermal environment was monitored using a digital thermohygrometer, which performed the maximum and minimum readings of temperature (ºC) and relative air humidity (RAH%) in the morning and afternoon.

When necessary, ventilators and nebulizers were activated to maintain the thermal comfort of the birds. The diets were formulated based on corn and soybean meal, according to the nutritional recommendations for Poultry (Rostagno et al. 2011) in the pre-starter (1 to 7 days), starter (8 to 21 days), and grower/finisher (22 to 29 days) phases, as shown in Table I. Water and feed were provided *ad libitum*.

Experimental design

The animals were distributed in a completely randomized design, in a 2 x 3 factorial scheme, considering the following factors: sex (male and female) and nutritional level (recommendations to meet male, female or mixed flock requirements), totaling 6 treatments and 6 repetitions of 5 birds each (Table II).

Table I. Percentage and calculated composition of the experimental diets.

Ingredient (%)	Diets								
	1 to 7 days			8 to 21 days			22 to 29 days		
	M	F	MI	M	F	MI	M	F	MI
Corn (7.88%)	58.56	60.14	59.39	60.88	62.46	61.80	63.71	66.01	64.82
Soybean meal (45%)	35.58	34.18	34.86	32.70	31.46	31.87	29.08	27.50	28.34
Dicalcium phosphate	1.93	1.93	1.93	1.57	1.55	1.56	1.34	1.23	1.28
Soybean oil	1.32	1.01	1.15	2.36	2.05	2.16	3.47	3.03	3.27
Limestone	0.81	0.81	0.82	0.86	0.85	0.85	0.82	0.78	0.80
Salt	0.46	0.46	0.45	0.43	0.40	0.42	0.41	0.40	0.40
L-lysine HCl	0.39	0.46	0.43	0.34	0.36	0.36	0.34	0.29	0.32
DL-methionine	0.37	0.39	0.38	0.32	0.32	0.32	0.30	0.25	0.25
L-threonine	0.16	0.18	0.17	0.12	0.13	0.23	0.11	0.08	0.10
Supplement [1,2]	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Choline chloride 70%	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
ME and Calculated nutrient (%)									
ME (Mcal/kg)	2.96	2.96	2.96	3.05	3.05	3.05	3.15	3.15	3.15
Crude Protein	22.40	22.00	22.20	21.20	20.80	21.00	19.80	19.20	19.50
Lysine Dig.	1.32	1.34	1.33	1.22	1.20	1.21	1.13	1.06	1.09
Met+cys Dig.	0.95	0.97	0.96	0.88	0.86	0.87	0.83	0.77	0.77
Methionine Dig.	0.67	0.68	0.68	0.60	0.59	0.60	0.57	0.52	0.51
Threonine Dig.	0.86	0.86	0.87	0.79	0.78	0.78	0.74	0.69	0.71

M- Male; F- Female; MI- Mixed; based on requirements for higher bird performance, according to Rostagno et al. (2011).
[1]Vitamin, mineral, and additive supplementation per kilogram of feed (used during the period from 1 to 21 days): Folic Acid (min) 250.00 mg; Pantothenic Acid (min) 3750.00 mg; Cu (min) 25.00 g/; Choline (min) 86.56 g; Fe (min) 12.50 g; I (min) 300.00 mg; Mn (min) 17.50 g; Niacin (min) 10.00 g; Se (min) 50.00 mg; Vitamin A (min) 2000000.00 IU; Vitamin B1 (min) 600.00 mg; Vitamin B12 (min) 3500.00 mcg; Vitamin B2 (min) 1500.00 mg; Vitamin B6 (min) 1000.00 mg; Vitamin D3 (min) 600000.00 IU; Vitamin E (min) 3000.00 IU; Vitamin K3 (min) 500.00 mg; Zinc (min) 12.50 g; Virginiamycin 3750.00 mg; Nicarbazin 31.25 g.
[2] Vitamin, mineral, and additive supplementation per kilogram of feed (used during the period from 22 to 29 days): Folic Acid (min) 150.00 mg; Pantothenic Acid (min) 2750.00 mg; Cu (min) 25.00 g; Choline (min) 60.40 g; Fe (min) 12.50 g; I (min) 300.00 mg; Mn (min) 17.50 g; Niacin (min) 7500.00 mg; Se (min) 50.00 mg; Vitamin A (min) 1500000.00 UI; Vitamin B1 (min) 350.00 mg; Vitamin B12 (min) 2500.00 mcg; Vitamin B2 (min) 1000.00 mg; Vitamin B6 (min) 500.00 mg; Vitamin D3 (min) 500000.00 UI; Vitamin E (min) 2500.00 UI; Vitamin K3 (min) 400.00 mg; Zinc (min) 12.50 g; Virginiamycin 4125.00 mg; Salinomycin 16.50 g.

Table II. Description of the experimental treatments.

Treatments.	Factors		Broilers/treatment
	Sex	Diets: requirements	
MM	Male	Male	30
MF	Male	Female	30
MMI	Male	Mixed	30
FM	Female	Male	30
FF	Female	Female	30
FMI	Female	Mixed	30

M- Male; F- Female; MI- Mixed; Diets based on requirements for higher bird performance, according to Rostagno et al. (2011).

Performance characteristics

The birds and feed leftovers were weighed weekly to determine weight gain (WG), feed intake (FI), and feed conversion (FC). The latter was corrected along with the number of animals regarding mortality (Sakomura & Rostagno 2016), which was verified daily in order to calculate flock viability (FV = 100% - % mortality) and the productive efficiency index (PEI = [(average daily weight gain × FV) / (feed conversion × 10)]).

Digestibility test

During the period from 23 to 28 days of age, the digestibility assay was conducted using the total excreta collection method described by Sakomura & Rostagno (2016). The start and end of collection were determined by the supply of marker-containing feeds (addition of 1.0% ferric oxide). Excreta sampling was carried out twice daily, in the early morning and late afternoon, thus avoiding fermentation and nutrient loss. The collected excreta were subsequently stored in a freezer (-18ºC to -22ºC).

Laboratory analyses and coefficient calculation

The feed samples and the excreta, processed according to the procedures described by Sakomura et al. (2004b), were submitted to laboratory analyses to determine dry matter content (DM), in an oven at 105°C until constant weight, and gross energy (GE), using an IKA C200 calorimeter. Nitrogen (N) values were established by the Kjeldahl method and then transformed into crude protein (CP), according to Silva & Queiroz (2009). After obtaining the results in the DM, CP, and GE analyses, the apparent digestibility coefficients of the diets were calculated [ADC (%) = (Ingested nutrient – Excreted nutrient) * 100/Ingested nutrient] (Lara et al. 2013).

Carcass characteristics

At 29 days of age, one bird per experimental unit (six animals/treatment) was selected at random, identified, and submitted to a 10-hour fasting period, after which the animals were weighed and slaughtered at the PUSP-FC Slaughterhouse, in accordance with the regulation of industrial and sanitary inspection of products of animal origin (RIISPOA- MAPA 2017). After the chilling period, the following commercial cuts were obtained: breast fillet (BF), thighs (Th), drumsticks (DS), and wings (W). The carcass yield was calculated in relation to the live weight before slaughter [% carcass yield = (carcass weight*100/live body weight)] and the cut yield as a function of the weight of the eviscerated carcass including the feet, head, and neck [% cut yield = (cut weight * 100) / carcass weight] (Mendes et al. 2004).

Economic analysis

In the economic analysis, the gross income (GI), the total cost of the feed (TCF), and the gross trade margin (GM) were evaluated. The TCF was calculated using the diet cost and feed intake for each treatment. The costs of each diet were estimated according to the actual prices of each ingredient (corn, soybean meal, soybean oil, salt, and live chicken) using the monthly nominal prices of the past 10 years (April 2008 to April 2018) obtained from the databases of the Center for Advanced Studies in Applied Economics (Cepea/ESALQ/USP 2018) and the Institute for Agricultural Economics (IEA – APTA 2018). Once determined, the nominal prices were corrected by the National Consumer Price Index of the Brazilian Institute of Geography and Statistics (INPC/IBGE 2018) using the accumulated index number from January 1993 for the same period analyzed and according to the method presented by Hoffmann (2006):

$$PQ_{(corrected,\ t)} = PQ_{(nominal,\ t)} \times (INPC_{April/2018} / INCP_{t})$$

In which:

- $PQ_{(corrected,t)}$ represents the actual price of the ingredient in month t, corrected for April 2018;
- $PQ_{(nominal,t)}$ denotes the price of the ingredient in month t;
- $INPC_{April/2018}$ is the index for April 2018;
- $INPC_t$ represents the index for month t.

Given the other ingredients of the diets did not retain a historical series, their prices were obtained through quotations from suppliers and corrected using the INPC. The corrected average prices for each ingredient are shown in Table III.

After determining the TCF, the gross income (GI) was calculated, which is estimated by multiplying the sale price of the product on the market by the amount of product sold (live chicken weight) (Nascimento et al. 1998). The gross trade margin (GM) constitutes a measure that represents the profitability of the producer and is obtained from the difference between the gross income (GI) and the total cost of the feed (TCF) (Gameiro 2009). Likewise, the dollar used was calculated as the average of the daily official exchange rate for April 2018, that is, US$ 1.0000 equal to R$ 3.4075 according to the Brazilian Central Bank (BCB 2018).

Table III. Price of the live chicken and ingredients used during feed formulation in April 2018.

Ingredient	Price per kilogram (US$. kg−1)
Corn[1]	0.18
Soybean meal 45% [2]	0.40
Soybean oil[2]	0.97
Salt[2]	0.19
Live chicken [2]	0.84
Dicalcium phosphate[3]	0.82
Limestone[3]	0.06
Vitamin and Mineral Supplement[3]	7.34
L-lysine HCl[3]	2.30
DL-methionine[3]	6.05
L-threonine[3]	3.55
Choline chloride 70%[3]	1.92

Sources: [1]Cepea/ESALQ/USP; [2]IEA – APTA; [3] data collection with suppliers.

Statistical analysis

The results obtained for performance, carcass characteristics, digestibility, and the economic analysis were submitted to verification analyses regarding normal distribution, variance homogeneity, and presence of discrepant data using the statistical SAS program for Windows 9.0 (Copyright(c) 2002). Subsequently, the data underwent analysis of variance (ANOVA), executing the GLM (General Linear Model) procedure. In the case of significant difference and interaction between the factors (P<0.05), the treatment means were compared using the Tukey test at 5% probability.

RESULTS AND DISCUSSION

The results concerning the performance characteristics are shown in Table IV. A significant interaction was observed regarding the variable feed intake (FI), and the unfolding of the studied factors is expressed in Table V.

In the performance characteristics, evaluated from 1 to 28 days of age (Table IV), the male broilers showed better results (P<0.05) for body weight (BW), weight gain (WG), and feed conversion (FC) when compared to the females. The effect of the sex on the performance responses denoted that the male chicken exhibits better productive behavior at 28 days of age. Several authors have described that, as of 22 days of age, female poultry present worse feed conversion in relation to males, in view of the low feed consumption, which results in inferior weight gain (Costa et al. 2001, Corzo et al. 2005, Bernal et al. 2014, Tavernari et al. 2014). In turn, the results described by Almeida et al. (2002) contradict those obtained herein, since they reported that regardless of the diet and nutritional levels used in broiler feeding, a significant effect of sex on FC is not observed during the growth phase (28 days old).

According to Kessler & Brugalli (1999), the differences between sexes are related to the growth phase of the animals, in which male chickens present high rates of protein deposition between 28 and 35 days, and females exhibit maximum deposition between 21 and 28 days. This condition renders male chickens more efficient in transforming nutrients into

Table IV. Performance results of broiler chickens for the period from 1 to 28 days of age.

Factors	FI[1]	BW	WG	FC	FV	PEI
Sex (S)						
Male	2210.73	1556.23a	1506.37a	1.47a	93.33	341.93
Female	2054.27	1413.09b	1363.77b	1.51b	97.78	316.09
Diets (D)						
Male	2112.67	1478.53	1429.09	1.48	95.00	326.69
Female	2146.27	1500.05	1450.30	1.48	93.33	327.19
Mixed	2138.57	1475.41	1425.81	1.50	98.33	333.15
ANOVA	Probability					
S	<0.0001	<0.0001	<0.0001	0.0241	0.1777	0.0779
D	0.5553	0.5762	0.5807	0.5422	0.4444	0.9180
Interaction S x D	0.0275	0.2320	0.2359	0.6604	0.4444	0.7405
CV[2] (%)	3.70	4.18	4.31	3.11	10.11	12.90

FI (g)- Feed intake; BW (g)- Body weight; WG (g)- Weight gain; FC- Feed conversion; FV- Flock viability; PEI- production efficiency Index.
Means followed by the same letter in each column in the diet factor do not differ by the Tukey test (P<0.05).
Means followed by different letters in each column in the sex factor do differ by the F test (P <0.05).
[1]Significant interaction between factors (sex and diet), shown in Table V.
[2]Coefficient of variation.

live weight. Gonzales & Sartori (2002) stated that nutrient partition for growth is modulated primarily by the action of several hormones. The condition in which male broiler chickens retain more significant growth than females is related to stronger hormonal stimuli in males, thus denoting their importance in the process of more efficient muscle protein synthesis.

The relationship between the intake of the three diets by male and female chickens (comparison between rows) is shown in Table V. The nutritional variations did not affect consumption within each sex, a result that reflected on the other assessed performance characteristics, which were not influenced by the nutritional levels of the diets. Therefore, the nutritional requirements were met within each sex in the present study. Such an outcome is related to adequate animal development and growth, without interactions between the studied groups regarding the other analyzed performance characteristics. According to D'Mello (2003), Oliveira Neto et al. (2000) and Amarante-Junior et al. (2005), alterations in food intake and growth require an imbalance (excess or deficiency) in the amino acid pattern, as well as inefficient energy use. An interesting aspect of such a result is that, until 28 days of age, small changes in nutritional levels do not affect the growth of the male chicken, indicating that the nutritional use of the bird is in its exponential phase, with maximum deposition of nutrients, as described by Kessler & Brugalli (1999).

The effect of sex and dietary intake, shown in Table V (comparison between columns), may be related to the individual physiological behavior of each bird in response to strong hormonal stimuli, considering the characteristic animal growth at this age. An increment in feed consumption by the male chickens was verified when the nutritional levels of the diets increased, whereas, in the females, such relationship was the inverse, with decreased feed intake as the nutritional level of the diets enhanced. Oliveira Neto et al. (2000) and Andriguetto et al. (2002) described the effect on the consumption of female poultry, when compared to male broilers, as a consequence of the activation of physiological mechanisms to maintain homeostasis, depressing feed intake, since the bird has a number of nutrients that are superior to the metabolic demands to fulfill its processes of maintenance, work, and weight gain. According to this result, it can be noted that female birds require lower nutritional levels than males, as reported by Dozier et al. (2009), Salehifar et al. (2012) and Bernal et al. (2014).

Interestingly, in Table V, male and female broiler chickens fed the diet formulated to meet the nutritional requirements of females exhibited similar intakes. Such an effect can be due to the voluntary physiological adjustment of female poultry, motivated by the low concentration of nutrients in the diet. Kamran et al. (2008) also verified that birds receiving diets with low protein content and reduced nutritional

Table V. **Significant interaction for feed intake (g) of broiler chickens (1 to 28 days of age).**

	Diets: requirements			
Sex	**Male**	**Female**	**Mixed**	**Sem**
Male	2240.83Aa	2184.46Aa	2206.91Aa	32.1488
Female	1984.50Ab	2108.09Aa	2070.23Ab	

Means followed by the same lowercase letters do not differ in the columns, and same capital letters do not differ in the rows by the Tukey test (P<0.05).
Sem: Standard error of the mean.

levels increased feed consumption. Regarding the other diets, the male broilers displayed more substantial feed intake than females.

The coefficients of apparent digestibility during the period from 23 to 28 days of age are shown in Table VI. For the results of the dry matter digestibility coefficient (DMDC) and the gross energy digestibility coefficient (GEDC) an interaction was observed between the treatments, and the mean values are expressed in Table VII.

Considering the crude protein digestibility coefficient (CPDC) results, there was no difference (P>0.05) regarding the sex factor. However, when observing the nutritional levels of the diets, the CPDC showed a difference (P<0.05), with higher protein utilization in the diets formulated according to the requirements for male and mixed chickens, when compared to the required diet for females.

A difference was observed (P<0.05) in the interaction between the sexes (comparison between columns), in which the female poultry exhibited better retention of dry matter and energy than the males when fed the mixed flock diet. It was not possible to elucidate the difference regarding sex in the diets for males and females, indicating that the birds utilized the dry matter and gross energy available in the diets similarly.

With the interaction considering the DMDC variable, the dry matter retention of the broilers, of both sexes, was statistically similar when consuming the three diets (comparison between rows). Regarding the GEDC variable, an effect (P<0.05) on the dietary nutritional levels for female birds was observed, with better energetic retention when they were fed the diet formulated to meet the requirements for females and the mixed flock. However, the energy retention coefficients of the females fed

Table VI. Analysis of variance for the digestibility coefficients (%) of the broiler chickens at 28 days of age.

Factors	DMDC[1]	CPDC	GEDC[2]
Sex (S)			
Male	79.24	73.34	78.16
Female	79.50	72.49	78.90
Diets (D)			
Male	79.36	73.81a	78.39
Female	79.44	71.63b	78.83
Mixed	79.31	73.32a	78.37
ANOVA	Probability		
S	0.3592	0.1201	0.0342
D	0.8761	0.0049	0.4471
Interaction S x D	0.0246	0.3949	0.0062
CV[3] (%)	1.25	2.14	1.28

DMDC - dry matter digestibility coefficient; CPDC - crude protein digestibility coefficient; GEDC- gross energy digestibility coefficient.
Means followed by the same letter in each column in the diet factor do not differ by the Tukey test (P<0.05).
Means followed by different letters in each column in the sex factor do differ by the F test (P <0.05).
[1,2]Significant interaction between factors (sex and diet), shown in Table VII.
[3]Coefficient of variation.

with the mixed flock requirement diet differed (P<0.05) from the GEDC values when they were fed the male requirement diet. According to the results found for performance, the digestibility test showed that the diet formulated to meet the requirements for female poultry is more favorable or adequate since low nutritional levels resulted in better retention of DM and GE in both sexes.

The mean values of the DMDC (79.44%), CPDC (71.63%), and GEDC (78.83%) of the diet formulated to meet the requirements for females that demonstrates excellent digestibility with lower nutrient levels. They are similar with the results described by Lara et al. (2013), who reported an DMDC of 79.6% and an CPDC of 71.6% in 22-to 36-day-old broilers, when using diets based on corn and soybean meal. Nonetheless, the nutritional levels of the diets evaluated by the authors (3210 kcal/kg of ME; 21.0% of CP; 1.16% Lysine; 0.75% Met+Cys) differed since they used higher nutritional values than those used in the present study. The results obtained by Sakomura et al. (2004b), disagreed for DMDC when the authors reported the average value of 70.57% in 22-to 36-day-old broilers, with a diet of different energy, protein and amino acid ratios to those used in this study (2930 kcal / kg ME; 19.95% of CP; 1.05% Lysine; 0.90% Met+Cys). Similarly, Barbosa et al. (2007), observed different results, when they described that the diet with 3000 kcal / kg ME; 19.30% of CP; 1.043% Lysine; 0.750% Met+Cys, was the one that showed the best nutritional use with DMDC of 70.54% and GEDC of 68.24%.

Discrepancies in the literature regarding digestibility illustrate the importance of knowledge of the nutritional requirements of poultry. Such know-how enables the efficient use of feed, given the nutrients are adjusted avoiding deficiencies or excesses, factors which considerably influence animal performance. In this scenario, the diet formulated according to the requirements for females was suitable to obtain optimal coefficients of apparent digestibility, denoting adequate nutritional adjustments without negative effects on the performance of these animals.

The carcass and commercial cuts yields were evaluated at 29 days of age, and the results are shown in Table VIII.

Concerning the treatments, no effect on the mentioned variables was observed, confirming that, during this phase, the differences between the nutritional levels of the diets were not sufficiently significant to cause a deficiency or imbalance in amino acids, energy levels, vitamins, and minerals, factors which are linked to protein synthesis or degradation in muscle tissue growth. Several studies have described

Table VII. Significant interaction for the dry matter digestibility coefficient (DMDC) and the gross energy digestibility coefficient (GEDC) in broiler chickens at 28 days of age.

	DMDC (%)			Sem	GEDC (%)			Sem
	Diets: requirements				Diets: requirements			
Sex	Male	Female	Mixed		Male	Female	Mixed	
Male	79.54Aa	79.65Aa	78.37Ab	0.4428	78.43Aa	78.87Aa	77.17Ab	0.4116
Female	79.18Aa	79.23Aa	80.08Aa		78.34Ba	78.80ABa	79.57Aa	

Means followed by the same lowercase letters do not differ in the columns, and the same capital letters do not differ in the rows by the Tukey test (P<0.05).
Sem: Standard error of the mean.

Table VIII. Analysis of variance for carcass characteristics (%) of broiler chickens at 29 days of age.

Factors	Carcass Yield	Breast fillet	Thigh	Drumstick	Wing
Sex (S)					
Male	79.65	26.34	11.87	15.03	9.93
Female	78.37	26.58	11.47	15.44	9.82
Diets (D)					
Male	78.37	26.71	11.66	15.22	9.99
Female	78.92	26.53	11.78	15.23	9.93
Mixed	79.74	26.14	11.57	15.26	9.71
ANOVA			**Probability**		
S	0.0926	0.6847	0.0593	0.1143	0.5315
D	0.3315	0.7091	0.6938	0.9906	0.3435
Interaction S x D	0.3616	0.2256	0.9887	0.1393	0.6972
CV[1] (%)	2.81	6.47	5.22	5.03	5.02

[1]Coefficient of variation.

that carcass composition is decreased when the level of CP in the diet is reduced by 3%, even when all the known nutrient requirements are met (Sterling et al. 2005, Kamran et al. 2008). In the present study, variations in CP ranging around 1-3% during the analyzed period were not sufficient to affect the carcass yield results.

The similarities between the carcass and commercial cuts yields of male and female chickens may be due to the growth phases of each bird, as described by Kessler & Brugalli (1999). These authors reported that, at 28 days, female birds are at the age at which the maximum rate of protein deposition (maximum growth) occurs, whereas males are still undergoing development. Thus, during this period, muscle growth is equivalent for both sexes.

The results obtained in the economic analysis are shown in Table IX. An interaction (P<0.05) between the sex and diets factors was observed for the total feed cost and gross trade margin, as shown in Table X.

Regarding the nutritional levels of the diets, no effect on gross income was observed, suggesting that, despite the nutritional modifications, the three diets obtained similar profits considering the sale of the birds. In turn, concerning the sex factor, the gross income variable presented a significant effect (P<0.05), with male chickens retaining the highest values when compared to the female birds.

Considering the interaction, the gross trade margin results denoted the effect of sex (P<0.05) on the three diets (comparison between columns), suggesting that, in spite of the changes in nutritional levels, the male chickens exhibited higher profitability margins than the females. Likewise, the feed cost variable underwent the effect of sex (P<0.05), in which the male chickens retained the highest costs when fed diets formulated according to the recommendations for males and mixed flock. Nevertheless, when the male chickens were fed the diet required for females, no significant effect was observed, with similar costs between birds of both sexes.

In relation to the nutritional levels of the diets, within each sex (comparison between rows), an influence (P<0.05) was verified on the

Table IX. Economic viability of broiler chickens at the stage from 1 to 28 days of age.

Factors	TCF[1]	GI	GM[2]
Sex (S)			
Male	0.74	1.26a	0.52
Female	0.68	1.14b	0.45
Diets (D)			
Male	0.71	1.20	0.47
Female	0.70	1.21	0.50
Mixed	0.71	1.19	0.48
ANOVA	Probability		
S	<0.0001	<0.0001	<0.0001
D	0.5235	0.5807	0.0062
Interaction S x D	0.0228	0.2359	0.0080
CV[3] (%)	3.69	4.31	4.15

TCF- Total cost of feed (US$); GI- Gross income (US$/chicken); GM- Gross trade margin (US$ /chicken).
Means followed by the same letter in each column in the diet factor do not differ by the Tukey test (P<0.05).
Means followed by different letters in each column in the sex factor do differ by the F test (P <0.05).
Means followed by a different letter are significantly different at an alpha level of 0.05 according to an LSD test.
[1,2]Significant interaction between factors (sex and diet), shown in Table X.
[3]Coefficient of variation.

Table X. Significant interaction for total cost of feed (TCF) and gross trade margin (GM) of broiler chickens at 28 days of age.

	TCF (US$/kg)			Sem	GM (US$/kg)			Sem
	Diets: requirements				Diets: requirements			
Sex	Male	Female	Mixed		Male	Female	Mixed	
Male	0.76Aa	0.72Ba	0.73ABa	0.01071	0.52Aa	0.52Aa	0.51Aa	0.008969
Female	0.67Ab	0.69Aa	0.69Ab		0.42Bb	0.48Ab	0.45Bb	

Means followed by the same lowercase letters do not differ in the columns, and the same capital letters do not differ in the rows by the Tukey test (P<0.05).
Sem: Standard error of the mean.

cost of feed of the male chickens when they were fed the diet recommended for males and females, both of which retained the highest and lowest costs, respectively. Regarding the gross trade margin, the effect of the nutritional levels (P<0.05) on the female poultry results was evidenced, emphasizing the diet formulated according to female requirements, which reached the highest profitability when compared to the other types of diets provided to the female birds.

The economic results shown here suggest that broilers of both sexes, receiving a single diet formulated from the nutritional requirements for females up to 28 days of age, entailed a higher profit for the producer, without affecting the productive and digestibility characteristics of the birds. Similarly, Corzo et al. (2005) stated that rearing males and females separately constitutes a beneficial food strategy, especially in cases of market specificity based on the type of meat (*i.e.*, different weights).

The results obtained in the present study highlight two aspects that may be of interest at the productive level. The first comprises the possibility of using diets formulated according to female poultry requirements with lower nutritional density, without negative effects on performance and carcass and commercial cuts yields, in both sexes. Also, it provides optimal nutrient utilization responses and high economic return rates, indicating greater system profitability.

The second aspect consists of the economic and productive potential of female birds since, at 28 days, they have reached 1.41 kg of body weight and feed conversion of 1.51. These results, concerning weight, age, and feed conversion, were considered ideal (27 to 29 days of age, with 1.3-1.5 kg of live weight, and a feed conversion ratio of 1.5 kg of feed per 1 kg of meat) for the birds to be sold in the griller-type whole chicken category (Olivo 2006). When considering that world chicken production increased by an average of 2.94% in the last 5 years, according to USDA/Foreign Agricultural Service (2020). The economic interest for female birds is more expressive, since rearing is based on high population density (15-17 birds/m²) (Barbosa-filho et al. 2017), which enables to optimize aviary space, reducing feed and management costs, among other aspects that maximize the income of the producer.

CONCLUSIONS

The diet formulated according to female requirements was sufficient to satisfy the nutritional requirements of males and females, without impairing performance and the carcass and commercial cuts yields of both sexes, providing excellent nutritional utilization and high economic indexes.

The sex of the birds influenced performance, digestibility, and economic viability at 28 days of age. It is well known that male chickens retain better performance and economic return, products of greater weight gain.

The commercialization of female poultry in the griller-type whole chicken model has a high economic potential when in compliance with adequate conditions of age, weight, and feed conversion.

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