Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X Jan - Mar 2018 / v.20 / n.1 / 053-062

http://dx.doi.org/10.1590/1806-9061-2017-0523

Effects of Nutritional Levels on Performance, Carcass Characteristics and Nutrient Digestibility of Sexed Broilers

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■Keywords

Economic viability, metabolizability, nutrition, nutritional requirement, poultry.

Submitted: 10/February/2017
Approved: 20/September/2017

ABSTRACT

The objective of this study was to evaluate the effects of dietary nutrient levels on performance, carcass yield, commercial cuts, digestibility and economical viability of broilers from 1 to 42 days of age. During the experiment, 180 COBB 500™ chicks were housed in metal batteries and subjected to a completely randomized design in a 2x3 factorial arrangement, of two sexes and three diets (male, female and mixed), totaling 6 treatments and 6 repetitions of 5 birds each. Data were subjected to statistical analysis and the means were compared using the Tukey test, at 5% probability. The results indicate the effect of sex on performance and commercial cuts, except for breast and thigh fillets, in which males and females showed similar results when given the mixed diet. The influence of the nutritional levels on performance, digestibility and commercial cuts was observed, in which the female diet showed the highest results for feed intake, body weight and weight gain, in addition to greater retention of protein and crude energy. For drumstick and abdominal fat yield, the highest values were obtained using the mixed diet and the female diet, and the lowest values were obtained using the male diet. Regarding economic viability, the female diet showed the highest return per unit of Real (R$) spent on feed. Therefore, these data prove that the female diet had a positive effect when provided to both sexes, and it may be a promising alternative for its application at the production level.

INTRODUCTION

Despite the economic crisis that Brazil has suffered in recent years, the broiler industry has continued to grow, according to data from the Brazilian Animal Protein Association (BAPA) (2016). In the period from 2014 to 2015, increases in production, exportation, and consumption of chicken meat averaged at 3.5%, 5%, and 1.1%, respectively. This behavior provided the country with a privileged position in the international market as the second largest in poultry production and the first in exportation (BAPA, 2016). Such progress is a product of the scientific and technological contributions of different areas of study. Nutrition is directly related to this development and may be the area with the greatest impact on production profitability, deserving constant concern to precisely meet the nutritional requirements of birds (Tavernari *et al.*, 2014).

The nutritional requirements represent the daily amounts of nutrients that the animal must ingest in the diet in order to meet its maintenance and production needs (Gallardo *et al.*, 2014). The levels of nutritional imbalance, associated with nutrient deficiency or excess, can lead to increases in consumption, decreased growth, weight loss, and additional energy expenditure (metabolic caloric increment) due to the need to excrete the excess nutrients (Buteri *et al.*, 2009; NRC, 1994; Rostagno *et al.*, 2007; Toledo *et al.*, 2007). Therefore, knowledge of the nutritional requirements of birds enables the efficient use of feed.

However, in order for feed improvement and to change the nutritional levels of the diets, it is necessary to take the interference of the bird's sex into account, since each sex exhibits differentiated metabolic behavior. In other words, the male chicken may require higher amounts of nutrients, in comparison to the female, due to its greater growth capacity (more significant body weight gain), which will be represented in greater absolute weights for eviscerated carcass, thigh, drumstick and, in some cases, larger absolute weights of breast with bone and breast fillet (Sá *et al.*, 2012; Bernal *et al.*, 2014; Tavernari *et al.*, 2014).

It is known that researchers and producers are interested in adjusting nutritional feed density to allow the attendance of the nutritional needs of chickens according to sex, but also aiming at maximum productive performance with minimum production costs. According to Cias/Embrapa (2016), production expenses increased by 14.34% in comparison to December 2015, with feed costs being primarily accountable for this increase (12.33%). Therefore, the objective of the present study was to assess the productive behavior of male and female chickens applying different nutritional levels, and their adaptability to achieve optimum nutrient utilization at lower production costs.

MATERIAL AND METHODS

The experiment was conducted in the Metabolism Aviary of the Poultry Laboratory at the Faculty of Animal Science and Food Engineering at the University of São Paulo (FZEA/USP). This experimental study was conducted in accordance with Brazilian guidelines, based on the Federal Law No. 11,794 of October 8th, 2008, and approved by the Research Ethics Committee - CEP / FZEA / USP, process number 3979011015.

A total of 180 one day-old COBB-500™ chicks, of which 90 were male (initial weight of 49.87 ± 1.07 g) and 90 were female (initial weight of 49.32 ± 1.74 g), were used in the experiment, housed in metal batteries (36 galvanized wire cages, measuring 90 x 70 x 50 cm) and distributed in a completely randomized 2 x 3 factorial design: sex (male and female) and diets (male, female and mixed), totaling 6 treatments and 6 repetitions of 5 birds each. The facilities provided nipple-type drinkers, 250 Watt lamps, infant and gutter-type feeders, a thermo-hygrometer (reading was performed daily, in the morning and afternoon), fans and foggers. The set lighting program was 23:1 (23 hours light and 1 hour dark), except for the first week (24 hours of light), shown in Figure 1.

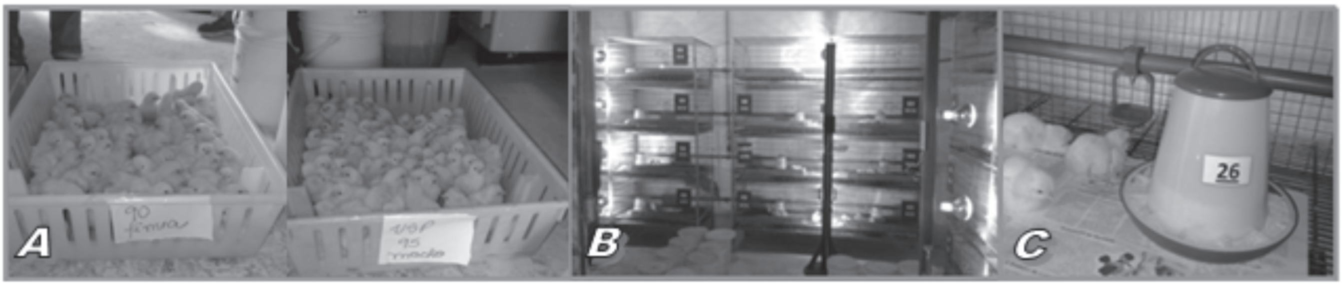

Figure 1 – Male and female Chicks (A), metal batteries, lamps and intern view of the aviary (B), Infant feeders and nipple-type drinkers (C).

The experimental diets were formulated using corn and soybean meal. Dietary composition was calculated according to the nutritional levels recommended in the Brazilian Tables for Poultry and Swine (Rostagno *et al.*, 2011) for the pre-starter (1 to 7 days), starter (8 to 21 days), grower (22 to 34 days) and finisher (35 to 42 days) phases, as shown in Table 1.

Birds, experimental diets and feed leftovers were weighed weekly, and feed intake (FI) was determined considering the number of birds, corrected for mortality (Sakomura & Rostagno, 2007), weight gain (WG), feed conversion (FC) and flock viability (FV = 100% - % mortality, in which the % of mortality was obtained by subtracting the number of housed birds by the dead poultry, or those that were withdrawn, divided by the total number of housed birds, multiplied by 100). Next, the European index of production efficiency was determined; PEI= [(average daily weight gain × VF) / (feed conversion × 10)]. At 37 days of age, the digestibility assay was conducted, using the total excreta collection method. The assay was carried out for five days; the first for the preparation of labeled feed (adding 1.0% ferric oxide) and collecting trays (plastic coating of the trays), and four days to harvest excreta, according to Sakomura & Rostagno (2007).

Table 1 – Percentage and calculated composition of experimental diets.

Ingredient (%)	Diets											
	1 to 7 days			8 to 21 days			22 to 34 days			35 to 42 days		
	M	F	MI	M	F	MI	M	F	MI	M	F	MI
Corn (7.88%)	58.55	60.15	59.38	60.87	62.45	61.80	63.70	66.01	64.81	66.36	70.33	69.18
Soybean meal (45%)	35.58	34.18	34.86	32.70	31.46	31.87	29.08	27.50	28.34	26.52	23.79	24.43
Dicalcium phosphate	1.93	1.93	1.93	1.57	1.55	1.56	1.34	1.23	1.28	1.11	0.93	1.03
Soybean oil	1.32	1.01	1.15	2.36	2.05	2.16	3.47	3.03	3.27	3.74	3.00	3.21
Limestone	0.81	0.81	0.82	0.86	0.85	0.85	0.82	0.78	0.80	0.74	0.67	0.71
Salt	0.46	0.46	0.45	0.43	0.40	0.42	0.41	0.40	0.40	0.40	0.37	0.39
L-lysine HCl	0.39	0.46	0.43	0.34	0.36	0.36	0.34	0.29	0.32	0.33	0.24	0.31
DL-methionine	0.37	0.39	0.38	0.32	0.32	0.32	0.30	0.25	0.25	0.27	0.19	0.23
L-threonine	0.16	0.18	0.17	0.12	0.13	0.23	0.11	0.08	0.10	0.10	0.05	0.08
Supplement [1,2]	0.40	0.40	0.40	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	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	100.00	100.00	100.00
ME and Calculated nutrient composition (%)												
ME (kcal kg^{-1})	2960	2960	2960	3050	3050	3050	3150	3150	3150	3200	3200	3200
Crude Protein	22.40	22.00	22.20	21.20	20.80	21.00	19.80	19.20	19.50	18.40	17.80	18.10
Dig. Lysine	1.32	1.34	1.33	1.22	1.20	1.21	1.13	1.06	1.09	1.06	0.93	1.00
Dig. Met+cys	0.95	0.97	0.96	0.88	0.86	0.87	0.83	0.77	0.80	0.77	0.68	0.73
Dig. Methionine	0.67	0.68	0.68	0.60	0.59	0.60	0.57	0.52	0.54	0.52	0.44	0.48
Dig. Threonine	0.86	0.87	0.87	0.79	0.78	0.79	0.74	0.69	0.71	0.69	0.61	0.65

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

[1]Vitamin, mineral, and additive supplementation per kilogram of feed (used in 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; A Vitamin (min) 2000000.00 IU; B1 Vitamin (min) 600.00 mg; B12 Vitamin (min) 3500.00 mcg; B2 Vitamin (min) 1500.00 mg; B6 Vitamin (min) 1000.00 mg; D3 Vitamin (min) 600000.00 IU; E Vitamin (min) 3000.00 IU; K3 Vitamin (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 in the period from 22 to 42 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; A Vitamin (min) 1500000.00 UI; B1 Vitamin (min) 350.00 mg; B12 Vitamin (min) 2500.00 mcg; B2 Vitamin (min) 1000.00 mg; B6 Vitamin (min) 500.00 mg; D3 Vitamin (min) 500000.00 UI; E Vitamin (min) 2500.00 UI; K3 Vitamin (min) 400.00 mg; Zinc (min) 12.50 g; Virginiamycin 4125.00 mg; Salinomycin 16.50 g.

Excreta samples were collected twice a day, at dawn and dusk, during the four days. The samples were placed in labeled plastic pots, after disposing the unmarked excreta from the first harvest and those marked during the last harvest on the fourth day. Afterwards, they were weighed and placed in a freezer (-18 to -22°C) until the end of the harvest period.

At the end of the digestibility assay, quantities of feed intake and total produced excreta were determined. After thawing at room temperature, excreta of each repetition were homogenized for posterior removal of a 400 g sample, which was placed in a forced ventilation oven at 55°C for 72 hours, in order to promote pre-drying and determine the weight of air-dried samples. Next, the air-dried samples were weighed and processed in a knife-type mill with a 1 mm sieve, according to the procedures described by Sakomura *et al.* (2004). Subsequently, the samples were sent to the laboratory, along with samples of the experimental diets, to determine dry matter (DM) in an oven at 105°C, until constant weight; crude protein (CP- nitrogen) by the Kheldahl method; and gross energy (GE) using an IKA C200 calorimeter, according to the methodology described by Silva & Queiroz (2009).

Based on the results of DM, CP and GE, the apparent digestibility coefficients of the diets were calculated [ADC (%) = (Nutrient intake - Excreted nutrient) * 100 / Nutrient intake] and the variables were expressed in units per mass unit (Lara *et al.*, 2013).

The animals were slaughtered at 42 days of age at the PUSP-FC Slaughterhouse, according to Caetano *et al.* (2015). On bird per experimental unit was selected at random, totaling 36 birds, which were individually weighed, marked with a leg ring, and then subjected to a food fasting period of ten hours. After this period, each bird was stunned by electroshock, bled by cross sectioning of the jugular vein, scalded, plucked, cleaned, eviscerated and cooled by air in chambers, after the removal of abdominal fat (fat attached to the abdominal wall and gizzard). After the cooling period, the carcass cuts were obtained: breast fillet, thigh, drumstick and wing. The carcass yield was calculated by the ratio of the eviscerated carcass mass by live body weight [% carcass yield = (carcass weight * 100 / live body weight)]; and the cut yields, calculated in function of the weight of the eviscerated carcass by the feet, head and neck [% cut yield = (Cut weight * 100) / carcass weight] (Mendes *et al.*, 2004).

During the economic analysis, the gross income (GI), the total cost of feed (TCF) and the gross trade margin (GM) were assessed. The TCF was calculated using the diet cost and the feed intake for each treatment. To calculate the cost of the diet, the quantities of ingredients were multiplied by their average price per kilogram (surveyed in the Brazilian market in August 2015 - Table 2).

Table 2 – Price of the live chicken and ingredients used in the feed formulation in August 2015.

Ingredient	Price per kilogram (R$.kg^{-1})
Corn[1]	0.56
Soybean meal 45% [2]	1.12
Soybean oil[2]	3.40
Salt[2]	0.68
Live chicken [2]	2.50
Dicalcium phosphate[3]	2.07
Limestone[3]	0.15
Vitamin and Mineral Supplement[3]	11.98
L-lysine HCl[3]	5.87
DL-methionine[3]	23.40
L-threonine[3]	10.20
Choline chloride 70%[3]	3.27

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

After determining the TCF, the gross income (GI) was calculated, which is determined by the sales cost of the product in the market, multiplied by the amount of product sold (weight of live chicken) (Nascimento *et al.*, 1998). The gross trade margin (GM) is a measurement that represents producer profitability, and is obtained by the difference between gross income (GI) and the total cost of feed (TCF) (Gameiro, 2009).

The results for performance, carcass characteristics, digestibility and economic analysis were submitted to variance analyses (ANOVA), using the GLM procedure (General Linear Model) of the SAS statistical system program for Windows 9.0 (Copyright(c) 2002), and means were compared by the Tukey test, at 5% probability.

RESULTS AND DISCUSSION

The performance results for the period from 1 to 41 days of age of the birds are shown in Table 3.

There was significant difference (p<0.05) regarding the sex factor, in which the male broiler presented the highest body weight (BW), WG and PEI, and lower FC rate when compared to results obtained from the females. However, there was no significant difference for sex (p>0.05) regarding flock viability. In this period, an interaction (p<0.05) between factors (sex and diet) was observed in the feed intake (Table 4), with males consuming diets in greater proportion (around 9.3% more) than females. Similar results were reported by Costa *et al.* (2001); Mendes *et al.* (2004); Sabino *et al.* (2004); Kolling *et al.* (2005); Lima *et al.* (2008); Bernal *et al.* (2014) and Tavernari *et al.* (2014), who, when evaluating diets with different levels of crude protein, energy and amino acids in the finisher phase, observed differences regarding sex, in which male broilers showed best performance.

Table 3 – Performance results of broiler chickens for the period from 1 to 41 days old.

Factors	FI[1]	BW	WG	FC	VF	PEI
Sex (S)						
Male	4658.25	2874.61a	2824.74a	1.63b	93.33	393.03a
Female	4221.99	2549.10b	2499.78b	1.67a	97.78	357.00b
Diets (D)						
Male	4344.28	2653.65b	2604.21b	1.64	95.00	365.66
Female	4537.69	2772.71a	2722.96a	1.65	93.33	374.39
Mixed	4438.39	2709.22ab	2659.62ab	1.65	98.33	385.00
ANOVA			Probability			
S	<0.0001	<0.0001	<0.0001	0.0054	0.1777	0.0063
D	0.0441	0.0281	0.0286	0.4920	0.4444	0.4453
Interaction S x D	0.0225	0.0981	0.0998	0.5733	0.4444	0.7795
CV[2] (%)	4.05	3.79	3.86	2.06	10.11	9.81

FI (g)- Feed intake; BW (g)- Body weight; WG (g)- Weight gain; FC- Feed conversion; VF- Flock viability; PEI- Index of production efficiency.

Means followed by the same letter in each column and each factor do not differ by Tukey test (p<0.05).

[1]Significant interaction between factors (sex and diet), shown in Table 4.

[2]Coefficient of variation.

Table 4 – Significant interaction for feed intake (g) of broiler chickens (1 to 41 days old).

	Diets (D)		
Sex (S)	Male	Female	Mixed
Male	4685.80Aa	4679.60Aa	4609.33Aa
Female	4002.80Bb	4395.78Ab	4267.44ABb

Means followed by the same lowercase letters do not differ in columns and same capital letters do not differ on the lines by Tukey test ($p<0.05$).

According to Leeson & Summers (2005), during the first 20 days of age, male and female broilers consume almost identical quantities of feed, thus having similar growth, and after this period, differential growth between sexes occurs, as a consequence of increased feed intake by males. Kessler & Brugalli (1999) and Sabino *et al.* (2004) verified that males have a higher daily rate of protein retention, when compared to females, and thus require higher amounts of nutrients to supply this increased growth potential.

The nutrient levels of diets showed effects ($p<0.05$) on BW and WG, and the highest results were obtained with the female diet and the mixed diet, followed by the male diet. Regarding the other characteristics, FC, FV and PEI, nutritional levels of the diets did not differ ($p>0.05$).

Male FI showed no statistical difference ($p>0.05$) regarding the diets (Table 4). In accordance with this result, Borges *et al.* (2002); Amarante Jr. *et al.* (2005); Trindade Neto *et al.* (2011); Duarte *et al.* (2012) and Ospina-Rojas *et al.* (2014) did not observe any effects of different amino acid levels in the diet (lysine, methionine+cystine and threonine) on the FI of male broilers. However, Kamran *et al.* (2008) and Ghahri *et al.* (2010), when assessing diets with different levels of crude protein and metabolizable energy, observed effects on the FI and reported that consumption is increased when CP and ME levels are reduced in the diet. Therefore, in this study, the behavior displayed by males might be due to an insufficient capacity of nutrient levels to alter appetite mechanisms.

Considering the interaction between diets and females on feed intake, significance was determined ($p<0.05$), in which, while the nutrient levels in the diets increased, food consumption decreased. Leeson & Summers (2005) and Silva Jr. *et al.* (2005) described this behavior as the ability that broiler chickens have in adjusting consumption, and may lead to reductions in feed intake, due to the inclusion of energy and amino acids beyond their nutritional requirements.

According to Kessler & Brugalli, (1999) and Macari *et al.* (2002), as the female broiler grows, nutrient requirements are smaller for retention (gain) of lean tissue, and, as a result, the consumption of diets will aim at satisfying the nutrient demand for the attendance and repair of protein expense in the body.

Concerning carcass yield results (Table 5), there was no difference ($p>0.05$) among the factors, i.e., regardless of their diets and nutritional levels, similar behaviors were reported for males and females. Costa *et al.* (2001); Almeida *et al.* (2002); Mendes *et al.* (2004); Bernal *et al.* (2014) and Tavernari *et al.* (2014) confirmed this result, having reported that male and female chicken carcass yields were not influenced by the nutritional levels of treatments (changes in ME, CP, and AA). Significant effects regarding carcass yield were shown by Sabino *et al.* (2004) and Lima *et al.* (2008), indicating that the carcass yield can improve with an increase in CP, or amino acid levels in the diet followed by average levels of energy, respectively.

Table 5 – Analysis of variance for carcass characteristics of broiler chickens at 42 days old.

Factors (%)	Carcass Yield	Breast fillet[1]	Thigh[2]	Drumstick	Wing	Abdominal fat
Sex (S)						
Male	80.66	28.92	12.20	15.74a	9.39	1.70b
Female	79.92	31.16	11.42	15.09b	9.45	2.22a
Diets (D)						
Male	80.32	30.18	11.92	15.07b	9.59a	1.61b
Female	80.27	29.82	11.69	15.45ab	9.56ab	2.00ab
Mixed	80.29	30.13	11.82	15.72a	9.16b	2.27a
ANOVA				Probability		
S	0.1212	0.0002	<0.0001	0.0039	0.5402	0.0023
D	0.9957	0.8358	0.5409	0.0484	0.0350	0.0065
Interaction S x D	0.9727	0.0327	0.0088	0.8697	0.9146	0.5690
CV[3] (%)	1.74	5.37	4.25	4.04	4.58	23.91

Means followed by the same letter in each column and each factor do not differ by Tukey test ($p<0.05$).

[1,2] Significant interaction between factors (sex and diet), shown in Table 6.

[3] Coefficient of variation.

Regarding the sex factor, results showed that males presented better yields for drumstick and abdominal fat when compared to females. In reference to the significant interaction regarding breast fillet and thigh yield (Table 6), females showed higher values for breast fillet and reduced thigh yields when compared to males, except in the mixed diet, since both sexes showed similar results. These results are in accordance with those reported by Mendes *et al.* (2004) and Lima *et al.* (2008), who suggested the influence of sex on thigh, drumstick and abdominal fat yield, with the males presenting higher results. Costa *et al.* (2001); Almeida *et al.* (2002) and Sabino *et al.* (2004) determined significant effect of sex on abdominal fat yield, with the females presenting higher percentages. Nevertheless, Silva Jr. *et al.* (2005, 2006) observed the effect of sex only on thigh and drumstick yield, with males presenting 9% more yield than females.

Table 6 – Significant interaction for breast fillet and thigh of broiler chickens at 42 days old.

	Breast fillet(%)			Thigh (%)		
	Diets			Diets		
Sex	Male	Female	Mixed	Male	Female	Mixed
Male	28.55Ab	28.15Ab	30.07Aa	12.24Aa	12.45Aa	11.90Aa
Female	31.81Aa	31.48Aa	30.20Aa	11.60Ab	10.94Ab	11.73Aa

Means followed by the same lowercase letters do not differ in columns and same capital letters do not differ on the lines by Tukey test ($p<0.05$).

The nutrient levels of the diets influenced ($p<0.05$) wing yields; with the male diet the best yields were achieved when compared to the mixed diet. Almeida *et al.* (2002) and Mendes *et al.* (2004) observed an opposite effect, since nutritional increase (ME and lysine) lead to a decrease in the wing yield.

In regard to the drumstick and abdominal fat yield, the influence ($p<0.05$) of the nutrient levels of the diets was observed; with the mixed diet presenting the highest percentages, and the male diet, smaller proportions. Previous studies by Costa *et al.* (2001); Mendes *et al.* (2004) and Silva Jr. *et al.* (2005, 2006) showed similar results to those suggested in the current study, regarding the influence of nutritional levels on abdominal fat yield. However, they reported that fat increases with the enhancement in dietary energy and reduces with the increase in CP and / or amino acids. Partially similar results were presented by Bernal *et al.* (2014) and Tavernari *et al.* (2014), who observed that the increase in amino acid levels lead to decreased abdominal fat in females, but were not able to prove the effect on males. Considering drumstick yield, Silva Jr. *et al.* (2005) and Bernal *et al.* (2014) reported similar results to the present study, when they verify that the increase in amino acid levels tends to lead to decreased drumstick yield.

An interaction ($p<0.05$) regarding breast fillet and thigh factors was observed (Table 6), however, during the unfolding, none were shown regarding nutritional levels on yields. Costa *et al.* (2001); Almeida *et al.* (2002); Mendes *et al.* (2004); Sabino *et al.* (2004); Silva Jr. *et al.* (2005, 2006) and Lima *et al.* (2008) also did not demonstrate any effect of different dietary levels of CP, ME, and amino acids on breast fillet and thigh yield. Nonetheless, Tavernari *et al.* (2014) presented divided results in comparison to the present study, since they showed no effect of different dietary amino acid levels on thigh yield, but observed an increase in female breast fillet yield with the increase of amino acid concentrations in the diet. Similarly, Bernal *et al.* (2014) reported that the increase in amino acid levels tended to lead to an increase in breast fillet yield in females, but no effect was demonstrated on males. Regarding thigh yield, the authors observed reduction with the increase in amino acids.

The results for the apparent digestibility coefficients of dry matter (ADCDM), crude protein (ADCCP) and gross energy (ADCGE) of broilers at 41 days of age are presented in Table 7.

Table 7 – Analysis of variance for broiler chickens digestibility coefficients at 41 days old.

Factors (%)	ADCDM	ADCCP [1]	ADCGE
Sex (S)			
Male	80.19	67.75	79.46
Female	80.75	67.17	79.92
Diets (D)			
Male	80.17	68.01	80.12a
Female	80.77	67.90	80.63a
Mixed	80.52	66.47	78.33b
ANOVA		Probability	
S	0.1154	0.4721	0.2012
D	0.3345	0.2342	<0.0001
Interaction S x D	0.2968	0.0400	0.1678
CV[2] (%)	1.19	3.58	1.34

ADCDM- apparent digestibility coefficients ofdry matter; ADCCP- apparent digestibility coefficients of crude protein; ADCGE- apparent digestibility coefficients of gross energy

Means followed by the same letter in each column and each factor do not differ by Tukey test ($p<0.05$).

[1]Significant interaction between factors (sex and diet), shown in Table 8.

[2]Coefficient of variation.

Concerning the DM digestibility coefficient, no effect (*p*>0.05) was observed for the studied factors (sex and diet), however difference (*p*<0.05) was shown regarding the GE digestibility coefficient on the diet factor, suggesting higher utilization of the male and female diets.

Regarding the CP digestibility coefficient, an interaction (*p*<0.05) was observed among the sex and diet factors (Table 8). While comparing the means of the interaction, no difference (*p*>0.05) was observed considering the sex factor in any of the diets. This data suggests that regardless of the supplied protein level, retention of this nutrient was statistically similar within each sex. However, difference was observed (*p*<0.05) regarding the different diets used for the males, demonstrating that the highest protein retention by males was obtained when they were fed with the diet for females, and lower retention of CP was obtained when the animals were fed with the diet for mixed sexes.

Table 8 – Significant interaction for the apparent digestibility coefficients of crude protein (%) of broiler chickens at 41 days old.

	Diets		
Sex	Male	Female	Mixed
Male	68.43ABa	69.45Aa	65.38Ba
Female	67.59Aa	66.35Aa	67.55Aa

Means followed by the same lowercase letters do not differ in columns and same capital letters do not differ on the lines by Tukey test (*p*<0.05).

Knowing that males given the mixed diet demonstrated similar feed consumption to the female diet and the male diet, but showed higher percentage of abdominal fat and lower retention of CP and GE, it is possible to suggest that the diet did not meet the requirements for the male chickens. These results are possibly due to nutritional imbalance and according to Kessler & Brugalli (1999), the excess or inadequate intake of feed, regarding lean tissue demand, leads to various levels of body fat deposition.

As evidenced with the DM, CP and GE digestibility coefficients, the female and male diets were considered the best alternatives to achieve proper utilization of nutrients in both sexes. However, because the female diet demonstrates excellent digestibility with lower nutrient levels, it becomes a more interesting and promising alternative.

The average ADCDM, ADCGE and ADCCP, regarding the female diet, corresponded to 80.77%; 80.63% and 67.90%, respectively. These results differed from those obtained by Lopez *et al.* (2007), who reported an ADCDM of 73.66% and an ADCCP of 62.77% in 1-to 42-day-old broilers, when using diets based on corn and soybean meal. Sakomura *et al.* (2004) verified the digestibility of broiler chickens from 36 to 42 days of age, using a diet consisting of 2930 kcal/kg of ME; 19.95% of CP; 1.05% Lysine; 0.90% Met+Cys; based on corn and soybean meal, and disagreed with the results in the present study, since they observed an ADCDM of 71.80%. Similarly, Sakomura & Rostagno (2016) also observed different results from the ones in the present study, having reported an average ADCDM and ADCCP of 72.60% and 62.96%, respectively, while conducting studies using the excreta sampling method. However, when Gerber *et al.* (2006) evaluated the digestibility of broilers from 39 to 42 days of age, using diets consisting of 46% corn and soybean meal, containing 3200 kcal/kg of ME; 19.12% of CP; 0.94% Lysine; 0.78% Met+Cys; they obtained similar results regarding the ADCGE (80.90%). However, their results differed in ADCDM (73.80%), due to lower dry material retention.

The parameters evaluated for the economic analysis of animals from 1 to 41 days of age are shown in Table 9. In the economic analysis, an effect (*p*<0.05) of the sex and diet factors was observed on the gross income and gross trade margin. Regarding the total cost of feed, a significant interaction was observed, shown in Table 10.

Table 9 – Economic viability for broiler chickens males and females at the stage from 1 to 41 days old.

Factors	TCF[1]	GI	GM
Sex (S)			
Male	4.38	7.05a	2.67a
Female	3.97	6.24b	2.27b
Diets (D)			
Male	4.15	6.50b	2.34b
Female	4.20	6.80a	2.60a
Mixed	4.18	6.64ab	2.46ab
ANOVA	Probability		
S	<0.0001	<0.0001	0.0008
D	0.8478	0.0286	<0.0001
Interaction S x D	0.0178	0.0998	0.9157
CV[2] (%)	4.06	3.86	5.95

TCF- Total cost of feed (R$); GI- Gross income (R$/chicken); GM- Gross trade margin (R$/chicken).

Means followed by the same letter in each column and each factor do not differ by Tukey test (*p*<0.05).

[1]Significant interaction between factors (sex and diet), shown in Table 10.

[2]Coefficient of variation.

Table 10 – Significant interaction for total cost of feed (R$) of broiler chickens at 41 days old.

	Diets		
Sex	Male	Female	Mixed
Male	4.48Aa	4.33Aa	4.34Aa
Female	3.83Ab	4.06Ab	4.02Ab

Means followed by the same lowercase letters do not differ in columns and same capital letters do not differ on the lines by Tukey test (p<0.05).

The results suggest that during male chicken rearing, feed expenses are higher due to greater feed consumption; however, the increased intake resulted in higher weight gain, which enabled increases in gross income and gross trade margins.

When the diets were fed to the birds, no differences between male and female feed costs were observed. Regarding gross income (GI) and gross trade margin (GM), the greatest monetary results were shown using the female diet, and lowest using the male diet. In other words, the female diet, when given to the birds, provided greater weight gain, which is directly related to the sale price, increasing economic returns.

ACKNOWLEDGEMENTS

We thank CAPES (Brazil), for the scholarship, and the University of São Paulo - Faculty of Animal Science and Food Engineering, for the contributions in the development of this research.

CONCLUSIONS

The female diet was sufficient to meet the nutritional requirements of males and females, as it endowed improved performance and digestibility, which provided consistent results with intermediate income for breast fillet, leg, wing and abdominal fat, when compared to the other diets. In addition, by improving the performance of the birds, the female diet provided the highest gross income and gross margin, which represents the economic return.

The sex of the animal is a factor that affects performance, carcass characteristics and economic viability. Emphasis should be given to the male broiler, since it showed better performance, greater leg yields and lower percentages of abdominal fat. In the economic level, despite presenting higher feed costs, the male provided the highest returns (higher gross margin), due to its greater weight gain, leading to improved remuneration.

REFERENCES

ABPA - Associação Brasileira de Proteína Animal. Relatório anual 2015 [cited 2015 Mar 12]. Available from: http://abpa-br.com.br/setores/avicultura/publicacoes/relatorios-anuais.

Almeida ICL, Mendes AA, Oliveira EG, Garcia RG,Garcia EA. Efeito do nível de lisina da dieta e do sexo sobre o desempenho e rendimento de carcaça de frangos de corte. Revista Brasileira de Ciência Avícola 2002;4(1):1-8.

Amarante Junior VS, Costa FGP, Barros LR, Nascimento GAJ, Brandão PA, Silva JHV, *et al.* Níveis de metionina + cistina para frangos de corte nos períodos de 22 a 42 e de 43 a 49 dias de idade. Revista Brasileira de Zootecnia 2005 34(4):1195-1201.

Bernal LEP, Tavernari FC, Rostagno HS, Albino LFT. Digestible lysine requirements of broilers. Brazilian Journal of Poultry Science 2014;16(1):49-55.

Borges AF, Oliveira RFM, Donzele JL, Orlando UAD, Ferreira RA, Saraiva EP. Exigência de lisina para frangos de corte machos no período de 22 a 42 dias de idade, mantidos em ambiente quente (26ºC). Revista Brasileira de Zootecnia 2002;31(5):1993- 2001.

Caetano VC, Faria DE, Caniatto ARM, Faria Filho DE, Nakagi VS. Desempenho e rendimento de carcaça em frangos de corte de um a 46 dias alimentados com dietas contendo diferentes níveis de valina e reduzido teor proteico. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2015;67(6):1721-1728.

CEPEA - Centro de Estudos Avançados em Economia Aplicada. Indicadores de preços 2015 [cited 2015 Ago 05]. Piracicaba: ESALQ/USP; 2015. Available from: http://cepea.esalq.usp.br.

CIAS - Central de Inteligência de Aves e Suínos. Índice de custos de produção de frangos [cited 2016 Mar 20]. Concórdia: Embrapa Suínos e Aves; 2016. Available from: http://www.cnpsa.embrapa.br/cias/index.php?option=com_content&view=article&id=278.

Costa FGP, Rostagno HS, Albino LFT, Gomes PC, Toledo RS, Vargas Junior JG. Níveis dietéticos de proteína bruta para frangos de corte de 1 a 21 e 22 a 42 dias de idade. Revista Brasileira de Zootecnia 2001;30(5):1498-1505.

Duarte KF, Junqueira OM, Filardi RS, Siqueira JC, Garcia EA, Laurentiz AC. Exigências em treonina para frangos de corte de 2 2 a 4 2 dias de idade. Revista Brasileira de Zootecnia 2012;41(1):72-79.

Gameiro AH. Avaliação econômica aplicada à zootecnia: avanços e desafios. In: Santos MV, Prada e Silva LF, Renno FP, Albuquerque R, editors. Novos desafios da pesquisa em nutrição e produção animal. Pirassununga: Editora 5D; 2009. p.9-32.

Gerber LFP, Penz Júnior AM, Ribeiro AML. Efeito da composição do farelo de soja sobre o desempenho e o metabolismo de frangos de corte. Revista Brasileira de Zootecnia 2006;35(4):1359-1365.

Ghahri H, Gaykani R,Toloie T. Effect of dietary crude protein level on performance and lysine requirements of male broiler chickens. African Journal of Agricultural Research 2010;5(11):1228-1234.

IEA - Instituto de Economia Agrícola. Banco de dados, preços agrícolas [cited 2015 Ago 05]. São Paulo: Secretaria de agricultura e abastecimento; 2015. Available from: http://www.iea.sp.gov.br/out/bancodedados.html.

Kamran Z, Sarwar M, Nisa M, Nadeem MA, Mahmood S, Babar ME, *et al.* Effect of low-protein diets having constant energy-to-protein ratio on performance and carcass characteristics of broiler chickens from one to thirty-five days of age. Poultry Science 2008;87(3):468-474.

Kessler AM, Brugalli I. Recentes avanços do efeito da nutrição no crescimento especifico de componentes da carcaça de frangos de corte [documentos, 58]. Anais do Simpósio Internacional sobre Tecnologia de Processamento e Qualidade da Carne de Aves; 1999; Concórdia, Santa Catarina. Brasil: Embrapa-CNPSA; 1999. p.1-19.

Kolling AV, Kessler AM, Ribeiro AML. Desempenho e composição corporal de frangos de corte alimentados com diferentes níveis de proteína e de aminoácidos ou com livre escolha das dietas. Revista Brasileira de Zootecnia 2005;34(1):98-103.

Lara LJC, Campos WE, Baião NC, Lana AMQ, Cançado SV, Rocha JSR, *et al.* Efeitos da forma física da ração e da linhagem de frangos de corte sobre a digestibilidade dos nutrientes e determinação de energia líquida. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 2013;65(6):1849-1857.

Leeson S, Summers JD. Commercial poultry nutrition. 3rd ed. Ontario: University Books; 2005. 398 p.

Lima LMB, Lara LJC, Baião NC, Cançado SV, Michell BC, Ferreira FC. Efeitos dos níveis de energia, lisina e metionina + cistina sobre o desempenho e o rendimento de carcaça de frangos de corte. Revista Brasileira de Zootecnia 2008;37(8):1424-1432.

Lopez CAA, Baião NC, Lara LJC, Rodriguez NM, Cançado SV. Efeitos da forma física da ração sobre a digestibilidade dos nutrientes e desempenho de frangos de corte. Arquivo Brasileiro Medicina Veterinária e Zootecnia 2007;59(4):1006-1013.

Macari M, Furlan RL, Gonzáles E. Fisiologia aviária aplicada a frangos de corte. Jaboticabal: FUNEP; 2002. 375 p.

Mendes AA, Moreira J, Oliveira EG, Garcia EA, Almeida MIM, Garcia RG. Efeitos da energia da dieta sobre desempenho, rendimento de carcaça e gordura abdominal de frangos de corte. Revista Brasileira de Zootecnia 2004;33(6):2300-2307.

Nascimento AH, Gomes PC, Rostagno HS, Albino FT, Gomes MFM, Runho RC. Uso do farelo de canola em rações para frangos de corte. Revista Brasileira de Zootecnia1998;27(6):1168-1176.

Ospina Rojas IC, Murakami AE, Eyng C, Picoli KP, Scapinello C, Duarte CAR. Threonine-lysine ratio on the requirements of digestible lysine in diets for broilers. Acta Scientiarum 2014;36(2):157-16 2.

Rostagno HS, Albino LFT, Donzele JL, Gomes PC, Oliveira RF, Lopes DC, *et al.* Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais. 3rd ed. Viçosa: Departamento de Zootecnia, Universidade Federal de Viçosa; 2011. 252p.

Sá L, Nogueira E, Goulart C, Costa FP. Aminoácidos na nutrição de frangos de corte [cited 2016 Fev 10]. Limeira: Ajinomoto; 2012. Available from: http://www.lisina.com.br/publicacoes_detalhes.aspx?id= 2189.

Sabino HFN, Sakomura NK, Neme R, Freitas ER. Níveis proteicos na ração de frangos de corte na fase de crescimento. Pesquisa Agropecuária Brasileira 2004;39(5):407-412.

Sakomura NK, Bianchi M, Pizauro Junior JM, Café MB, Freitas ER. Efeito da idade dos frangos de corte sobre a atividade enzimática e digestibilidade dos nutrientes do farelo de Soja e da Soja Integral. Revista Brasileira de Zootecnia 2004;33(4):924-935.

Sakomura NK, Rostagno HS. Métodos de pesquisa em nutrição de monogástricos. Jaboticabal: Funep; 2007. 283p.

Sakomura NK, Rostagno HS. Métodos de pesquisa em nutrição de monogástricos. 2nd ed. Jaboticabal: Funep; 2016. cap.1, p.1-31.

Silva DJ, Queiroz AC. Análise de alimentos: Métodos químicos e biólogicos. 3rd ed. Viçosa: Universidade Federal de Viçosa; 2009. 235p.

Silva Junior RGC, Lana GRQ, Rabello CBV, Barboza WA, Lana SRV. Exigências de metionina + cistina para frangos de corte machos de 1 a 21 e de 22 a 42 dias de idade, em clima tropical. Revista Brasileira de Zootecnia 2005;34(6):2399- 2407.

Silva Junior RGC, Lana GRQ, Rabello CBV, Lana SRV, Barboza WA. Exigências de metionina + cistina para frangos de corte fêmeas de 1 a 21 e de 22 a 42 dias de idade criados em região de clima tropical. Revista Brasileira de Zootecnia 2006;35(2):497-503.

Tavernari FC, Bernal LEP, Rostagno HS, Albino LFT, Vieira RA. Relação metionina + cistina / lisina digestível para frangos de corte Cobb. Revista Ceres 2014;61(2):193-201.

Trevisan RB, Nakagi VS, Bravo PT, Faria DE. Feeding programs and their effects on broiler performance and economic indexes. Journal of Applied Poultry Research 2014;23:593–604.

Trindade Neto MA, Toledo AL,Takeara P, Kobashigawa E, Donato DCZ, Albuquerque R. Dietary levels of lysine for male broilers from 23 to 36 days of age: performance and body composition. Revista Brasileira de Zootecnia 2011;40(3):609-615.