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Níveis de lisina digestível para aves caipira Caneludos do Catolé de 1 a 105 dias de idade

Levels of digestible lysine for free-range chicken of the Caneludo Catolé from 1 to 105 days of age

Niveles de lisina digerible para aves de corral del Caneludo Catolé de 1 a 105 días de edad

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Resumo

Objetivou-se determinar níveis de lisina digestível para aves caipira Caneludo do Catolé machos e fêmeas, durante as fases, inicial, crescimento e terminação. Utilizou-se 150 aves confinadas. Os níveis de lisina digestível avaliados por fase foram: inicial 0.856; 0.978; 1.100; 1.223 e 1.345%, crescimento 0.705; 0.806; 0.906; 1.007 e 1.108% e terminação 0.624; 0.713; 0.802; 0.891; e 0.980 %, perfazendo 5 tratamentos, três repetições e 10 aves por unidade experimental em delineamento inteiramente casualizado. Parâmetros avaliados: Desempenho: consumo de ração, ganho de peso e conversão alimentar; Características de carcaça: rendimento de carcaça, peito, coxa, sobrecoxa, asa, pescoço, dorso, pé, moela, fígado e coração; Qualidade da carne: pH, força de cisalhamento (kgf/g), perda de peso por cozimento (%). Observou-se na fase inicial efeito quadrático ($P<0.01$) no ganho de peso 1.225% e conversão alimentar 1.175% lisina digestível. Na fase crescimento os níveis de lisina digestível demonstraram efeito linear crescente o consumo de ração ($P<0.05$) e ganho de peso ($P<0.01$) e linear decrescente ($P<0.01$) a conversão alimentar. Na fase final o consumo de ração aumentou linearmente ($P<0.05$), o ganho de peso e conversão alimentar responderam de forma quadrática ($P<0.01$) atingindo 0.757 e 0.713%. Respostas lineares crescentes foram observadas rendimentos de carcaça (%), peito ($P<0.05$) e sobrecoxa ($P<0.01$). O pH do peito apresentou efeito linear crescente ($P<0.01$), a força de cisalhamento e perda de peso por cozimento apresentaram efeito linear decrescente ($P<0.01$) com o aumento dos níveis de lisina digestível. Recomenda-se níveis de lisina digestível para as fases inicial 1.175%, crescimento 1.108% e terminação 0.713%.

Palavras-chave: Aminoácidos; Rendimento de carcaça; Qualidade da carne; Necessidade nutricional; Desempenho zootécnico.

Abstract

Determine levels of digestible lysine for free-range chicken of the Caneludo Catolé, during the initial, growth and termination phases. Were used150 male and female poultry in confinement cages. The digestible lysine levels used per phase: initial (1-30 dias) 0.856, 0.978, 1.100, 1.223, 1.345%, growth (30-75 dias) 0.705, 0.806, 0.906, 1.007, 1.108% and termination (75-105 dias) 0.624, 0.713, 0.802, 0.891, 0.980%. Five treatments, three replicates, 10 chickens per experimental unit, distributed in a completely randomized design. Parameters of zootechnical evaluated: feed intake, weight gain, feed conversion ratio. The carcass characteristics evaluated: carcass, breast, drumstick, thigh, wing, neck, back, foot, gizzard, liver and heart yields. Meat quality evaluated: pH, shear force (kgf/g), cooking weight loss (%).The levels of digestible lysine influence in the initial phase with quadratic effect ($P<0.01$) in weight gain 1.225% and feed conversion ratio 1.175%. In the growth phase digestible lysine had a positive linear on feed intake (P<0.05) and weight gain (P<0.01) and linear decrease (P <0.01) for feed conversion ratio. In the termination phase, feed intake linearly increased (P<0.05), weight gain and feed conversion were quadratic (P<0.01), with levels calculated as 0.757 and 0.713%, respectively. Increasing linear responses were observed for carcass (%), breast (P<0.05) and drumstick (P<0.01) yields. The pH of the breasts showed a linear increasing effect (P<0.01), while shear force and cooking weight loss had a linear decreasing effect (P <0.01) with the increase of digestible lysine levels. The levels of digestible lysine recommended per phases: 1.175% initial, 1.108% growth and 0.713% termination.

Keywords: Amino acids; Carcass yield; Meat quality; Nutritional requirement; Zootechnical performance.

Resumen

El objetivo fue determinar los niveles de lisina digestible para las aves de corral de Caneludo do Catolé machos y hembras, durante las fases, inicial, crecimiento y terminación. Se utilizaron 150 aves confinadas. Los niveles de lisina digestible evaluados por fase fueron: inicial 0.856; 0.978; 1.100; 1,223 y 1,345%, crecimiento 0.705; 0,806; 0,906; 1,007 y 1,108% y terminación 0.624; 0,713; 0,802; 0,891; y 0.980%, que comprende 5 tratamientos, tres repeticiones y 10 aves por unidad experimental en un diseño completamente al azar. Parámetros evaluados: Rendimiento: consumo de alimento, aumento de peso y conversión de alimento; Características de la canal: rendimiento de la canal, pecho, muslo, muslo, ala, cuello, espalda, pie, molleja, hígado y corazón; Calidad de la carne: pH, fuerza de corte (kgf / g), pérdida de peso al cocinar (%). Observó en la fase inicial, un efecto cuadrático (P <0.01) en el aumento de peso 1,225% y conversión alimenticia del 1,175% de lisina digestible. Fase de crecimiento, los niveles de lisina digestible mostraron un efecto lineal creciente sobre la ingesta de alimento (P <0.05) y el aumento de peso (P <0.01) y la disminución de la conversión alimenticia lineal (P <0.01). En la fase final, el consumo de alimento aumentó linealmente (P <0.05), el aumento de peso y la conversión de alimento respondieron de manera cuadrática (P <0.01) alcanzando 0.757 y 0.713%. Se observaron respuestas lineales crecientes para los rendimientos de carcasa (%), pecho (P <0.05) y muslo (P <0.01). El pH de la mama mostró un efecto lineal creciente (P <0.01), la fuerza de corte y la pérdida de peso al cocinar mostró un efecto lineal decreciente (P <0.01) con el aumento en los niveles de lisina digestible. Se recomiendan niveles de lisina digeribles para las fases iniciales 1.175%, crecimiento 1.108% y terminación 0.713%.

Palabras clave: Aminoácidos; Rendimiento en canal; Calidad de la carne; Necesidad nutricional; Rendimiento zootécnico.

1. Introduction

Slow-growing chicken have different nutritional requirements than poultry. As such, these chickens tend to respond differently to nutritional levels of diets. The nutritional requirements of amino acids found in the literature are mostly applied to commercial chicken; as the requirements found in the Brazilian Tables for Poultry and Swine presented by Rostagno etal. (2017), therefore, additional research is needed to estimate the levels of amino acids that are the most suitable for slow-growing chicken.

In order to adapt to the amino acid requirements of slow-growing poultry and to reduce the negative effects of excess amino acids in feed on reproductive and productive performance, being used according to Cardoso, 2017, the use of synthetic amino acids.

Another great advantage of the use of industrial amino acids is the possibility of establishing an ideal ratio between all amino acids in the diet by applying the concept of ideal protein, which entails the adequacy of the amino acid balance in order to meet the requirements of essential and non-essential amino acids. To this end, lysine is used as the reference amino acid in feed formulations (Santos, 2016) and the ratio between the other amino acids is defined by dividing the requirement value found for the different amino acids by the value of required lysine (Rostagno etal. (2017).

Lysine is classified as a nutritional reference because it is a strictly essential amino acid (Brasil et al., 2018) that is, its endogenous production takes place in insufficient quantities to maintain the adequate nitrogen balance for an optimal animal growth rate, making it indispensable to supply in feed. The techniques for laboratory determination of lysine levels in raw materials, feed and body tissues are accurate, and the knowledge of lysine requirements for nutrition at the different stages of poultry production have deepened (Bertechini, 2012).

Lysine-deficient diets may have negative effects on body protein deposition, directly affecting performance, carcass characteristics and body composition of chicken, as well as composition and total solid content of the eggs (Zhai et al., 2015; Lima et al., 2016).

According to Kidd & Kerr (1998), excess lysine promotes symptoms of arginine deficiency, an amino acid structurally related to lysine. This deficiency is caused by lysine-arginine competition for intestinal absorption sites and by their antagonism in the organism, since similar amino acids interact so that the excess of one raises the requirement of the other.

The aim of the study was to determine the levels of digestible lysine for free-range chicken of the Caneludo Catolé breed, in the initial (1 to 30 days), growth (30 to 75 days) and termination (75 to 105 days) phases.

2. Methodology

The project was approved by the Ethics Committee in the Use of Animals – CEUA / UESB, registered under no. 139/2016.

A total of 150 free-range poultry of the Caneludo Catolé were used. They were born in the hatchery of the Experimental Poultry Laboratory at the State University of the Southwest of Bahia (UESB), Itapetinga campus. The batch was composed of one-day old male and female free-range chicken which were followed up to determine digestible lysine levels in the initial (1 to 30 days), growth (30 to 75 days) and termination (75 to 105 days) phases of poultry raised in confinement.

The inclusion of feed for the initial phase began on day 1 and was maintained until day 30, when the initial diet was suspended to begin the weighing of the chicken and the feed provided. At 30 days of age, the feed for the growth phase was introduced at midday. This feed was supplied until the poultry reached 75 days of age. On that day, the growth-phase feed was suspended for weighing and, at midday, the diet for termination was introduced, which was maintained until 105 days of age, followed by slaughter.

The poultry were housed in a $2m^2$ cage, equipped with a bell jar containing 100W incandescent bulbs, a tubular feeder and a pendulum-type drinker. The bed was made of wood shavings, eight centimeters thick.

The diets were formulated following the recommendations made by Rostagno et al. (2011) for medium performance broilers (treatment 4). In the other experimental feeds, the levels of all amino acids were maintained according to Rostagno et al. (2011), modifying only digestible lysine levels, automatically changing the amino acids ratio. L-glutamic acid was used to render the feeds isoproteic. The dietary level of soybean oil and inertwas added to replace L-glutamic acid, thus maintaining the feeds isoproteic and isoenergetic.

Five levels of digestible lysine were used for each distinct phase of development of the free-range chicken Caneludo Catolé. In the initial phase, levels of digestible lysine were 0.856; 0.978; 1.100; 1.222 and 1.345% (Table 1), in the growth phase they were 0.705; 0.806; 0.906; 1.007 and 1.108% (Table 2) and in the termination phase they were 0.624; 0.713; 0.802; 0.891;

and 0.980% (Table 3). Thus, a total of five experimental diets with three replicates were applied to ten poultry per experimental unit, distributed in a completely randomized design.

Table 1. Composition percentage of the experimental feeds in the initial phase (1 to 30 days).

Ingredient (%)	Digestible Lysine (%)				
	0.856	0.978	1.100	1.223	1.345
Corn	65.80	65.80	65.80	65.80	65.80
Soybean meal 45%	28.25	28.25	28.25	28.25	28.25
Limestone	0.974	0.974	0.974	0.974	0.974
Dicalcium phosphate	1.748	1.748	1.748	1.748	1.748
Salt	0.494	0.494	0.494	0.494	0.494
dl-Met 99%	0.357	0.357	0.357	0.357	0.357
L-Thr 98,5%	0.176	0.176	0.176	0.176	0.176
L-Val	0.170	0.170	0.170	0.170	0.170
L-isoleuc	0.105	0.105	0.105	0.105	0.105
L-Trp 98%	0.007	0.007	0.007	0.007	0.007
Vitamin mix[1]	0.200	0.200	0.200	0.200	0.200
Mineral mix[2]	0.200	0.200	0.200	0.200	0.200
Antioxidant[3]	0.010	0.010	0.010	0.010	0.010
L-Lys HCl 99%	0.000	0.156	0.312	0.469	0.625
LGglutamic acid	1.028	0.771	0.514	0.257	0.000
Soybean oil	0.477	0.489	0.501	0.513	0.525
Inert[4]	0.000	0.088	0.177	0.266	0.355
Total	100	100	100	100	100
Calculated chemical composition					
CP (%)	19.90	19.90	19.90	19.90	19.90
Ca (%)	0.890	0.890	0.890	0.890	0.890
Available P (%)	0.427	0.427	0.427	0.427	0.427
ME (kcal/kg))	2952.5	2952.5	2952.5	2952.5	2952.5
Digestible Arg (%)	1.139	1.139	1.139	1.139	1.139
Digestible Ile (%)	0.820	0.820	0.820	0.820	0.820
Digestible Met (%)	0.622	0.622	0.622	0.622	0.622
Digestible Met + Cys (%)	0.881	0.881	0.881	0.881	0.881
Digestible Thr (%)	0.795	0.795	0.795	0.795	0.795
Digestible Trp (%)	0.208	0.208	0.208	0.208	0.208
Digestible Val (%)	0.942	0.942	0.942	0.942	0.942
Digestible Le (%)	1.550	1.550	1.550	1.550	1.550
Digestible Lys (%)	0.856	0.978	1.100	1.222	1.345
Na (%)	0.215	0.215	0.215	0.215	0.215
Cl(%)	0.341	0.341	0.341	0.341	0.341
K (%)	0.780	0.780	0.780	0.780	0.780

[1]Vitamin premix per kilogram of feed: vitamin A, 15 000 000 IU; vitamin D_3, 1 500 000 IU; vitamin E, 15 000 IU; vitamin B_1, 2.0 g; vitamin B_2, 4.0 g; vitamin B_6, 3.0 g; vitamin B_{12}, 0.015 g; nicotinic acid, 25 g; pantothenic acid, 10 g; vitamin K_3, 3.0 g; acido fólico, 1.0 g; Se, 250 mg. [2]Mineral premix per kilogram feed:Mn, 60 g; Fe, 80 g; Zn, 50 g; Cu, 10 g; Co, 2 g; I, 1 g.[3]Etoxiquim , [4]Sand. Source: Authors.

Table 2. Composition percentage of the experimental feeds for the growth phase (30 to 75 days)

Ingredient (%)	Digestible Lysine (%)				
	0.705	0.806	0.906	1.007	1.108
Corn	76.02	76.02	76.02	76.02	76.02
Soybean meal 45%	18.97	18.97	18.97	18.97	18.97
Limestone	0.893	0.893	0.893	0.893	0.893
Dicalcium phosphate	1.178	1.178	1.178	1.178	1.178
Salt	0.450	0.450	0.450	0.450	0.450
dl-Met 99%	0.280	0.280	0.280	0.280	0.280
l-Thr 98,5%	0.155	0.155	0.155	0.155	0.155
l-val	0.157	0.157	0.157	0.157	0.157
l-isoleuc	0.121	0.121	0.121	0.121	0.121
l-Trp 98%	0.026	0.026	0.026	0.026	0.026
Vitamin mix[1]	0.200	0.200	0.200	0.200	0.200
Mineral mix[2]	0.200	0.200	0.200	0.200	0.200
Antioxidant[3]	0.010	0.010	0.010	0.010	0.010
l-Lys HCl 99%	0.000	0.156	0.312	0.469	0.598
L-glutamic acid	0.851	0.638	0.425	0.212	0.000
Soybean oil	0.485	0.495	0.505	0.515	0.525
Inert[4]	0.000	0.046	0.093	0.139	0.213
Total	100	100	100	100	100
Calculated chemical composition					
CP (%)	17.78	17.78	17.78	17.78	17.78
Ca (%)	0.700	0.700	0.700	0.700	0.700
Available P (%)	0.313	0.313	0.313	0.313	0.313
ME (kcal/kg))	3075	3075	3075	3075	3075
Digestible Arg (%)	1.088	1.088	1.088	1.088	1.088
Digestible Ile (%)	0.685	0.685	0.685	0.685	0.685
Digestible Met (%)	0.508	0.508	0.508	0.508	0.508
Digestible Met + Cys (%)	0.735	0.735	0.735	0.735	0.735
Digestible Thr (%)	0.655	0.655	0.655	0.655	0.655
Digestible Trp (%)	0.181	0.181	0.181	0.181	0.181
Digestible Val (%)	0.786	0.786	0.786	0.786	0.786
Digestible Le (%)	1.350	1.350	1.350	1.350	1.350
Digestible Lys (%)	0.705	0.806	0.906	1.007	1.108
Na (%)	0.198	0.198	0.198	0.198	0.198
Cl(%)	0.316	0.316	0.316	0.316	0.316
K (%)	0.613	0.613	0.613	0.613	0.613

[1]Vitamin premix per kilogram of feed: vitamin A, 15 000 000 IU; vitamin D_3, 1 500 000 IU; vitamin E, 15 000 IU; vitamin B_1, 2.0 g; vitamin B_2, 4.0 g; vitamin B_6, 3.0 g; vitamin B_{12}, 0.015 g; nicotinic acid, 25 g; pantothenic acid, 10 g; vitamin K_3, 3.0 g; acido fólico, 1.0 g; Se, 250 mg. [2]Mineral premix per kilogram feed:Mn, 60 g; Fe, 80 g; Zn, 50 g; Cu, 10 g; Co, 2 g; I, 1 g.[3]Etoxiquim , [4]Sand. Source: Authors.

Table 3. Composition percentage of the experimental feeds for the termination phase (75 to 105 days).

Ingredient (%)	Digestible Lysine (%)				
	0.624	0.713	0.802	0.891	0.980
Corn	76.43	76.43	76.43	76.43	76.43
Soybean meal 45%	18.27	18.27	18.27	18.27	18.27
Limestone	0.769	0.769	0.7693	0.769	0.769
Dicalcium phosphate	0.897	0.897	0.897	0.897	0.897
Salt	0.430	0.430	0.430	0.430	0.430
dl-Met 99%	0.201	0.201	0.201	0.201	0.201
l-Thr 98,5%	0.087	0.087	0.087	0.087	0.087
l-val	0.075	0.075	0.075	0.075	0.075
l-isoleuc	0.054	0.054	0.054	0.054	0.054
l-Trp 98%	0.009	0.009	0.009	0.009	0.009
Vitamin mix[1]	0.200	0.200	0.200	0.200	0.200
Mineral mix[2]	0.200	0.200	0.200	0.200	0.200
Antioxidant[3]	0.010	0.010	0.010	0.010	0.010
l-Lys HCl 99%	0.000	0.114	0.228	0.342	0.456
L-glutamic acid	0.751	0.563	0.375	0.187	0.000
Soybean oil	1.614	1.623	1.632	1.641	1.649
Inert[4]	0.000	0.065	0.129	0.194	0.259
Total	100	100	100	100	100
Calculated chemical composition					
CP (%)	16.74	16.74	16.74	16.74	16.74
Ca (%)	0.582	0.5820	0.582	0.582	0.582
Available P (%)	0.260	0.260	0.260	0.260	0.260
ME (kcal/kg))	3150	3150	3150	3150	3150
Digestible Arg (%)	0.962	0.962	0.962	0.962	0.962
Digestible Ile (%)	0.606	0.606	0.606	0.606	0.606
Digestible Met (%)	0.426	0.426	0.426	0.426	0.426
Digestible Met + Cys (%)	0.650	0.650	0.650	0.650	0.650
Digestible Thr (%)	0.579	0.579	0.579	0.579	0.579
Digestible Trp (%)	0.160	0.160	0.160	0.160	0.160
Digestible Val (%)	0.695	0.695	0.695	0.695	0.695
Digestible Le (%)	1.332	1.332	1.332	1.332	1.332
Digestible Lys (%)	0.624	0.713	0.802	0.891	0.980
Na (%)	0.190	0.190	0.190	0.190	0.190
Cl(%)	0.304	0.304	0.304	0.304	0.304
K (%)	0.599	0.599	0.599	0.599	0.599

[1]Vitamin premix per kilogram of feed: vitamin A, 15 000 000 IU; vitamin D_3, 1 500 000 IU; vitamin E, 15 000 IU; vitamin B_1, 2.0 g; vitamin B_2, 4.0 g; vitamin B_6, 3.0 g; vitamin B_{12}, 0.015 g; nicotinic acid, 25 g; pantothenic acid, 10 g; vitamin K_3, 3.0 g; acido fólico, 1.0 g; Se, 250 mg. [2]Mineral premix per kilogram feed:Mn, 60 g; Fe, 80 g; Zn, 50 g; Cu, 10 g; Co, 2 g; I, 1 g.[3]Etoxiquim , [4]Sand. Source: Authors.

The diets were provided daily at two times, 8:00 a.m. and 4:00 p.m., ensuring the chicken consumed feed and water at will throughout the experimental period. A continuous lighting

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program was used, with 24 hours of light in the first 7 days, followed by 23 hours of light from the 8th to 105th day, controlled by a timer. The poultry were debeaked and vaccinated following a vaccination schedule for common diseases (Fowlpox, Marek, Gumboro, Infectious Bronchitis, New Castle, Typhus and Cholera). Biweekly sprays were made with 10 ml of quaternary ammoniadiluted into 2 l of water for prevention of respiratory diseases.

The poultry and the feed were weighed biweekly throughout the experimental period. The parameters of zootechnical performance evaluated were:

Daily feed intake - Was determined by the difference between the feed supplied and the leftover at the end of each experimental period, corrected for mortality as appropriate. In case of death of free-range chicken, the mean consumption of the period was discounted and corrected, obtaining the true mean consumption for the experimental unit in question.

Daily weight gain - The final weight was subtracted by the initial weight of the birds and the result divided by the number of days of the experimental period.

Feed conversion ratio - Obtained by dividing daily feed intake by daily weight gain.

For carcass characteristics, carcass yield, calculated in relation to body weight, was evaluated, with cut yields calculated in relation to plucked and eviscerated carcass weight.

Before slaughter, the chicken went on an eight-hour liquid fast so that there was no content in the gastrointestinal tract, which would cause contamination in the carcass, and a 30-minute dry fast. Four chickens per experimental unit were sacrificed by cervical dislocation followed by jugular vein rupture. The poultry were then eviscerated after bleeding and plucking. Cuts were made to evaluate the performance of the carcass, parts (breast, drumstick, thigh, wing, back, foot, neck and internal organs (liver, gizzard, heart).

Carcass yield (%) was obtained by the ratio between the weight of the cold carcass (without head) and the weight of the fasting chicken. The yields of breast, thigh, drumstick, wing and back (%) were obtained by the ratio between the weight of these parts and that of the cold carcass. The proportion of feet, neck, liver, gizzard and heart (%) were obtained by the ratio between the weight of these parts and organs and fasting weight.

To evaluate the quality of the meat, samples were collected from the breast of chicken slaughtered at 105 days of age.

The breast quality analyses were performed according to a methodology described by Mendes (2001). For pH determination, a penetration electrode was applied directly in the breast of the chicken 24 hours *post mortem*. This measurement was performed on all sampled chicken.

For the determination of cooking weight loss and shear force, the pectoral muscles of 4 chicken per experimental unit were used. The pectoral muscles were packed and frozen inside plastic bags. For the determination of cooking weight loss, the left fillet of each breast was removed and, after weighing, it was packed in aluminum foil and baked on a plate (with electric heating on both sides) until reaching an internal temperature of approximately 82 to 85 ° C. Next, the fillets were cooled at room temperature on absorbent paper until temperature reached approximately 20 to 25 ° C. The internal temperature of the samples was measured using a digital rod-type thermometer, after which a new weighing was carried out and the difference between the weight of the cooled *in natura* fillet and that of the cooked fillet resulted in loss of weight during cooking (Honikel, 1987).

The shear force analysis was performed with the same fillets used in the determination of cooking weight loss. The samples were trimmed and cut to obtain three units (1.0 x 1.0 x 1.3 cm). The analysis was performed using a Brookfield CT3 Texture Analyzer texturemeter with Warner-Bratzler shear force blade - for mechanical texture analysis, with a capacity of 20 kg and a cutter speed of 20 cm/minute, providing the measurement of the shear force (SF) of the sample, in kilogram-force ($kgf.cm^2$).

The statistical analyses of the variables evaluated to estimate lysine requirements were performed according to the SAEG - System for Statistical and Genetic Analysis (UFV, 2005) using the regression models (linear and quadratic), and significance levels of 1% and 5% probability.

Statistical model for analysis of variance was:

$Yij = \mu + Ti + eij$

Where:

Yij = observation of treatment, in the replicate j;

μ = general mean

Ti = effect of treatment;

eij = random error associated with each observation.

3. Results and Discussion

The levels of digestible lysine did not influence (P>0.05) the feed intake in the initial phase of the Caneludo Catolé chicken. This can be explained by the use of isoenergetic diets, since poultry normally regule the feed intake primarily to satisfy energetic demands (Bertechini, 2006); however, there was an increasing linear effect (P<0.01) for digestible lysine, regule the intake ($\hat{Y} = 1423x – 0.014$; $r^2 = 0.98$) (Table 4). The lack of significant effect on feed intake has been reported for fast-growing chicken by Bernal et al. (2014) when evaluating five levels of

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digestible lysine (1.06 to 1.30%) for Cobb 500 broilers from 10 to 22 days of age. In addition, Dias (2015) evaluated four levels of digestible lysine, between 1.016 and 1.265%, for Cobb 500 broilers in the period from 8 to 21 days of age, and did not observe an effect on feed intake, corroborating with the present study.

A quadratic effect ($P<0.01$) was observed for weight gain and feed conversion ratio (Table 4). Excess, as well as deficiency of some amino acids such as lysine, may impair performance of chicken, increasing nitrogen excretion and/or resulting in the catabolism of other amino acids (Costa et al., 2015).

The body weight of the chicken increased as lysine levels in the diet increased, until reaching an optimum level followed by a fall, responding in the same manner to feed conversion.

In the growth phase, which corresponded to the period from 30 to 75 days of age (Table 4), the levels of digestible lysine used had an increasing linear effect ($P<0.05$) on feed intake ($Y= 13.657x + 41.563$; $r^2 = 0.99$), an increasing linear effect ($P<0.01$) on the intake of lysine ($Y= 0.6493x – 0.0967$; $r^2 = 0.97$) and weight gain ($Y= 13.318x + 6.7829$; $r^2= 0.95$),and a decreasing linear effect ($P < 0.01$) on feed conversion ratio ($Y= - 1.2751x + 4.0974$; $r^2 = 0.81$).

These results can be justified by the possibility of free-range chicken of Caneludo Catolé being more efficient in using dietary lysine to gain weight. There is a need for consumption of an increasing amount of lysine in the growth phase, when the intensification of muscle development occurs, especially because poultry metabolism uses almost all the lysine available for the increase of muscle protein (Friesenet et al., 1996, Lawrence & Fowler, 1997). As a result, the chicken increased feed intake, with a consequent increase in the ingestion of lysine, promoting greater development of the muscular structure, with an increase in body weight, thus improving their feed efficiency.

The improvement in feed conversion ratio corresponds to the 33.5% variation in weight gain, coinciding with the increase in the efficiency of nutrient utilization by free-range chicken of the Caneludo Catolé.

In the final phase of breeding (Table 4), feed intake increased linearly ($P<0.05$) with increasing levels of digestible lysine in diets according to equation $Y= 32.785x + 53.2$; $r^2= 0.90$. An increase of 16.3% was found in feed intake, as well as a linear increase ($P <0.01$) in the lysine intake ($Y= 1.0544x – 0.2019$; $r^2= 0.99$), a result that is consistent with the increase in feed intake and the increasing levels studied.

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Table 4. Performance of free-range chickens of the Caneludo Catolé, submitted to diets containing different levels of digestible lysine in the period from 1 to 105 days of age.

Parameters	Initial Phase (1 to 30 day)							
	Levels of digestible lysine (%)							
	0.856	0.978	1.100	1.222	1.345	L	Q	SEM
Feed intake (g/chicken/day)	13.62	13.32	13.17	13.30	13.12	0.6931	0.8610	0.2412
Lysine intake (g/chicken/day)	0.111	0.125	0.136	0.161	0.180	<0.0001	0.2875	0.026
Weight gain (g/chicken/day)	5.27	6.19	6.71	6.93	6.74	0.0003	0.0119	0.1922
Feed conversion ratio (g/g)	2.44	2.18	2.01	1.82	2.13	0.0079	0.0094	0.0435
	Growth Phase (30 to 75 day)							
	0.705	0.806	0.906	1.007	1.108	L	Q	SEM
Feed intake (g/chicken/day)	51.20	52.57	53.94	55.32	56.69	0.0224	0.0547	0.4112
Lysine intake (g/chicken/day)	0.354	0.414	0.517	0.572	0.602	<0.0001	0.095	0.0181
Weight gain (g/chicken/day)	15.81	17.97	18.61	20.76	21.12	0.001	0.6955	0.2716
Feed conversion ratio (g/g)	3.17	2.98	3.11	2.82	2.62	0.0001	0.0449	0.0560
	Termination phase (75 to 105 day)							
	0.624	0.713	0.802	0.891	0.980	L	Q	SEM
Feed intake (g/chicken/day)	72.50	78.23	79.04	83.96	84.33	0.0114	0.5698	0.4449
Lysine intake (g/chicken/day)	0.452	0.558	0.634	0.748	0.826	<0.0001	0.8742	0.0311
Weight gain (g/chicken/day)	17.19	21.09	19.57	16.33	15.11	<0.0001	<0.0001	0.1752
Feed conversion ratio (g/g)	4.24	3.64	4.15	5.04	5.61	<0.0001	0.0028	0.1243

L: linear effect; Q: quadratic effect; SEM: standard error of the mean. Source: Authors

This may have occurred due to a possible nutritional imbalance in the diets, since the feeds used, although isoenergetic and isoproteic, had different ratios between amino acids and lysine, and chicken tend to regulate feed intake according to their nutritional needs.

Weight gain and feed conversion ratio corresponded in a quadratic manner ($P<0.01$) to the levels of digestible lysine used. In this context, diets nutritionally higher than 0.713% of digestible lysine would be unnecessary to obtain an adequate feed conversion ratio for free-range chicken of the Caneludo Catolé aged between 70 to 105 days, since it would only result in feed costs without proper use of the nutrients by the animal.

These results can be explained by the possible excess of amino acids, which can limit the performance of the chicken due to amino acid catabolism, which requires extra energy expenditure for excretion of nitrogen as uric acid (Jordão Filho et al., 2006), reducing the availability of this energy ,which should be used for adequate animal development.

Increasing linear responses were observed for yield of carcass% (Y= 5.8539x + 70.437; r^2= 0.78) and breast % (Y= 2.9213x + 15.015; r^2= 0.92) (P<0.05) and thigh % (P<0.01) (Y= 2.8315x + 8.9032; r^2= 0.63), (Table 5).

It can be inferred that the increase in carcass weight observed in this study is directly related to the increase in breast and drumstick yield. These results confirm that digestible lysine is mainly used in the processes of protein synthesis for the constitution of muscle mass (Lawrence & Fowler, 1997).

The yield of the viscera (gizzard, liver and heart) did not present statistical differences (P>0.05), indicating that the deficiency and/or the excess of lysine does not affect the development of the viscera (Table 5).

No deposition of abdominal fat was observed. This may have occurred because they did not reach sexual maturity since, according to Kessler et al. (2000), chicken deposit more body fat as they mature, additionally because the isoproteic and isoenergetic diets.

Table 5. Carcass yield means of free-range chickens of the Caneludo Catolé, submitted to diets containing different levels of digestible lysine at 105 days of age.

Parameters	Levels of digestible lysine (%)					Valor de P		SEM
	0.624	0.713	0.802	0.891	0.980	L	Q	
Carcass Weight (kg)	1536.2	1671.2	1704.6	1723.7	1660.8			
Carcass (%)	73.95	75.07	75.03	75.04	76.57	0.0237	0.7422	1.8040
Breast (%)	16.72	17.13	17.54	17.63	17.77	0.0393	0.3301	1.0909
Drumstick (%)	10.85	10.91	10.76	10.65	10.88	0.4447	0.2257	0.8133
Thigh %)	10.52	11.29	11.12	11.03	11.91	0.0006	0.6649	0.7122
Wing (%)	9.33	9.66	9.47	9.33	9.56	0.7311	0.7833	0.4587
Neck (%)	6.16	6.17	6.14	6.17	6.14	0.9215	0.9464	0.3610
Back (%)	14.66	14.37	14.71	14.61	14.67	0.7918	0.8342	1.0397
Foot (%)	4.54	4.77	4.04	4.25	4.54	0.3462	0.1122	0.5770
Gizzard (%)	2.29	2.28	2.30	2.28	2.30	0.0612	0.0801	0.1474
Lever (%)	1.75	1.74	1.73	1.75	1.73	0.8138	0.9517	0.1019
Heart (%)	0.37	0.37	0.35	0.36	0.37	0.7897	0.3062	0.0340

L: linear effect; Q: quadratic effect; SEM: standard error of the mean. Source: Authors.

The pH of the 24-hour postmortem breast meat of free-range chicken presented a linear increasing effect ($P<0.01$), according to equation ($Y= 0.3004x + 5.5281$; $r^2 = 0.89$). According to Venturini et al. (2007), chicken breast meat must have a final pH (after 24 hours) between 5.6 and 5.9. Thus, the values obtained for the breast meat of free-range chicken of the Caneludo Catolé were acceptable, with values that fit within the stipulated pH range for chicken breast meat (Table 6).

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Table 6. Mean data of the physical and chemical characteristics of the breast meat of free-range chickens of the Caneludo Catolé submitted to diets containing different levels of digestible lysine in the termination phase (75 to 105days).

Parameters	Levels of digestible lysine (%)					SEM	Effect	
	0.624	0.713	0.802	0.891	0.980		Linear	Quad.
PH	5.73	5.73	5.75	5.80	5.83	0.0749	0.0005	0.3073
Shear force (kgf/g)	2.62	2.14	2.00	1.61	1.37	0.4568	<0.0001	0.6947
Cooking weight loss (%)	24.84	23.99	23.48	23.06	22.48	1.7928	0.0021	0.7535

L: linear effect; Q: quadratic effect; SEM: standard error of the mean. Source: Authors.

The pH directly interferes with water losses in breast meat of free-range chicken. With the loss of muscle glycogen reserves, the accumulation of lactic acid in the post-mortem muscle consequently decreases. Thus, the final pH of the meat tends to remain high, well-above the isoelectric point of the main muscle proteins. Under these conditions, the ability of these proteins to retain water tends to be high, reducing water losses during processing (Dransfield & Sosnicki, 1999).

This can be observed in this research, where cooking weight loss had a linear decreasing effect (P<0.01), equation ($Y= - 6.3483x + 28.661$; $r^2 = 0.98$), resulting in less water loss due to cooking.

The succulence of the meat directly affects shear force according to Brossi et al. (2009). According to Anadón (2002), the greater the amount of water present in the muscle, the greater the softness of the meat. This can be proven in this study, since the shear force suffered a linear decreasing effect (P<0.01), equation ($Y= -3.4045X + 4.6784$; $r^2 = 0.98$); that is, the smaller the loss of water from the meat, the greater the softness.

4. Final Considerations

For better efficiency, feeds for free-range chicken of the Caneludo Catolé must be formulated with digestible lysine levels of 1.175% for the initial phase (1 to 30 days of age), 1.108% for the growth phase (30 to 75 days of age) and 0.713% for the termination phase (75 to 105 days of age).

For better meat quality, it is concluded that the level of 0.624% of digestible lysine can be used, since it kept the pH within the desired standard.

The results obtained showed a difference in the requirements when compared with the nutritional recommendations of lysine for commercial chicken, found in the Brazilian tables of food composition and nutritional requirements which are considered as the main Brazilian reference of nutritional recommendations for poultry and swine. Thus demonstrating the need for more research regarding this breed.

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