Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X Oct - Dec 2017 / v.19 / n.4 / 559-566

http://dx.doi.org/10.1590/1806-9061-2017-0508

Live Performance, Carcass, and Bone Quality Responses of Grower and Finisher Broilers to Dietary Metabolizable Energy Levels

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■Keywords

Bone, carcass, energy efficiency, feed conversion ratio, feed intake.

Submitted: 22/March/2017
Approved: 11/June/2017

ABSTRACT

Broiler energy nutrition has attracted attention due to its economic importance, particularly during the rearing period of 22-42 days of age. There are many evidences that broilers changed their feed intake capacity due to genetic selection, especially when good quality pellets are fed, which suggests that modern broiler strains may achieve good performance when fed low metabolizable energy levels. The objective was to evaluate the energy efficiency, performance parameters, bone parameters, and carcass yield of 22- to 42-d-old broilers fed diets with energy levels below or above their requirements, while maintaining the density of all other nutrients. In total, 900 male broilers were distributed in a randomized block design, with five treatments consisting of five ME levels (2850, 2950, 3050, 3150 and 3250 kcal/kg). As expected, increasing dietary metabolizable energy reduced feed intake, feed conversion ratio, and energy efficiency. Interestingly, body weight, carcass and cut yields, and bone quality were not affected (p>0.05) by dietary ME levels. In conclusion, 22- to 42-d-old broilers fed pelleted and crumbled diets containing 2,850 to 3,250 kcal ME/kg (14% difference) achieved the same body weight and carcass yield at slaughter. The results show that energy efficiency may provide a more accurate interpretation of broiler performance than feed conversion ratio, and that broilers are able to change their feed intake, indicating an opportunity to improve their nutritional management.

INTRODUCTION

Broiler energy nutrition has attracted attention due to its economic importance, particularly during the period from 22 up to 42 days of age. At this stage, broilers require a large amount of feed to achieve adequate body development, which represents approximately 80% of feed supplied during the entire grow-out cycle. This has a strong impact on production costs, and therefore needs to be closely monitored.

Metabolizable energy is the standard measure used to describe the energy requirement of poultry (NRC, 1994). The increase of expenses with dietary energy sources, especially for grower and finisher broilers, has been a subject of continued research (Abudabos *et al*., 2014).

Dietary energy plays a key role for animals because it is used in metabolic, maintenance and production processes. Poultry feeding programs are established based on energy requirements to allow the optimization of the productive, economic and environmental aspects of the production systems (Sakomura *et al*., 2014). In this sense, it is important to explore the energy metabolism of broilers taking into consideration sex, age, environmental conditions, the physical form of feed, energy efficiency, and protein and fat carcass deposition.

Dietary metabolizable energy level plays a key role in broiler feed intake regulation and feed efficiency (Abudabos *et al*., 2014). Indeed, the influence of dietary apparent metabolizable energy (ME) content on poultry feed intake has been well demonstrated (Leeson & Summers, 2001), as the feed intake of broilers with unrestricted access to feed increases or decreases as a function of dietary ME levels.

Broiler genetic selection has focused on live performance, particularly on feed conversion ratio and weight gain in particular. Commercial broiler strains have been selected for high growth rate and high feed efficiency based on the use of highly digestible diets with no metabolizable energy (ME) limitations, and it was demonstrated that fast-growing broiler strains have higher feed intake capacity compared with non-selected strains (Krás *et a*l., 2012).

Therefore, the knowledge on broiler growth and energy metabolism needs be revaluated, considering the factors that affect them, as well as the supply of other dietary nutrients, such as protein. This will allow the manipulation of feed formulation to improve carcass characteristics by promoting protein accretion and reducing fat deposition in the carcass.

This experiment was designed to better understand the nutrient requirements and the feeding behavior of a modern high-yield broiler strain, based on field observations reported by farmers and broiler companies, considering that genetic companies supply a new genetic package of broilers every four year. It is believed that modern high-yield broiler strains may present good performance when fed lower dietary metabolizable energy content than the current practice. The objective of this study was to evaluate the energy efficiency of broilers fed diets with energy density below and above the recommended levels, while maintaining the nutritional density of all other nutrients. Cobb male broilers between 22 and 42 days of age, were evaluated for growth performance, bone parameters and carcass yield.

MATERIAL AND METHODS

A total of 900maleCobb 500 (year 2014) broilers were housed in an experimental conventionally-built broiler house located at EMBRAPA, Concordia, SC, Brazil. The house concrete floor was covered with pine wood shavings litter. Pens were equipped with nipple drinkers (five nipples/pen) with a flow of 50 mL/min, and a tube feeder with capacity of 15 kg. During the experimental period (from 22 to 42 days of age), the birds received feed and water *ad libitum*, and alighting program of 14 hours of light and 10 hours of dark was applied, controlled by a timer. Light was provided by 60-W incandescent bulbs.

A fan ventilation system and adjustable curtains were used for the control of environmental house conditions. Maximum and minimum house temperatures and air humidity were recorded fulltime using five data loggers (model 175-T1, Testo, Brazil) placed inside pens at the birds' height.

Birds were distributed according a randomized block design, using initial body weight as blocking criterion, with five treatments (five dietary metabolizable energy levels) with nine replicates of 20 bird each, totaling 45 experimental units (pens).

The experimental diets were formulated to supply the nutritional requirements of grower (22 to 35 days of age) and finisher (36 to 42 days of age) broilers, according to recommendations of Rostagno *et al.* (2011). Five levels of dietary metabolizable energy (ME) were evaluated: 2,850; 2,950; 3,050; 3,150; and 3,250 kcal/kg, as shown in Table 1. These dietary ME levels aimed at supplying two levels lower and two levels higher than those recommended by Rostagno *et al*. (2011), of 3,050 kcal/kg for 22- to 35-d-old broiler, and 3,100 kcal/kg for 36- to 42-d-old broilers.

The diets were manufactured at the feed mill of EMBRAPA, Concordia, SC, Brazil. The ingredients were ground and mixed in a vertical mixer. The mash was pelleted in a pellet mill (model Koppers Júnior C40, CPM, Brazil), with a nominal capacity of 3 ton/h, operating at a pressure of 2.4 kgf/cm². The mash was conditioned at a temperature at the exit of the equipment of 68-70ºC for 15 s. The pelleting die 50-mm thick, with 4.75-mm holes. After pelleting, the feeds were crumbled in a roll mill for particle size reduction. The increase in dietary ME levels was achieved by increasing the inclusion of soybean oil at the expense of inert material.

The following growth performance parameters were evaluated: body weight (BW), weight gain (WG), feed intake (FI), and feed conversion ratio (FCR). The birds were weighed on day 1 of the experiment (22 days old), and then weekly until the end of the experimental period (42 days of age). The feeders were checked daily, and refilled to provide always the same feed allowance. The leftover feed in the feeders was weekly weighed to calculate weekly FI and FCR. Mortality was recorded daily. All dead birds were weighed, and their weight used to adjust FCR. Furthermore, the ratio between dietary energy intake and weight gain was

Table 1 – Ingredients and nutritional composition of the experimental diets fed to grower (22-35 days old) and finisher (36-42 days old) 500 male Cobb broilers.

Ingredient, %	22-35 days old					36-42 days old				
	Dietary ME levels (kcal/kg)					Dietary ME levels (kcal/kg)				
	2,850[1]	2,950[1]	3,050[1]	3,150[1]	3,250[1]	2,850[1]	2,950[1]	3,050[1]	3,150[1]	3,250[1]
Corn (7.5%)	56.00	56.00	56.00	56.00	56.00	59.04	59.04	59.04	59.04	59.04
Soybean meal (45%)	33.11	33.11	33.11	33.11	33.11	31.08	31.08	31.08	31.08	31.08
Soybean oil	2.34	3.48	4.61	5.75	6.89	1.73	2.87	4.01	5.15	6.28
Inert material (kaolin)	5.00	3.86	2.73	1.59	0.45	5.00	3.86	2.73	1.59	0.45
Dicalcium phosphate [2]	1.26	1.26	1.26	1.26	1.26	1.01	1.01	1.01	1.01	1,01
Limestone[3]	0.87	0.87	0.87	0.87	0.87	0.81	0.81	0.81	0.81	0.81
Salt	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
DL-Methionine	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Mycotoxin adsorbent	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
L-Lysine	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19
Vitamin premix[4]	0.10	0.10	0.10	0.10	0.10	0.07	0.07	0.07	0.07	0.07
Mineral premix[5]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
L-Threonine	0.08	0.08	0.08	0.08	0.08	0.06	0.06	0.06	0.06	0.06
Choline	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Antoxidant (BHT)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Coccidiostat[6]	0.05	0.05	0.05	0.05	0.05	-	-	-	-	-
Colistin	0.005	0.005	0.005	0.005	0.005	-	-	-	-	-
TOTAL	100	100	100	100	100	100	100	100	100	100
Nutritional composition										
ME, kcal/kg	2850	2950	3050	3150	3250	2850	2950	3050	3150	3250
CP, %	19.19	19.19	19.19	19.19	19.19	18.46	18.46	18.46	18.46	18.46
Ca, %	0.73	0.73	0.73	0.73	0.73	0.64	0.64	0.64	0.64	0.64
Av. P, %	0.35	0.35	0.35	0.35	0.35	0.30	0.30	0.30	0.30	0.30
Total P, %	0.59	0.59	0.59	0.59	0.59	0.54	0.54	0.54	0.54	0.54

[1]ME - kcal/kg

[2]Calcium: minimum 210g/kg, maximum 250g/kg; Phosphorus: 180g/kg;

[3]Calcium: minimum 33%;

[4]Guaranteed levels per kg of product: Vitamin A: 9,000,000 IU, Vitamin D3: 2,500,000 IU, Vitamin E: 20,000 IU, Vitamin K3: 2,500mg, Vitamin B1: 1,500mg, Vitamin B2: 6,000mg, Vitamin B2: 6,000mg, Vitamin B6: 3,000mg, Vitamin B12: 12,000mcg, Pantothenic Acid: 12g, Niacin: 25g, Folic Acid: 800mg, Biotin: 60mg, Selenium: 250mg.

[5]Guaranteed levels per kg of product: Copper: 20g, Iron: 100g, Manganese: 160g, Cobalt: 2,000mg, Iodine: 2,000mg, Zinc: 100g.

[6]Sodium monensin (Coban, Elanco)

calculated to determine the efficiency of the utilization of dietary energy, and expressed as calorie intake per gram of body weight gain.

At 42 days of age, two birds per pen (18 per treatment) with BW closest to the average BW of the pen (± 5%) were selected, duly identified with numbered leg bands, weighed, and slaughtered at the experimental processing plant of EMBRAPA, Concordia, SC, Brazil. The birds were electrically stunned and bled, according to the guidelines of the Ethics Commission on the Use of Animals of the Brazilian Agricultural Research Agency, Swine and Poultry, protocol n. 012/2013, in agreement with the Brazilian legislation, resolution n. 1000 of 05/2012.

Immediately after slaughter, carcasses were weighed to determine hot eviscerated carcass weight (no head, feet, and viscera). Chilled carcass weight was determined after the carcasses remained for 24 hours in a cooling chamber (0-5°C). After carcass cutup, breast, thighs, drumsticks, wings and abdominal fat weights were recorded. Parts yields were calculated as part weight (g) relative to chilled carcass weight, according to the formula: Yield = [(part weight/chilled carcass weight)*100].

At the end of the experimental period, two other birds per experimental unit with BW closest to the average BW of the pen (± 5%) were selected, duly identified with numbered leg bands, and sacrificed by cervical dislocation. The left tibia was removed for the evaluation of bone quality parameters, which included bone strength, rigidity, and flexibility. Bone strength was determined using a texture analyzer (TA XT Plus Texture Analyzer ©Texture Technologies Corporation, USA) with a 3-PointBending Rig probe (HDP/3PB and HDP/90), coupled to the software Exponent (Stable Micro Systems). The bones were held on two supports with a total distance of 40 cm between the two supporting ends. Bone strength (kgf) is given by force applied per bone area, and is influenced by factors such as bone size and mineral composition. The ratio between bone strength and distance (bone size) represents bone rigidity (mm). Bone flexibility is represented by the area. The flexibility measures the bone deformity as a function of the force applied on it.

After physical analysis, the tibiae were dried in an oven at 105°C (Instituto Adolfo Lutz, 2008) to determine DM content and then burnt in a muffle (CBAA, 2009) to determine bone ash content (A), according to the AOAC (1995).

Data were subjected to analysis of variance using the MIXED procedure of SASÔ statistical package (SAS, 2008). The fixed effect of treatments and the random effect of blocks were tested. Means were compared by the least significant difference (LSD) test. When parameters were significantly different (p≤0.05), polynomial contrasts were tested, and regression equations were generated.

RESULTS

During the grower period (22 to 35 days of age), feed intake and feed conversion ratio were significantly influenced by dietary ME levels (p≤0.05), as shown in Table 2. Feed intake was linearly reduced and FCR linearly improved as ME levels increased (Figures 1 and 2). There was no effect of the treatments on WG or BW during this period (*p*>0.05). The highest energy efficiency ratio (EER) was observed with the highest dietary ME level (3,250 kcal ME/kg), whereas the birds fed the diets containing 2,850; 2,950; and 3,050 kcal ME/kg presented statistically similar EER (*p*>0.05; Table 2).

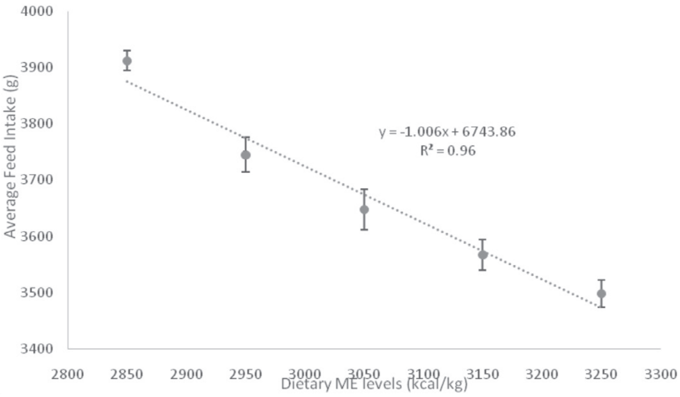

Figure 1 – Effect of dietary energy levels on the feed intake 22- to 42-d-old broilers

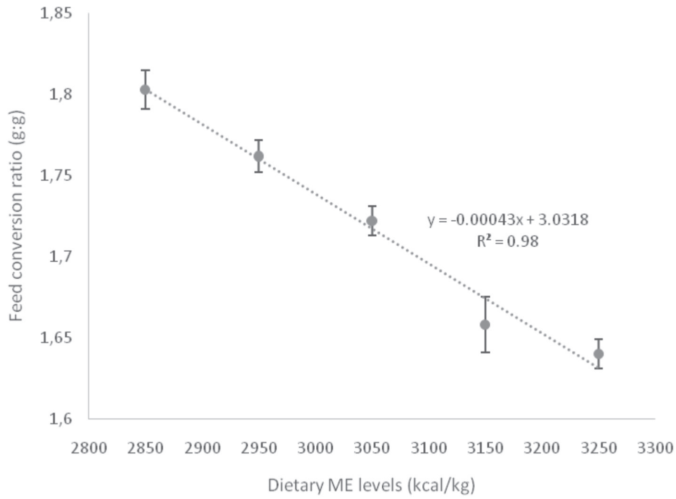

Figure 2 – Effect of dietary energy level on the feed conversion ratio of 22- to 42-d-old broilers

Table 2 – Growth performance of Cobb 500 male broilers fed diets withdifferent metabolizable energy levels (mean ± standard error) from 22 to 42 days age

		Dietary ME levels (kcal/kg)						
Age (days)	Parameters	2,850	2,950	3,050	3,150	3,250	CV (%)	*p*-value
22 –35	WG (g)	1409± 8.12	1392±11.81	1397±13.57	1394±16.59	1394± 8.17	2.51	0.8148
	FI (g)*	2342±17.17 a	2248±19.70 b	2194±23.36 c	2144±23.97 d	2135±10.76 d	4.30	<0.0001
	FCR (g:g)*	1,662±0.009 a	1,615±0.01 b	1,571±0.008 c	1,538±0.008 d	1,532±0.01 d	3.55	<0.0001
	BW (g)	2310±12.10	2296±13.80	2300±16.80	2291±22.40	2294±12.44	2.00	0.8197
	EE (kcal:g)	4.737±0.02 c	4.765±0.02 c	4.790±0.02 bc	4.846±0.02 b	4.980±0.03 a	2.48	<0.0001
35 – 42	WG (g)	761± 8.39	734±11.15	723±20.37	760±22.46	740± 9.63	6.31	0.3127
	FI (g)*	1570±12.63 a	1497±16.68 b	1455±24.31 bc	1423±17.22 c	1363±25.58 d	6.19	<0.0001
	FCR (g:g)*	2,066±0.023 a	2,040±0.018 a	2,019±0.031 a	1,882±0.046 b	1,845±0.036 b	6.57	<0.0001
	BW (g)	3068±11.03	3032±21.83	3022±20.82	3029±19.77	3029±18.08	1.84	0.3203
22 – 42	WG (g)	2170± 8.75	2126±20.87	2119±18.35	2154±31.49	2133±14.96	2.85	0.2855
	FI (g)*	3912±17.43 a	3745±30.66 b	3648±35.62 c	3567±27.09 d	3498±24.31d	4.53	<0.0001
	FCR (g:g)*	1,803±0.01 a	1,762±0.010 b	1,722±0.009 c	1,658±0.01 d	1,640±0.009 d	4.13	<0.0001
	EER (kcal:g)	5.158±0.03 c	5.203±0.03 bc	5.251±0.02 b	5.260±0.03 b	5.348±0.03 a	2.14	<0.0001

CV: coefficient of variation; WG: weight gain (g); FI: feed intake (g); FCR: feed conversion ratio; BW: body weight (g); EER: energy efficiency ratio (kcal:g).* Significant linear effect. Equation for FI (22-35 d) =3792.71 - 0.518x; R^2= 0.92; Equation for FCR (22-35 d)= 2.6102 - 0.00034x; R^2= 0.94; Equation for FI (35-42 d)= 2951.15 - 0.4883x; R^2= 0.98; Equation for FCR (35-42 d)= 3.8045 - 0.0006x; R^2= 0.90; Equation for FI (22-42 d)= 6743.86 - 1.006x; R^2= 0.96; Equation for FCR (22-42 d)= 3.0318 - 0.00043x; R^2= 0.98;

During the finisher period (35 to 42 days of age), FI linearly decreased with increasing dietary ME levels, with the lowest FI ($p \leq 0.05$) obtained with the highest dietary ME level (3,250 kcal/kg). Birds fed the diets with ME levels below the requirements (<3,150 kcal/kg) presented worse FCR than those fed 3,150 and 3,250 kcal ME/kg diet. Again, WG and BW were not affected by dietary ME levels.

Considering the entire experimental period (22-42 days of age), FI and FCR results linearly decreased as dietary ME level increased. The birds fed 3,250 and 3,150 kcal ME/kg presented the lowest FI and FCR values compared with the other treatments. Broiler WG was not affected by the treatments. The increase in dietary levels promoted a linear increase in EER, with the best EER observed in the birds fed the diets containing 2,850 and 2,950 kcal ME/kg.

The tested dietary ME levels did not influence ($p > 0.05$) carcass and parts cut yields (Table 3), nor the evaluated bone quality parameters (tibial bone strength, rigidity, flexibility, and ash content; Table 4).

DISCUSSION

The results indicate that feed intake was reduced and feed conversion ratio improved with increasing dietary levels of metabolizable energy, as previously reported by Leeson & Summers (1996). According to those authors, broiler chickens are capable of regulating their feed intake, which is reduced as dietary energy density increases. Zhai *et al*. (2014) also determined that increasing dietary ME levels reduced the feed intake of 28- to 35-d-old broilers. On the other hand, according to Leeson *et al.* (1996), when the energy levels of broiler diets were reduced, feed intake increased and body weight and weight gain decreased, resulting in worse feed conversion ratio. Dietary energy levels are usually increased by the inclusion of fats and oils, and therefore, the FI reduction and FCR improvement observed in the present experiment may be attributed to the high energy density of fats and to their extra caloric effect, i.e., dietary fat inclusion increases the availability of the nutrients in the feed ingredients and energy efficiency (Sakomura *et al*., 2004). On the other hand, Abudabos *et al*. (2014) fed broilers with diets containing 75, 50 and 25 kcal ME/kg below the requirements (3,150 kcal/kg), and did not observe any effect on FI, WG, or FCR in none of the evaluated periods (22-35 and 35-42 days of age, or during the entire experimental period, from 22 to 42 days of age).

In general, dietary energy levels are calculated to supply the maintenance and growth requirements of animals. According to Leeson & Summers (2001), voluntary feed intake of broilers is regulated by energy

Table 3 – Carcass and parts yields of Cobb 500 male broilers fed diets with different metabolizable energy levels (mean ± standard error) from 22 to 42 days age.

	Dietary ME levels (kcal/kg)						
Yields, %	2,850	2,950	3,050	3,150	3,250	*p*-value	CV
Hot carcass*	79.75±0.54	78.91±0.62	78.84±0.21	79.47±0.37	78.14±0.55	0.184	1.89
Chilled carcass**	81.26±0.48	80.26±0.60	80.21±0.21	81.03±0.35	79.58±0.50	0.089	1.78
Breast	34.10±0.62	34.64±0.38	34.50±0.55	34.69±0.38	34.11±0.62	0.878	4.44
Wing	9.28±0.10	9.37±0.10	9.29±0.09	9.23±0.13	9.25±0.10	0.916	3.38
Thigh	12.27±0.15	11.94±0.16	11.87±0.11	12.02±0.13	12.41±0.17	0.075	3.91
Drumstick	16.73±0.15	16.99±0.20	17.24±0.19	16.99±0.23	16.91±0.17	0.402	3.42
Abdominal fat	1.33±0.07	1.40±0.098	1.58±0.17	1.48±0.09	1.51±0.12	0.597	23.72

*eviscerated carcass weight measured before chiller; ** carcass weight after chiller for 24 hours in a cooling chamber (0 and 5°C).Parts yields are expressed relative to cold carcass yield. *P*-value: 5% significance level by the LSD test; CV- Coefficient of variation (%).

Table 4 – Tibial strength, rigidity, flexibility, and ash content of Cobb 500 male broilers fed diets with different metabolizable energy levels (mean ± standard error).

ME (kcal/kg)	Strength (kgf)	Rigidity (mm)	Flexibility (kgf.mm)	Ash content (%DM*)
2,850	47.79±1.14	10.17±1.11	102± 4.52	21.80±0.39
2,950	47.88±1.40	9.904±1.24	102± 6.74	22.31±0.21
3,050	44.54±2.32	9.928±0.72	93.75±5.60	22.40±0.30
3,150	46.54±2.90	10.66±0.58	95.60±8.37	22.09±0.23
3,250	50.63±2.10	10.27±0.97	120± 8.36	21.80±0.34
p-value	0.353	0.980	0.079	0.448
CV (%)	13.19	27.06	21.23	4.11

*Dry Matter. *p*-value- 5% significance level by the LSD test; CV- Coefficient of variation (%).

intake; therefore, broilers fed diets with energy levels higher than those required may reduce their feed intake. On the other hand, broiler fed diets with energy values lower than the requirements increase their feed intake up to the physical limitation of their digestive system, resulting in a reduction in the efficiency of digestive enzymes (Sakomura *et al*., 2004). In the present experiment, there seemed to be no physical limitation of intake, as shown by the lack of significant differences in weight gain. This may be attributed to the high feed intake capacity of the modern broiler strain evaluated and to the fact that the feed was pelleted and crumbled. According to Abdollahia *et al.* (2013), pelleting has a positive effect on feed efficiency.

As an alternative to feed conversion ratio, energy efficiency ratio has become important as a measure of broiler productivity in recent years. In the present study, the broilers fed low ME levels (2,850 and 2,950 kcal/kg) showed better energy efficiency for weight gain, whereas better FCR were obtained with the higher ME levels (3,150 and 3,250 kcal/kg).

Carcass and parts yields were not influenced by dietary ME levels, indicating the extraordinary yield potential of modern broiler strains. However, these results raise questions on nutrient partition in the body, and suggest that broiler production is a multifactorial and dynamic process that is influenced by multiple factors, such as genetics, nutrition, management, health and environment, and their interactions. Therefore, further research to evaluate the influence of the association of these factors on carcass parameters are needed. The results of the present study are consistent with those of Abudabos *et al*. (2014), who fed broilers with diets with 75, 50 and 25 kcal ME/kg lower than the requirements, and did not observe any effects on breast, thigh, drumstick and abdominal fat yields. On the other hand, Azizi *et al*. (2011) reported higher carcass and breast weights in broilers fed diets which ME level was reduced from 3,125 kcal/kg to 2,968 kcal/kg and which protein level was reduced from 18.38% to 17.46% during the finishing phase (21-42 days old). Zhai *et al*. (2014) observed that an increase in ME levels increased carcass fat yield and reduced wing yield, which was not observed in this study. Leeson *et al.* (1996) found that broilers fed low dietary energy levels presented reduced abdominal fat content. In the present trial, there was no effect of dietary ME content on abdominal fat deposition, which also indicates that the tissue deposition of broilers changed over time, even when consuming diets with 3,250 kcal ME/kg.

The evaluated bone quality parameters were not affected by dietary metabolizable energy levels. The reduction of feed intake and, consequently of mineral intake due to the increase in dietary energy levels did not affect the evaluated bone quality parameters. Calcium and phosphorus intakes were 27.14 g and 12.97 g, respectively, for the diet with 2,850 kcal ME/kg, and 24.30 g and 11.56 g, respectively, for the diet with 3,250 kcal ME/kg. This indicates that, although the ME level of the diet containing 2,850 kcal ME/kg was below the requirements, the nutrients essential for bone formation were adequately absorbed and their deposition in the bones was not affected. These results are important not only because of the fast body weight gain of modern broiler strains, but also their rate of bone formation. In addition, the possible reduction in broiler growth rate due to the consumption of reduced-energy diets was not observed in the present study because the birds compensated the energy deficiency by increasing feed intake.

CONCLUSIONS

In conclusion, 22- to 42-day-oldmale consuming pelleted and crumbled diets containing 2,850 to 3,250 kcal ME/kg are able to compensate dietary energy deficiencies by increasing their feed intake, and eventually achieved the same body weight, carcass yield and bone quality at 42 days of age. The difference in feed intake was 11.8% between the diets with highest and lowest ME levels.

Energy efficiency ratio may provide a more accurate interpretation of broiler performance than feed conversion ratio, both from the economic and sustainability perspectives, as less energy would need to added to the feeds, resulting in savings in feed costs and land use for energy crops.

The results show that broilers are able to change their feed intake as a function of dietary ME level, indicating an opportunity to improve their nutritional management. A broader analysis, combining economic assessments, sustainability, feed production capacity, and other aspects, on dietary metabolizable energy levels for grower and finisher broilers may aid decision-making in the poultry industry.

REFERENCES

Abdollahia MR, Ravindrana V, Svihusb B. Pelleting of broiler diets: an overview with emphasis on pellet quality and nutritional value. Animal Feed Science and Technology 2013;179:1– 23.

Abudabos AM, Saleh F, Lemme A, Zakaria HAH. The relationship between guanidino acetic acid and metabolizable energy level of diets on performance of broiler chickens. Italian Journal of Animal Science 2014;13:548-556.

AOAC - Association of Official Analitical Chemists . Official methods of analysis. 16th ed. Washington;1995. 1094p.

Azizi B, Sadeghi G, Karimi A, Abed F. Effects of dietary energy and protein dilution and time of feed replacement from starter to grower on broiler chickens performance. Journalof Central EuropeanAgriculture 2011;12:44-52.

CBAA - Compêndio Brasileiro de Alimentação Animal. Cinzas ou matéria mineral. São Paulo: Sindirações; 2009. 127 p.

Instituto Adolfo Lutz. Métodos físico-químicos para análise de alimentos. 4th ed. São Paulo; 2008.

Krás RV, Kessler AM, Ribeiro AML, Henn JDi, Santos II dos, Halfen DP, et al. Effect of dietary fiber and genetic strain on the performance and energy balance of broiler chickens. Brazilian Journal of Poultry Science 2013;15(1):15-20.

Leeson S, Caston L, Summers JD. Broiler response to energy or energy and proteindilution in the finisher diet. Poultry Science 1996;75:522-528.

Leeson S, Summers DJ. Nutrition of the chicken. 4th ed. Ontario: University Books; 2001.

NRC - National Research Council. Nutrient requirements of poultry. 9th ed. Washington: National Academy Press; 1994.

Rath NC, Balog JM, Huff WE, Kulkarni GB, Tierce JF. Comparative differences in the composition and biomechanical properties of tibiae of seven- and seventy-two-week-old male and female broiler breeder chickens. Poultry Science 1999;78:1232–1239.

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: UFV; 2011.

Sakomura NK, Hauschild L, Bonato MA. Modelagem da utilização da energia nas aves. In: Sakomura, NK. Nutrição de não ruminantes. Jaboticabal: Funep; 2014. p.313- 329.

Sakomura NK, Longo FA, Rabello CB, Watanabe K, Pelícia K, Freitas ER. Efeito do nível de energia metabolizável da dieta no desempenho e metabolismo energético de frangos de corte. Revista Brasileira de Zootecnia 2004;33:1758-1767.

SAS Institute Inc. System for microsoft windows. Release 9.2 [CD ROM]. Cary; 2008.

Zhai W, Peebles ED, Mejia L, Zumwalt CD, Corzo A. Effects of dietary amino acid density and metabolizable energy level on the growth and meat yield of summer-reared broilers. Journal Applied Poultry Research 2014;23:501–515.