METABOLIZABLE ENERGY FOR BROILERS WITH DIFFERENT GENETIC GROWTH POTENTIALS UNDER A FREE-RANGE SYSTEM

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ABSTRACT: The objective of this study was to evaluate the effects of different levels of metabolizable energy (ME) on performance parameters and carcass characteristics in slow-growing (experiment 1) and fast-growing (experiment 2) broilers in a free-range system. Were evaluated broilers from 35 to 70 days old in experiment 1 and 28 to 49 days old in experiment 2. A completely randomized experimental design was employed in both experiments, with five treatments and four replicates totaling 20 experimental units containing 15 broilers each. The treatments consisted of rations that had increasing metabolizable energy levels obtained by the substitution of soybean oil in the basal diet for the inert sand ingredient. The metabolizable energy levels studied in experiment 1 were 2700, 2800, 2900, 3000 and 3100 kcal/kg, and in experiment 2, they were 2800, 2900, 3000, 3100 and 3200 kcal/kg. In experiment 1, there was a linear (P<0,05) reduction in consumption with the increase in the metabolizable energy level, and a quadratic effect (P<0,05) on the feed conversion was observed, which was estimated as 3046 kcal/kg the level that resulted in a better feed conversion of 2.648. In experiment 2, the metabolizable energy level exerted a significant quadratic effect (P<0,05) on the feed intake and metabolizable energy consumption, with a maximum feed intake (3361.27 g) estimated for 2842 kcal/kg, and the maximum energy intake was estimated at 10020 kcal. The feed conversion decreased linearly (P<0,05) with there was an increase in the studied levels. For broilers reared in a free-range system, for better feed conversion, the recommended metabolizable energy levels are as follows: for slow-growing broilers from 35 to 70 days of age, 3046 kcal/kg, and 3200 kcal/kg is recommended for fast-growing broilers from 28 to 49 days of age.

Key words: carcass characteristics, energy protein ratio, fast-growing, performance, slow-growing

ENERGIA METABOLIZÁVEL PARA FRANGOS DE CORTE COM DIFERENTES POTENCIAIS GENÉTICOS PARA CRESCIMENTO CRIADOS EM SISTEMA DE LIVRE ACESSO AO PIQUETE

RESUMO: O objetivo deste estudo foi avaliar os efeitos de diferentes níveis de energia metabolizável (EM) nos parâmetros de desempenho e características de carcaça em frangos de corte de crescimento lento (experimento 1) e crescimento rápido (experimento 2) criados em sistemas de livre acesso ao piquete. Os frangos de corte tinham de 35 a 70 dias de idade no experimento 1 e 28 a 49 dias de idade no experimento 2. Um delineamento experimental inteiramente casualizado foi usado em ambos os experimentos, com cinco tratamentos e quatro repetições, totalizando 20 unidades experimentais com 15 frangos de corte cada. Os tratamentos consistiram em rações com níveis crescentes de energia metabolizável obtido pela adição de óleo de soja na dieta basal em substituição ao ingrediente inerte areia. Os níveis de energia metabolizável estudados no experimento 1 foram 2700, 2800, 2900, 3000 e 3100 kcal/kg e, no experimento 2, foram 2800, 2900, 3000, 3100 e 3200 kcal/kg. No experimento 1, houve uma redução linear (P<0,05) no consumo com o aumento do nível de energia metabolizável e observou-se um efeito quadrático (P<0,05) na conversão alimentar, que foi estimada em 3046 kcal /kg que resultou na melhor conversão alimentar de 2.648. No experimento 2, os níveis de energia metabolizável exerceram um efeito quadrático (P<0,05) no consumo de ração e no consumo de energia metabolizável, com um consumo máximo de ração (3361,27 g) estimado em 2842 kcal EM/kg, e a ingestão máxima de energia foi estimada em 10020 kcal. A conversão alimentar diminuiu linearmente (P<0,05) com o aumento dos níveis estudados. Para melhor conversão alimentar de frangos de corte criados em um sistema de livre acesso ao piquete, os níveis de energia recomendados são os seguintes: 3046 kcal/kg para frangos de crescimento lento de 35 a 70 dias de idade, e 3200 kcal/kg para frangos de corte de crescimento rápido de 28 a 49 dias de idade.

Palavras-chave: característica de carcaça, relação proteína energia, crescimento rápido, desempenho, crescimento lento

INTRODUCTION

Metabolizable energy (ME) is one of the factors that has the most influence on feed cost, and it is greatly important for animal performance because it is required for many different metabolic processes, ranging from maintenance to full productive potential. Several factors can contribute to the magnitude of the energy demand, including the lineage and the system of creation.

The use of alternative systems for slow-growing broiler strains has been growing in order to provide the market with a differentiated product because of the meat has different physical-chemical properties; it is redder (Narinç et al., 2015) and firmer (Mello et al, 2012), with a stronger flavor, and the carcass has a lower fat content with higher polyunsaturated fatty acids in their meat muscles as well as a healthier ratio of n-6/n-3 PUFA acids (Sokołowicz et al., 2016). In contrast, fast-growing broilers have excellent growth and feed conversion rates and are generally raised in high densities in confined systems. However, the use of these fast-growing strains in alternative systems is possibly linked with the excellent production characteristics of this broiler due to the inherent advantages of the ecological system in relation to animal welfare (Moyle et al. 2014). A lower density, greater freedom of movement and access to an enriched environment that includes contact with the soil, pasture and natural shade allow these characteristics to influence the energy requirements.

The nutritional requirements of fast-growing broilers have been well established in the literature, and these data are commonly extrapolated for the formulation of diets in alternative broiler production systems. However, the energy requirements may differ because different broilers have different growth potentials, as well as housing and handling requirements. Połtowicz and Doktor (2011) found different growth rates for birds of conventional lineages (Ross 308) raised outdoors and confined and Cömert et al. (2016) found differences in carcass characteristics and meat quality. However, contrary results are found in the literature, showing no effect of free access on the performance and the carcass yield (Moyle et al., 2014) or on the muscle yield and the protein content of the meat (Chen et al., 2013).

Because lineages with different genetic growth potentials are used in free-range systems, a question arises about the impact of greater movement on the energy requirements of the birds. Branciari et al. (2009) reported that commercial strains of birds have a lesser capacity to adapt to management with free access to pasture, so such birds tend to remain in a closed shed to reduce energy costs.

Although the growth performance of slow-growing birds is less efficient than that of fast-growing birds, slow-growing birds are more adapted to natural systems (Fanatico et al., 2005). Research is needed to determine the suitability of slow-growing birds for more outdoor movements and if the energy expenditure would be greater because of the movements over a larger area and to return to the shed to access feeders containing balanced feed. There is an increasing proportion of slow-growing broiler strains with great relevance in natural poultry meat production in some regions (Ganzer et al., 2017).

The present study was carried out with the objective of evaluating the effects of the metabolizable energy level in the ration on the performance, carcass characteristics, and absolute and relative organ weight of slow-growing and fast-growing broilers in a free-range system.

MATERIALS AND METHODS

All the procedures used in this research were approved by the Ethics Committee on the Use of Animals of the Federal Rural University of Rio de Janeiro, under protocol number 23083.002588/2015-53.

Experiment 1

This experiment used 300 slow-growing broilers of the commercial strain "Caipira Light" from the farm "Fazenda Aves do Paraíso". The chicks were vaccinated in the hatchery against Marek's disease, Fowlpox and Gumboro disease. At 3 days old, they were vaccinated against coccidiosis and were vaccinated against Newcastle disease at 10 days old. Heating was provided in enclosed brooders with gas heaters until 7 days of age.

Until they were 34 days old, the broilers were housed in a brick-and-mortar pen containing bedding composed of wood shavings. The initial feed intake was formulated to meet the nutritional recommendations established by Figueiredo et al. (2006).

At 35 days old, the broilers were weighed to determine their average initial weight, which was 457 g. Fifteen broilers per experimental unit were distributed in a completely randomized design, with five treatments and four replicates totaling 20 experimental units, each consisting of two 100 m² paddocks and a brooder measuring 1.85 × 2.20 m. Two paddocks per shelter allowed pasture rotation according to the growth conditions of the Tifton 85 forage (Cynodon nlemfuensis x C. dactylon). The average and maximum temperatures were 26ºC and 35.37ºC, respectively, during the experimental period. No artificial lighting existed and the natural light was supplied during all experimental period, from August to October.

The treatments comprised feed energy levels of 2700, 2800, 2900, 3000 and 3100 kcal/kg of diet, obtained by the substitution of soybean oil in the basal diet for the inert sand ingredient (Table 1). The other nutrients were kept constant in all treatments and met the requirements of Figueiredo et al. (2006). The broilers were given ad libitum access to feed and water.

Evaluations of feed intake, weight gain, feed conversion and viability were performed during the period from 35 to 70 days of age. To study the carcass characteristics, the birds were slaughtered at 71 days old, similar to the slaughter age in organic (Codex Alimentarius, 2001) and free-range (ABNT, 2016) systems. Two broilers per replicate were slaughtered for a total of 8 broilers per treatment, in which the selected broilers had the average weight of the plot of broilers, had fasted for 6 hours and were weighed after fasting. The broilers were stunned, slaughtered by a jugular incision, scalded, plucked and eviscerated, and their heads, necks and feet were cut off. After dripping, the carcasses were weighed to determine the carcass yield.

Assessments were also made of the absolute carcass weight, abdominal fat, total fat, head, feet, proventriculus, bowel, ceca, heart, liver and gizzard. Abdominal fat was taken as all the adipose tissue around the cloaca, the bursa of Fabricius, the adjacent abdominal muscles and around the gizzard. The relative weights were expressed in percentages and calculated based on the absolute weights compared with the carcass weight.

Table 1 - Centesimal composition of basal diets for slow-growing broilers in a free-range system.

Ingredients	Composition (%)
Corn (7.46% CP)[1]	58.568
Soybean meal (45.8% CP)[1]	29.459
Sand	7.500
Soybean oil	0.500
Dicalcium phosphate	1.859
Limestone	1.172
Salt	0.409
DL-Methionine	0.091
Mineral premix[2]	0.110
Vitamin premix[3]	0.110
Choline chloride	0.035
Total (kg)	100.00
Nutrients	**Calculated composition**
Crude Protein (%)	18.02
Metabolizable energy (kcal kg^{-1})	2.700
Sodium (%)	0.180
Calcium (%)	1.000
Available phosphorous (%)	0.435
Methionine (%)	0.380
Methionine + cysteine (%)	0.679
Lysine (%)	0.965
Threonine (%)	0.717
Tryptophan (%)	0.225
Linoleic acid (%)	1.549
Crude fiber (%)	2.623

[1] Value determined in the laboratory of bromatology of the Institute of Zootecnia of UFRRJ.
Mineral premix composition per kg of product: Iron 60 g; Copper 13 g; Manganese 120 g; Zinc 100 g; Iodine (min) 2.500 mg; and Selenium 500 mg.
[2] Vitamin premix composition per kg of product: Vitamin A (min) 7.500.000 UI; Vitamin D3 2.500.000 UI; Vitamin E 1.200 mg; Vitamin K3 1.200 mg; Thiamine 1.500 mg; Riboflavin 5.500 mg; Pyridoxine 2000 mg; Vitamin B12 12.000 mcg; Niacin 35 g; Calcium Pantothenate 10 g; and Biotin 67 mg.

Experiment 2

A total of 500 male broilers of the "Cobb Avian 48" commercial strain was initially housed. The birds were raised to 27 days old in a conventional shed on a bed. In the first seven days, the chicks were raised according to the recommendations in the strain manual. Rations and water were provided at will throughout the breeding period, and in the period from 1 to 27 days old, rations with nutritional values were included to meet the minimum recommendations recommended by Rostagno et al. (2005).

At 28 days old, the broilers were weighed, and 300 broilers that had body weight close to the average weight of the lot, which was 1433 g, were selected for the experiment. The broilers were then sorted into the experimental units. The experimental design was completely randomized, with five treatments, four replicates and with 15 birds per experimental unit. The treatments consisted of rations with increasing levels of metabolizable energy obtained by the substitution of soybean oil in the basal diet for the inert sand ingredient (Table 2). The amounts of oil were 560, 1697.65, 2835.3, 3972.95 and 5110.60 g in 100 kg of diet, resulting in 2800, 2900, 3000, 3100 and 3200 kcal/kg of diet, respectively. The other nutrients were kept constant in all treatments and met the minimum requirements recommended by Rostagno et al. (2005).

An experimental unit consisted of 15 birds housed in a shelter and two paddocks. The shelter had the same dimensions and characteristics as for experiment 1. The broilers had free access to the paddocks during the experimental period.

The feed intake, weight gain, feed conversion and energy intake were evaluated for the period from 28 to 49 days old. The metabolizable energy intake was calculated from the average feed intake multiplied by the energy value.

To determine the carcass characteristics, the birds were slaughtered at 50 days old. Four birds with a mean representative weight of the experimental unit were selected for a total of sixteen birds per treatment, which were fasted for six hours and then weighed. For slaughtering, each broiler was stunned, bled, scalded at 54°C, plucked in a mechanical plucker and manually gutted, and the head, neck and feet were removed. After dripping, the carcasses were individually weighed and packed in plastic bags. The absolute weights (total weight in grams) of the carcass, abdominal fat, head, feet and edible viscera (heart, liver and gizzard) were evaluated.

Table 2 - Centesimal composition of basal diets for fast-growing broilers in a free-range system.

Ingredients	Composition (%)
Corn (7.46% CP)[1]	60.524
Soybean meal (45.8% CP)[1]	30.571
Sand	5.200
Limestone	0.747
Dicalcium phosphate	1.503
Salt	0.435
Soybean oil	0.560
DL-Methionine	0.177
L-Lysine HCL	0.118
Mineral-vitamin mix[2]	0.130
Choline chloride	0.035
Total (kg)	100.00
Nutrients	Calculated composition
Crude protein (%)	18.73
Metabolizable energy (Kcal kg^{-1})	2800
Sodium (%)	0.191
Calcium (%)	1.751
Available phosphorous (%)	0.374
Methionine + cystine (%)	0.788
Lysine (%)	1.094
Threonine (%)	0.744
Tryptophan (%)	0.235
Fiber (%)	2.99

[1] Value determined in the laboratory of bromatology of the Institute of Zootecnia of UFRRJ.
[2] Guaranteed levels per kg of product: iron: 60000 mg; copper: 13000 mg; manganese: 120000; zinc: 100000 mg; iodine: 2500 mg; selenium: 500 mg and excipient q.s.: 1000 g; Vit. A: 600,000 UI; Vit D3: 2000000 IU; Vit E: 12000 mg; Vit K3: 800 mg; Vit B1: 1000 mg; Vit B2: 4500 mg; Vit B6: 1500 mg; Vit B12: 12000 mg; niacin: 30000 mg; calcium pantothenate: 10000 mg; folic acid: 550 mg; biotin: 50 g; antioxidant: 5000 mg; and excipient q.s.: 1000 g.

Statistical analysis

In both experiments, the statistical analyses were performed using the SAEG program, System of Statistical and Genetic Analysis (UFV, 2000), considering a P value of 0.05 to be significant. The means were studied by regression analysis, and nutritional requirements estimates were established when possible with a quadratic model.

RESULTS AND DISCUSSION

Experiment 1 - Metabolizable energy in slow-growing broilers in a free-range system

The energy level did not influence weight gain, the intake of metabolizable energy or viability (Table 3). In a similar fashion as in the fast-growing lineages, slow-growing broilers do not show major changes in weight gain as a result of variations in the feed energy level within a certain range. It is known that dietary metabolizable energy level plays a key role in broiler feed intake regulation and feed efficiency (Abudabos et al.,2014) .

Mendonça et al. (2007), working with females of the slow-growing broiler lineage "Isa Label" from 22 to 49 days and from 50 to 84 days did not observe an effect of the energy level on weight gain during either evaluation period. However, in Mendonça et al. (2008), a quadratic effect of the metabolizable energy level (2800 to 3400 kcal/kg) on the weight gain of slow-growing male broilers between 50 and 70 days old reared in a free-range system was observed, with an estimated 3222 kcal/kg energy level expected to provide greater weight gain.

By contrast, the feed intake decreased linearly with an increase in the metabolizable energy level of the feed in both periods. Slow-growing broilers adjusted their feed intake in accordance with the feed energy level. Previous research has also shown similar behavior. Mendonça et al. (2007), working with females of the lineage "Isa Label", observed a linear decrease in the intake during three study stages. The same effect was reported by Mendonça et al. (2008) when working with males of the same lineage. By contrast, Moreira et al. (2012) found an increase in the feed intake as the feed energy level increased (3100, 3200 and 3300 kcal/kg), when working with slow-growing broilers of both sexes of the lineage "Caipira Francês Exótico" from 29 to 90 days old in an intensive system. Santos et al. (2012) evaluated 3 feed energy levels (3100, 3200 and 3300 kcal/kg) in broilers of the lineage "Caipira Francês Barré" of both sexes and found no effect of energy variation on feed intake.

There was a quadratic effect of the feed energy level on feed conversion, and the feed energy level was estimated at 3046 kcal/kg for the best response in food conversion. Mendonça et al. (2007) tested 5 feed energy levels ranging from 2800 to 3400 kcal/kg during the initial phase (1 to 21 days old), the growth phase (22 to 49 days old) and the final phase (50 to 85 days old) and found a linear effect of the feed energy level on the feed conversion in all evaluation periods. Similarly, Ferreira et al. (2015), working with free-range broilers, observed a linear effect on the improvement of feed conversion with an increase in the feed energy level.

Several authors reported that feed conversion improved with an increase in the feed energy level, with either free-range broilers or slow-growing broilers (Mendonça et al., 2008; Moreira et al., 2012).

A quadratic effect was observed for the absolute weight after fasting, the absolute carcass and small gut weight, the absolute and relative gizzard weight and the relative foot weight. There is a linear effect in the variable relative weight of the small intestine, whose weight increased as the metabolizable energy level increased (Table 4).

According to the proposed model, a live weight after fasting of 1671 g is obtained with a feed consumption of 2890 kcal/kg of feed. The best absolute weight of the carcass (1105 g) was obtained with an energy level of 2894 kcal/kg. There was no influence of the feed energy level on the carcass yield. Nascimento et al. (2016) found a quadratic effect on the carcass weight but did not observe significant results for the carcass yield in slow-growing broilers raised in a free-range system. Mendonça et al. (2008), working with "Isa Label" males, also found no significant differences in the carcass yield when the feed energy level was varied from 70.73 % to 72.09 %. However, Mendonça et al. (2012) found a lower carcass yield in a group of broilers fed with feeds with a greater energy level.

The best relative weight of the gizzard (3.50 %) was obtained with a feed consumption

Table 3 - Energy level effect on weight gain, feed intake, feed:gain ratio, metabolizable energy intake and viability of slow-growing broilers in a free-range system.

	Metabolizable energy level (kcal kg^{-1})							
	2700	2800	2900	3000	3100			
	Energy:protein ratio							
Variables	149.8	155.3	160.9	166.4	172.0	Mean	Anova	CV (%)
Weight gain (g)	1211	1208	1219	1201	1174	1203	NS	2.48
Feed intake (g)	3646	3403	3286	3224	3104	3332	L[1]	2.65
Feed:gain	3.01	2.82	2.70	2.68	2.64	2.77	Q[2]	2.19
ME intake (kcal)	9845	9527	9529	9671	9622	9639	NS	2.55
Viability (%)	100	98.33	100	98.33	98.33	99.00	NS	2.61

NS – not significant (P>0.05); L – linear effect (P<0.05); Q – quadratic effect (P<0.05).
[1]$\hat{Y}$= 6.999.8 – 1.2646x. R^2=0.9414; [2]$\hat{Y}$= 30.149 – 0.018058x +0.000002964x^2. R^2 = 0.9838;
CV (%) = coefficient of variation.

containing 2858 kcal/kg and the absolute weight of the small intestine (43.86 g) was obtained with a level of 2962 kcal/kg. Barbosa et al. (2008) studied different levels of metabolizable energy in broiler chickens and did not find effects on gizzard weight. Madeira et al. (2010) evaluated the performance and carcass yield of four broiler strains in two breeding systems and did not observe effects on foot yield.

Experiment 2 - Metabolizable energy in fast-growing broilers in a free-range system

The energy level did not influence the final live weight and weight gain, and a significant effect was found for the feed intake, the metabolizable energy intake and the feed conversion (Table 5).

The lack of significant effects on weight gain can be explained in part by the ability of the birds to adjust their consumption to meet their energy needs (Gopinger et al., 2017). The results observed in the present research agree with those of Ávila et al. (2005), who evaluated different metabolizable energy levels for fast-growing broiler breeders with access to picket and did not observe effects on the weight gain from 28 to 41 days old. Similar results were found by Barbosa et al. (2008), who reported the absence of effects of the energy level on weight gain.

An estimate of the maximum feed intake of 3361.27 g occurred for a level of 2842 kcal/kg of feed. The lowest value of feed intake was found in broilers that received a ration with the highest energy value (3100 kcal/kg), who consumed, on average, 538.27 g less than the amount estimated for the aforementioned energy requirement, which evidences the need for an adequate amount of other nutrients in relation to the energy level used. A reduction in the feed intake due to an increase in the energy level of the ration is evidenced in several studies (Nahashon et al., 2005; Dozier et al., 2006). Avila et al. (2005) reported a reduction in the feed intake with an increase in the energy level (2600, 3000 and 3200 kcal/kg) in broilers of conventional lineage from 56 to 70 days old created with access to picket.

The feed conversion decreased linearly as the feed energy level increased, so that the broilers that consumed a ration with the maximum energy value (3200 kcal/kg) had the best feed conversion (1.64). The reduction in feed conversion due to an increase in the metabolizable energy level can be partially explained by the reduction of the caloric increment resulting from the inclusion of increasing amounts of oil (Oliveira et al., 2018). According to Sakomura et al. (2004), this extra caloric effect consists in part of the extra metabolic effect of lipids, which results in an improvement in energy efficiency by increasing the net energy of the feed. Other authors also observed improvements in the feed conversion index due to an increase in the energy level (Araújo et al., 2005; Ghaffari et al.,2007; Gopinger et al., 2017). The effect of seven levels (2575 to 3176 kcal/kg) of metabolizable energy on diets formulated with

Table 4. Energy level effect on carcass characteristics and viscera of slow-growing broilers on free-range system slaughtered at 70 days old.

	Metabolizable energy level (kcal kg^{-1})							
	2700	2800	2900	3000	3100			
	Energy:protein ratio							
Variables	149.8	155.3	160.9	166.4	172.0	Mean	Anova	CV (%)
Absolute weight (g)								
Live weight	1633	1597	1710	1661	1584	1637	Q[1]	3.98
Carcass	1071	1044	1129	1106	1032	1077	Q[2]	4.86
Abdominal fat	8.98	14.97	20.82	21.24	23.85	17.97	Q[3]	11.92
Head and neck	156.25	160.00	165.62	159.37	157.50	159.75	NS	6.12
Heart	9.48	9.70	9.26	10.20	9.51	9.63	NS	10.81
Proventriculus	7.31	7.43	7.00	7.62	7.03	7.28	NS	11.18
Gizzard	38.12	40.00	38.12	38.12	43.12	39.50	Q[4]	7.39
Liver	30.62	28.12	29.37	30.62	26.87	29.12	NS	13.19
Feet	85.62	81.25	82.50	86.25	82.50	83.62	NS	6.39
Small gut	38.75	41.25	44.37	43.12	42.50	42.00	Q[5]	8.19
Cecum	10.11	10.43	10.47	10.31	10.67	10.40	NS	9.25
Yield (%)								
Carcass	65.57	65.38	66.05	66.59	65.19	65.76	NS	2.50
Relative weight (%)								
Abdominal fat	0.85	1.46	1.86	1.94	2.34	1.69	Q[6]	13.10
Head and neck	14.76	15.55	14.81	14.52	15.41	15.01	NS	6.18
Heart	0.89	0.95	0.83	0.93	0.94	0.91	NS	12.23
Proventriculus	0.69	0.72	0.63	0.70	0.69	0.68	NS	12.74
Gizzard	3.60	3.90	3.41	3.49	4.23	3.73	Q[7]	10.01
Liver	2.89	2.74	2.63	2.79	2.63	2.74	NS	14.44
Feet	8.06	7.90	7.38	7.88	8.05	7.85	Q[8]	6.37
Small gut	3.63	3.96	3.93	3.91	4.12	3.91	L[9]	9.49
Cecum	0.95	1.00	0.93	0.93	1.03	0.95	NS	10.06

NS – not significant ($P>0.05$); L – linear effect ($P<0.05$); Q – quadratic effect ($P<0.05$).
[1]$\hat{Y} = 12.837 + 10.039x - 0.00174x^2$. $R^2 = 0.4201$; [2]$\hat{Y} = -10.976 + 8.3478x - 0.0014x^2$. $R^2 = 0.4397$; [3]$\hat{Y} = -816.9 + 0.54097x - 0.000087063x^2$. $R^2 = 0.9795$; [4]$\hat{Y} = 502.86 - 0.3285x + 0.000058x^2$. $R^2 = 0.5937$; [5]$\hat{Y} = -622.29 + 0.4498x - 0.000075936x^2$. $R^2 = 0.9216$; [6]$\hat{Y} = -53.906 + 0.034951x - 0.0000054286x^2$. $R^2 = 0.9717$; [7]$\hat{Y} = 86.916 - 0.0584x + 0.000012x^2$. $R^2 = 0.4857$; [8]$\hat{Y} = 109.73 - 0.0704x + 0.000012x^2$. $R^2 = 0.6624$; [9]$\hat{Y} = 1.1651 + 0.0009x$. $R^2 = 0.6970$.
CV (%) = coefficient of variation.

total and digestible amino acids in broilers was studied, and Ghaffari et al. (2007) found significant differences in feed conversion, with a decrease in the conversion value from 2.43 to 1.79. The results of the present study are consistent with those of Gopinger et al. (2017), that found a linear effect on feed:gain ratio, with the better feed conversion (1,64) obtained with the higher energetic value (3250 kcacl/kg). On the other hand, ABUDABOS et al. (2014) fed broilers from 22 to 42 days of age with diets containing 75, 50 and 25 kcal ME/kg below the requirements (3,150 kcal/kg), and did not observe any effect on feed:gain ratio. Oliveira et al. (2018) did not found any difference in performance of broilers that receive diets from 3050 to 3275 kcal/kg.

The mean intake of metabolizable energy

Table 5 - Energy level effect on body weight, weight gain, feed intake, feed:gain ratio, metabolizable energy intake of fast-growing broilers in a free-range system.

Variables	Metabolizable energy level (kcal kg^{-1})							
	2800	2900	3000	3100	3200			
	Energy:protein ratio							
	149.5	154.8	160.1	165.5	170.8	Mean	Anova	CV (%)
Body weight (g)	2988	3140	3038	3115	3077	3072	NS	3.84
Weight gain (g)	1653	1725	1719	1724	1720	1708	NS	2.27
Feed intake (g)	3427	3376	3295	3177	2823	3220	Q^1	1.62
Feed:gain ratio	2,08	1,96	1,92	1,84	1,64	1,887	L^2	2.60
ME intake (kcal)	9595	9790	9886	9849	9032	9630	Q^3	1.64

NS – not significant (P>0.01); L – linear effect (P<0.01); Q – quadratic effect (P<0.01).
$^1\hat{Y} = -33803 + 26.15x - 0.0046x^2$. $R^2 = 0.975$; $^2\hat{Y} = 4.8356 - 0.001x$. $R^2 = 0.9306$; $^3\hat{Y} = -125497 + 91.358x - 0.0154x^2$. $R^2 = 0.8958$.
CV (%) = coefficient of variation.

was 9630 kcal, and the highest intake was 10020 kcal, with an estimated value of 2966.75 kcal/kg of diet, according to the quadratic model. These variations in energy intake differ from those found by Barbosa et al. (2008), who did not find significant differences in ME intake during any of the phases tested (22 to 35, 36 to 42 and 43 to 49 days old) in confined broilers.

The results obtained for the carcass weight and yield and the absolute and relative weights of the viscera and abdominal fat of broilers slaughtered at 49 days old are shown in Table 6. Significant effects (p <0.05) were observed for the absolute carcass weight, abdominal fat, heart and head and neck, in addition to the carcass yield and the relative weights of the fat, gizzard and liver.

The average carcass yield for the different energy levels studied was 72.68%. Avila et al. (2005) reported a higher carcass weight in semi-confined fast-growing broilers slaughtered at 70 days old fed with higher amounts of metabolizable energy (3000 and 3200 kcal/kg).

The weight and yield of abdominal fat increased linearly with an increase in the energy level of the diet. The mean abdominal fat weight was 54.17 g, and the maximum metabolizable energy tested resulted in 21% abdominal fat at values higher than the lowest value studied. Avila et al. (2005), working with fast-growing broilers raised with free picket access, reported an increase in abdominal fat deposition with an increase in the feed energy level. Dozier III et al. (2008) concluded that a higher level of metabolizable energy significantly increased the absolute weight and the abdominal fat yield.

It is interesting to note that broilers that received rations that had the highest energy content (3200 kcal/kg), even if they showed a lower metabolizable energy consumption than broilers from other treatments, had higher levels of abdominal fat deposition. It is necessary to consider in this discussion that isoprotein rations were used, with an increase in the ME:CP ratio with an increase in the energy levelof the ration. The results could be different in a situation in which an adjustment of the nutrients in relation to the energy content was performed. In fact, according to Silva et al. (2001), as the ME:CP ratio increases, there is a reduction in the energy targeted for protein deposition and uric acid synthesis, increasing the energy available for fat deposition in the carcass and, according to Sakomura et al. (2004), after the maintenance needs are met, the ingested energy is intended for the synthesis of organic compounds or the production or deposition of fat. Fat deposition in a broiler occurs in great proportion in the abdominal region (Laganá et al., 2005).

The absolute liver weight (57.41 g) was obtained with the level of 3109 kcal/kg, and the highest relative liver weight (2.56%), with a level of 3190 kcal/kg. This effect shows that the energy levels evaluated directly influenced the metabolism of the liver and, according to Xavier et al. (2008), higher amounts of metabolizable energy may increase the secretion of digestive enzymes due to hypertrophy of the secretory

Table 6 - Energy level effect on carcass characteristics and viscera of fast-growing broilers in a free-range system slaughtered at 50 days old.

Variables	Metabolizable energy level (kcal kg^{-1})							
	2800	2900	3000	3100	3200			
	Energy:protein ratio							
	149,5	154,8	160,1	165,5	170,8	Mean	Anova	CV (%)
Absolute weight (g)								
Carcass	2144	2193	2196	2309	2251	2218	L^1	7.09
Abdominal fat	49.10	52.92	55.07	57.64	56.11	54.17	L^2	19.93
Gizzard	39.54	39.96	39.73	39.70	39.09	39.61	NS	3.95
Liver	44.81	52.15	53.95	59.47	55.65	53.20	Q^3	9.36
Heart	14.20	14.33	14.67	15.66	14.65	14.67	NS	10.56
Foot	132.5	137.4	133.8	136.7	135.0	135.09	NS	7.64
Head and neck	249.40	265.0	261.3	271.7	253.7	260.25	Q^4	10.91
Yield (%)								
Carcass	73.24	71.85	72.72	72.23	73.25	72.68	Q^5	2.49
Relative weight (%)								
Abdominal fat	2.15	2.38	2.46	2.64	2.60	2.45	L^6	23.96
Gizzard	1.89	1.85	1.80	1.76	1.77	1.81	L^7	8.05
Liver	2.14	2.41	2.44	2.62	2.51	2.42	Q^8	10.45
Heart	0.6	0.67	0.67	0.71	0.67	0.68	NS	12.76
Foot	6.31	6.35	6.04	6.03	6.10	6.17	NS	7.95
Head and neck	11.88	12.21	11.83	12.02	11.41	11.87	NS	11.36

NS – not significant (P>0.01); L – linear effect (P<0.01); Q – quadratic effect (P<0.01).
$^1\hat{Y} = 1228.6 + 330x$. $R^2 = 0.6826$; $^2\hat{Y} = -2.0771 + 0.0187x$. $R^2 = 0.8003$; $^3\hat{Y} = -1227 + 826.25x - 132.88x^2$. $R^2 = 0.927$; $^4\hat{Y} = -3190.1 + 2289.8x - 379.04x^2$. $R^2 = 0.714$; $^5Y = 306.14 - 0.1566x + 0.026x^2$. $R^2 = 0.5978$; $^6\hat{Y} = -0.9717 + 0.0011x$. $R^2 = 0.8706$; $^7\hat{Y} = 2.8095 - 0.0003x$. $R^2 = 0.8968$; $^8\hat{Y} = -39.874 + 0.0273x - 0.0043x^2$. $R^2 = 0.9119$.
CV (%) = coefficient of variation.

cells, which may consequently alter the size of the liver.

CONCLUSIONS

Slow- and fast-growing broiler chickens raised in a free-range system adjust their food intake according to the metabolizable energy content of the feed without significantly altering their weight gain.

For slow-growing broiler chickens reared in a free-range system from 35 to 70 days of age, an ME level of 3,046 kcal/kg should provide better feed conversion.

For fast-growing chickens reared in a free-range system from 28 to 49 days of age, the level of 3200 kcal/kg of diet is recommended based on the better feed conversion ratio.

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REFERENCES

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS - ABNT. **NBR 16389:** Avicultura - Produção, abate, processamento e identificação do frango caipira, colonial ou capoeira. São Paulo: ABNT, 2016.

ABUDABOS, A.M.; SALEH, F.; LEMME, A.; ZAKARIA, H.A.H. The relationship between guanidino acetic acid and metabolizable energy level of diets on performance of broiler chickens. **Italian Journal of Animal Science**, v. 13, p. 548-556, 2014. https://doi.org/10.4081/

ijas.2014.3269

ARAÚJO, L. F.; JUNQUEIRA, O. M.; ARAÚJO, C. S. S., BARBOSA, L. C. G. S.; ORTOLAN, J. H.; FARIA, D. E.; STRINGHINI, J. H. Energy and lysine for broilers from 44 to 55 days of age. **Revista Brasileira de Ciência Avícola**, v.7, p.237–2412, 2005. https://doi.org/10.1590/s1516-635x2005000400007

AVILA, V. S.; COLDEBELLA, A.; BRUM, P. A. R.; FIGUEIREDO, E. A. P.; ARMILIATO, N. M. **Níveis de energia metabolizável para frangos de corte de alto desempenho, em criações alternativas**. Concórdia: Embrapa suínos e aves, 2005. (Comunicado Técnico, 398)

BARBOSA, F. J. V.; LOPES, J. B.; FIGUEIRÊDO, A. V.; ABREU, M. L. T.; DOURADO, L. R. B.; FARIAS, L. A.; PIRES, J. E. P. Níveis de energia metabolizável em rações para frangos de corte mantidos em ambiente de alta temperatura. **Revista Brasileira de Zootecnia**, v. 37, p. 849-855, 2008. https://doi.org/10.1590/s1516-35982008000500011

BRANCIARI, R., MUGNAI, C.; MAMMOLI, R.; MIRAGLIA, D.; RANUCCI, D.; DAL BOSCO, A.; CASTELLINI, C. Effect of genotype and rearing system on chicken behavior and muscle fiber characteristics. **Journal Animal Science**, v.87, p. 4109–4147, 2009. https://doi.org/10.2527/jas.2009-2090

CHEN, X.; JIANG, W.; TAN, H.Z.; XU, G.F.; ZHANG, X.B.; WEI, S.; WANG, X.Q. Effects of outdoor access on growth performance, carcass composition, and meat characteristics of broiler chickens. **Poultry Science**, v. 92, p. 435–443, 2013. https://doi.org/10.3382/ps.2012-02360

CODEX ALIMENTARIUS COMMISSION. **Codex guidelines for the production, processing, labeling and marketing of organically produced foods**. Roma, ITA: FAO-OMS, 2001.

CÖMERT, M.; ŞAYAN, Y.; KIRKPINAR, F.; BAYRAKTAR, Ö. H.; MERT, S. Comparison of carcass characteristics, meat quality, and blood parameters of slow and fast grown female broiler chickens raised in organic or conventional production system. **Asian-Australasian Journal of Animal Sciences**, v. 29, p. 987–997, 2016. https://doi.org/10.5713/ajas.15.0812

DOZIER III, W. A.; CORZO, A.; KIDD, M.T.; BRANTON, S.L. Dietary apparent metabolizable energy and amino acid density effects on growth and carcass traits of heavy broilers. **The Journal of Applied Poultry Research**, v.16, p.192–205, 2007. https://doi.org/10.1093/japr/16.2.192

DOZIER, W.A.; PRICE, C. J.; KIDD, M.T.; CORZO, A.; ANDERSON, J.; BRANTON, S. L. Growth performance, meat yield, and economic responses of broilers fed diets varying in metabolizable energy from 30 to 59 days of age. **Journal of Applied Poultry Research,** v.15, p.367–382, 2006. https://doi.org/10.1093/japr/15.3.367

FANATICO, A.C.; PILLAI, P.B.; CAVITT, L.C.; OWENS, C.M.; EMMERT, J.L. Evaluation of slower-growing broiler genotypes grown with and without outdoor access: growth performance and carcass yield. **Poultry Science**, v. 84, p. 1321–1327, 2005. https://doi.org/10.1093/ps/84.8.1321

FERREIRA, G. S.; PINTO, M. F.; PONSANO, E. H. G.; GONÇALVES, C. A.; BOSSOLANI, I. L. C.; PEREIRA, A. G. Ajuste preciso do nível de energia na dieta de frangos de corte para controle do desempenho e da composição lipídica da carne. **Ciência Rural**, v. 45, p. 104-110, 2015. https://doi.org/10.1590/0103-8478cr20130206

FIGUEIREDO, E. A. P.; ÁVILA, V. S.; BRUM, P. A. R.; JAENISCH, F. R. F.; PAIVA, D. R.; BOMM, E. **Frango de corte colonial Embrapa 041**. Concórdia, SC: EMBRAPA-Aves e Suínos, 2006. p. 1-8

GANZER, C.; SIERGET, W.; KLUTH, H.; BENNEWITZ, J.; RODEHUTSCORD, M. Prececal amino acid digestibility of soybean cake in fast and slow-growing broiler chickens. **Poultry Science**, v.96, p. 1-7, 2017. https://doi.org/10.3382/ps/pex090

GHAFFARI, M.; SHIVAZAD, M.; ZAGHARI, M.; TAHERKHANI, R. Effects of different levels of metabolizable energy and formulation of diet based on digestible and total amino acid requirements on performance of male broiler**. International Journal of Poultry Science,** v. 6, p.276-279, 2007. https://doi.org/10.3923/ijps.2007.276.279

GOPINGER, E.; KRABBE, E.L.; SUREK, D.; LOPES, L.S.; AVILA, V.S. Live Performance, Carcass, and Bone Quality Responses of Grower and Finisher Broilers to Dietary Metabolizable Energy Levels. **Brazilian Journal of Poultry Science**, v. 19, n. 4, p. 559-566, 2017. https://doi.org/10.1590/1806-9061-2017-0508

LAGANÁ C.; RIBEIRO, A. M. L.; KESSLER, A. M.; SOUZA, E. N. Influência do nível nutricional da dieta no rendimento de órgãos e gordura abdominal em frangos estressados por calor. **Revista Brasileira de Saúde e Produção Animal**, vol. 6, p. 59-66, 2005.

MADEIRA, L. A.; SARTORI, J. R.; ARAUJO, P. C.; PIZZOLANTE, C. C.; SALDANHA, E. S. P. B.; PEZZATO, A. C. Avaliação do desempenho e do rendimento de carcaça de quatro linhagens de frangos de corte em dois sistemas de criação. **Revista Brasileira de Zootecnia**, v. 39, n. 10, p. 2214-2221, 2010. https://doi.org/10.1590/s1516-35982010001000017

MELLO, J.LM.; BORBA, H.; VIEIRA, L.D.C.; RODRIGUES, A.B.B.; ALVA, J.C.R., GANECO, A.G. Relação entre maciez e concentração de colágeno do músculo pectoralis major em frangos de corte convencionais e do tipo “caipira”. **Revista Científica de Produção Animal**, v.14, p.181-183, 2012. https://doi.org/10.15528/2176-4158/rcpa.v14n2p181-183

MENDONÇA, M. O.; SAKOMURA, N. K.; SANTOS, F. R.; FREITAS, E. R.; FERNANDES, J. B. K.; BARBOSA, N. A. A. Níveis de energia metabolizável para machos de corte de crescimento lento criados em semiconfinamento. **Revista Brasileira de Zootecnia**, v. 37, p. 1433-1440, 2008. https://doi.org/10.1590/s1516-35982008000800014

MENDONÇA, M. O.; SAKOMURA, N. K.; SANTOS, F. R.; BARBOSA, N. A. A.; FERNANDES, J. B. K.; FREITAS, E. R. Níveis de energia metabolizável e relações energia: proteína para aves de corte de crescimento lento criadas em sistema semiconfinado. **Acta Scientiarum Animal Scienses**, v. 29, p. 23-30, 2007. https://doi.org/10.4025/actascianimsci.v29i1.248

MOREIRA, A. S.; SANTOS, M. S. V.; VIEIRA, S. S.; TAVARES, F. B.; MANNO, M. C. Desempenho de frangos caipiras alimentados com rações contendo diferentes níveis de energia metabolizável. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 64, p. 1009-1016, 2012. https://doi.org/10.1590/s0102-09352012000400030

MOYLE, J. R.; ARSI, K.; WOO-MING, A.; ARAMBEL, H.; FANATICO, A.; BLORE, P. J.; CLARK, F. D.; DONOGHUE, D. J.; DONOGHUE, A. M. Growth performance of fast-growing broilers reared under different types of production systems with outdoor access: Implications for organic and alternative production systems, **The Journal of Applied Poultry Research**, v. 23, p. 212–220, 2014. https://doi.org/10.3382/japr.2013-00882

NAHASHON, S.N.; ADEFOPE, N.; AMENYENU, A.; WRIGHT, D. Effects of dietary metabolizable energy and crude protein concentrations on growth performance and carcass characteristics of french guinea broilers. **Poultry Science**, v.84, p.337–344, 2005. https://doi.org/10.1093/ps/84.2.337

NARİNÇ, D.; AKSOY, T.; ÖNENÇ, A.; ÇÜREK, I. The Influence of Body Weight on Carcass and Carcass Part Yields, and Some Meat Quality Traits in Fast- and Slow-Growing Broiler Chickens. **Kafkas Univ Vet Fak Derg**, v. 21, p. 527-534, 2015. https://doi.org/10.9775/kvfd.2014.12878

NASCIMENTO, E. S.; LIMA, C. A. R.; BRASIL, R. J. M.; MACHADO, N. J. B.; SOUSA, F. D. R.; CORRÊA, G. S. S. Digestible lysine for broiler chickens with lower genetic potential grown on free-range system. **Ciência e Agrotecnologia**, v. 40, p. 454-463, 2016. https://doi.org/10.1590/1413-70542016404009316

OLIVEIRA, K.P.; FERREIRA, C.F.S.; TINOCO, I.F.F.; ANDRADE, R.R.; BARBARI, M.; CRUZ, V.M.F.; BAPTISTA, F.J.F.; VIEIRA, M.F.A.; CONTI, L.; ROSSI, G. Productive performance of broilers at the final stage of breeding submitted to different levels of metabolizable energy in different thermal environments. **Agronomy Research,** v. 16, p. 556- 563, 2018. http://dx.doi.org/10.15159/ar.18.069

POŁTOWICZ, K.; DOKTOR, J. Effect of free-range raising on performance, carcass attributes and meat quality of broiler chicken. **Animal Science Papers and Reports**. v. 29, p.139-149, 2011.

ROSTAGNO, H. S.; ALBINO, L. F. T.; DONZELE, J. L.; GOMES, P. C.; OLIVEIRA, R. F.; LOPES, D. C.; FERREIRA, A. S.; BARRETO, S. L. T. **Tabelas brasileiras para aves e suínos:** composição de alimentos e exigências nutricionais de aves e suínos. 2. ed. Viçosa, MG: UFV, 2005. 186 p.

SAKOMURA, N. K.; LONGO, F. A.; RABELLO, C. B.; WATANABE, K.; PELÍCIA, K.; FREITAS, E. R. Efeito do nível de energia metabolizável da dieta no desempenho e metabolismo energético de frango de corte. **Revista Brasileira de Zootecnia**, v. 33, p. 1758-176, 2004. https://doi.org/10.1590/s1516-35982004000700014

SANTOS, M. S. V.; VIEIRA, S. S.; TAVARES, F. B.; ANDRADE, P. A.; MANNO, M. C.; COSTA, H. S.; MOREIRA, A. S. Desempenho, carcaça e cortes de frangos caipira francês barré (gris barré cou plumé). **Archivos de zootecnia**, v. 61, p. 287-295, 2012. https://doi.org/10.4321/s0004-05922012000200013

SILVA, J. H. V.; ALBINO, L. F. T.; NASCIMENTO, A. H. Níveis de energia e relações energia: proteína para frangos de corte de 22 a 42 dias de idade. **Revista Brasileira de Zootecnia**, v. 30, p. 1791-1800, 2001. https://doi.org/10.1590/s1516-35982001000700017

SOKOŁOWICZ, Z.; KRAWCZYK, J.; ŚWIĄTKIEWICZ, S. Quality of Poultry Meat from Native Chicken Breeds – A Review. **Annals of Animal Science**, v. 16, p. 347-368, 2016. https://doi.org/10.1515/aoas-2016-0004

UNIVERSIDADE FEDERAL DE VIÇOSA - UFV. **SAEG – Sistema de análise estatística e genética**. Viçosa – MG: UFV, 2001. 96p.

XAVIER, S.A.G.; STRINGHINI, J.H..; BRITO, A.B.; ANDRADE, M.A.; LEANDRO, N.S.M.; CAFÉ, M.B. Níveis de energia metabolizável em rações pré-iniciais para frangos de corte. **Revista Brasileira de Zootecnia**, v. 37, p. 109-115, 2008. https://doi.org/10.1590/s1516-35982008000100016