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Metabolizable energy levels in diets for slow-growing chickens

Níveis de energia metabolizável em dietas para frangos de crescimento lento

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Abstract: In this study, we aimed to assess the impact of four levels of metabolizable energy (ME) in feed for slow-growing male and female chickens on their growth performance, carcass yield, and nutrient metabolizability. For growth performance and carcass yield analyses, 480 male and female Isa Label chicks were distributed in a completely randomized design in a 4 × 2 factorial scheme. The birds were fed experimental diets containing 4 different ME levels (2,725, 2,850, 2,975, and 3,100 kcal/kg) during two different feeding periods ranging from 1–28 and 1–56 days of age, with each treatment group consisting of 6 replicates of 10 birds each. The effects of these feeding treatments on growth performance were assessed at 28 and 56 days of age, whereas those on carcass yield were evaluated at 56 days of age. The metabolic analysis was carried out by total excreta collection from 17 to 21 days, using the same treatments as in the growth performance and carcass yield analyses and eight replicates of 10 birds, totaling 320 birds. The data were subjected to the analysis of variance and polynomial regression for ME levels. At 28 days, the chickens showed significant differences in their live weight, weight gain, and feed consumption. Moreover, a positive quadratic regression was found for live weight and weight gain, and a negative linear regression was obtained for feed conversion. At 56 days, a quadratic regression was found for feed consumption and conversion, with no effect on carcass or prime cut yields. Nitrogen balance and nitrogen metabolizability coefficient showed a quadratic regression effect. A positive linear regression was found for ether extract balance, and a quadratic regression was obtained for the metabolizability coefficient. The variables apparent ME and the ME corrected for nitrogen showed a positive linear regression effect. It can be concluded that feed containing 2,900-2,930 kcal ME/kg is recommended for broiler chickens during 1–28 days of their age, regardless of sex.

Key-words: growth performance; metabolizability; nutrition; carcass yield.

Resumo: Objetivou-se avaliar quatro níveis de energia metabolizável (EM) na ração para frangos machos e fêmeas: de crescimento lento, sobre desempenho, rendimento de carcaça e metabolizabilidade dos nutrientes. Para o estudo de desempenho e rendimento de carcaça, 480 pintos machos e fêmeas Isa Label foram distribuídos em delineamento inteiramente casualizado em esquema fatorial 4x2, quatro níveis de EM (2.725, 2.850, 2.975 e 3.100 kcal/kg), com seis repetições de 10 aves, sendo avaliados os períodos de 1 a 28 e um a 56 dias de idade. No segundo estudo, foi realizado um ensaio metabólico com coleta total de excretas de 17 a 21 dias, com os mesmos tratamentos do ensaio de desempenho, oito repetições com 10 aves cada, totalizando 320 aves. Os dados foram submetidos à análise de variância e regressão polinomial para níveis de energia metabolizável. Os resultados mostraram que, aos 28 dias, os frangos apresentaram diferenças significativas para peso, ganho de peso, consumo de ração, com regressão quadrática positiva para peso e ganho de peso, e regressão linear negativa para conversão alimentar. Aos 56 dias, observou-se regressão quadrática para consumo de ração e conversão alimentar, sem efeito para rendimento de carcaça ou cortes nobres. O balanço de nitrogênio e o coeficiente de metabolizabilidade de nitrogênio mostraram efeito de regressão quadrática. Para o extrato etéreo, houve regressão linear positiva para o balanço e quadrática para o coeficiente de metabolizabilidade. As variáveis energia metabolizável aparente e energia metabolizável corrigida pelo nitrogênio apresentaram efeito de regressão linear positiva. Conclui-se que a ração com níveis de 2.900-2.930 kcal de EM/kg é recomendada para frangos de corte, independentemente do sexo, no período de 1 a 28 dias.

Palavras-chave: desempenho; metabolizabilidade; nutrição; rendimento de carcaça.

1. Introduction

It is necessary to meet the nutritional levels, particularly metabolizable energy (ME) levels, to ensure adequate zootechnical performance of slow-growing chickens, as this can affect feed cost and carcass quality. However, most diets prepared for slow-growing chickens are based on nutritional information from research on industrial chickens, as few studies have been conducted to assess the nutritional requirements of slow-growing chickens, such as their ME requirements [(1)].

The required dietary levels of ME are defined based on various factors, such as the requirement of birds, the composition of feed, the cost of ingredients, and the product to be produced. Establishing the optimal dietary ME level is the main challenge in meeting the nutritional needs of slow-growing chickens and is necessary for ensuring their maximum performance and low-fat content in the carcass [(2)]. Studies related to ME requirements in slow-growing chicken feed have indicated a range of recommendations, namely 2,700 kcal [(2)] and 3,200 kcal [(3)] in all stages of rearing, 2,744 kcal to 2,908 kcal during the starter phase at 28 days [(4)], 2,850 kcal during the growth phase, and 3,100 kcal during the final rearing stage [(5)].

Increasing the ME levels in bird feed can help improve weight gain and feed conversion but can also lead to reduced slaughter age and increased abdominal fat in birds [(5)]. Consequently, the product may be relatively less acceptable to consumers looking for traditionally lean meat [(6)]. Extremely few studies have assessed the nutritional impact of feed on slow-growing chickens. These strains possess unique characteristics, exhibit growth curves and rates different from those of fast-growing strains, and use nutrients from food in a manner different from that observed in fast-growing birds.

Based on these considerations, in this study, we aimed to assess ME levels in starter diets for slow-growing chickens and their effects on the growth performances and carcass yields of males and females and determine the metabolizability coefficients of nutrients

2. Material and methods

Two studies were carried out, previously approved by the Ethics Committee on the Use of Animals under protocol 063/18 of the Federal University of Goiás (UFG). The first experiment was performed to determine the growth performance and carcass yield of slow-growing chickens fed diets containing different levels of ME during the starter phase, and the second experiment was performed to determine the metabolizability coefficients of nutrients.

In the first experiment, 480 Isa Label birds were purchased and distributed in a completely randomized design in a 4 × 2 factorial scheme (ME × sex), with 6 replicates of 10 birds. The ME levels of starter feed (fed during 1–28 days of age) were studied in slow-growing chickens, with four treatments corresponding to four different ME levels (2,725, 2,850, 2,975, and 3,100 kcal/kg) based on the recommended ME standards for this strain.

For the feeding schedule, two breeding phases were considered: the starter phase, during which the experimental diets were tested, and the growth phase (29–56 days), which was the same for all birds, as the aim was to assess the residual effect of different ME levels in the starter feed on the growth of males and females. The diets (Table 1) were provided ad libitum throughout the experimental period from 1–56 days and were formulated with corn, wheat bran, oil, and soybean meal. The food composition values for the diets were based on those cited by Rostagno *et al.* [(7)], and for nutritional requirements, we followed the recommendations specified in the Globo Poultry Line Handling Manual.

Table 1. Feed composition of experimental diets during the starter phase (1–28 days of age) and growth phase (29–56 days of age).

Feed (%)	Experimental diets				
	Starter phase				Growth phase
	2,725 kcal	2,850 kcal	2,975 kcal	3,100 kcal	
Corn	58.80	61.89	62.78	59.90	65.34
Soybean meal	28.53	29.46	30.24	30.73	27.36
Wheat	7.60	3.56	1.00	1.00	2.24
Dicalcium phosphate	1.85	1.89	1.92	1.92	2.10
Limestone	1.49	1.47	1.45	1.44	1.22
Soybean oil	1.00	1.00	1.88	4.28	1.00
Salt	0.470	0.470	0.470	0.470	0.524
Premix[1]	0.10	0.10	0.10	0.10	0.10
DL-methionine 99%	0.11	0.11	0.11	0.11	0.10
L-lysine HCl 98%	0.05	0.05	0.05	0.05	0.016
Total	100	100	100	100	100
Calculated composition					
Crude protein (%)	19.00	19.00	19.00	19.00	18.50
ME (kcal/kg)	2.725	2.850	2.975	3.100	2.950
Calcium (%)	1.15	1.15	1.15	1.15	1.11
Available phosphorus (%)	0.45	0.45	0.45	0,45	0.50
Total lysine (%)	1.05	1.06	1.07	1.08	0.95
Total methionine + cystine (%)	0.75	0.75	0.75	0.75	0.70
Sodium (%)	0.22	0.22	0.22	0.22	0.25

[1] Mineral and vitamin premix: Guaranteed levels per kilogram of product of folic acid 1,600.00 mg, pantothenic acid 24.96 g, biotin 80 mg, butylated hydroxy toluene 100 mg, niacin 67.20 g, selenium 600 mg, vitamin A 13,440,000 IU, vitamin B1 500 mg, vitamin B12 9,200 mcg, vitamin B2 9,600 mg, vitamin B6 4,992 mg, vitamin D3 3,200,000 IU, vitamin E 21,000 IU, vitamin K3 2,880 mg, copper 15 g, iron 90 g, iodine 1,500 mg, manganese 150 g, and zinc 140 g; free of growth promoters and anticoccidials.

Growth performance variables, such as feed consumption, live weight, weight gain, and feed conversion, were evaluated at 28 and 56 days of age, whereas carcass yield variables, including carcass weight, prime cut yield, and abdominal fat weight, were assessed at 56 days of age. For carcass yield, two birds from each plot, weighing close to the mean weight obtained, were selected after an eight-hour fast.

In the second experiment, to determine nutrient metabolizability, 320 Isa Label birds were distributed in a completely randomized design in a 4 × 2 factorial scheme (ME levels of 2,725, 2,850, 2,975, and 3,100 kcal/kg versus sex), with four replicates of 10 birds for each treatment. This experiment was performed until 21 days of age, and the total excreta collection was performed between days 17 and 21, using the same diet as in the first experiment (Table 1). The total excreta collection lasted 5 days and was performed twice daily, at 0800 h in the morning and 1700 h in the afternoon. The samples were stored daily and then frozen. On the last day of sample collection, the excreta was thawed at room temperature, homogenized, weighed, and 500 g was removed for pre-drying in a forced-air oven at 65 ^{0}C for 72 h.

The dry excreta samples were milled with a knife mill using a one-millimeter sieve to analyze dry matter (DM), ether extract (EE), crude protein (CP), and crude energy of the feed and excreta, according to the methodology described by Silva and Queiroz *et al.* [(8)]. The coefficient of metabolizability of dry matter (CMDM), the coefficient of metabolizability of nitrogen (CMN), and the coefficient of metabolizability of ether extract (CMEE), nitrogen balance (NB), ether extract balance (EEB), apparent ME (AME), and AME corrected for NB (AMEn) were then calculated using the equations described by Sakomura *et al.* [(9)].

The data were subjected to the analysis of variance, and when significant, Tukey's test was used to compare the means. Polynomial regression analysis was used to study the effects of ME levels in the feed on nutrient metabolizability. The statistical program SAS/STAT 9.2/2008 was used for statistical analysis.

3. Results and discussion

The growth performance analysis carried out during the period from one to 28 days (Table 2) showed no interaction ($p>0.05$) between the factors studied, but differences were found ($p<0.05$) between males and females for live weight, weight gain, and feed consumption, with males showing greater weight, weight gain, and feed consumption. A quadratic regression effect ($p<0.05$) was found for the variables live weight and weight gain, with a maximum ME level of 2,915.22 kcal/kg. ME levels also influenced feed conversion, with a negative linear regression effect ($p<0.05$), in which birds that consumed higher ME levels had better feed conversion (FC) values.

Table 2. Growth performance of slow-growing chickens fed diets containing different metabolizable energy (ME) levels during the starter phase from 1–28 days of age.

Growth performance variables				
ME (kcal/kg)	Live weight (g)	Weight gain (g\ bird\day)	Feed consumption (g)	Feed conversion
2.725	855[b]	29.12[b]	1,489	1.707[a]
2.850	851[b]	28.99[b]	1,424	1.638[ab]
2.975	863[ab]	29.42[ab]	1,459	1.652[ab]
3.100	885[a]	30.21[a]	1,440	1.606[b]
Sex				
Male	893[a]	30.48[a]	1,499[a]	1.641
Female	834[b]	28.38[b]	1,407[b]	1.660
p-value				
ME	0.025	0.023	0.072	0.020
Sex	<0.0001	<0.0001	<0.0001	0.369
ME × sex	0.245	0.232	0.089	0.222
CV (%)	2.07	2.14	2.67	2.93
Regression				
Live weight		p=0.001	R^2=0.81	CV (%)=4.28
Weight gain		p=0.001	R^2=0.84	CV (%)=4.44
Feed conversion		p=0.004	R^2=0.21	CV (%)=3.03

*Means in the same column followed by different lowercase letters differ (P<0.05) based on Tukey's test. CV = Coefficient of Variation. live weight – Y=0,6026422+8,6336e-5x+4,5584e-7x 2 weight gain – Y=0,0200704+3,0982 e-6x+1,625e-8x2. feed conversion- Y=2,3439542-0,0002371x.

During 1–56 days of age (Table 3), differences were found (p<0.05) between the sexes for all variables analyzed. Males exhibited higher mean values for live weight, weight gain, and feed consumption but lower mean values for feed conversion. A quadratic regression effect (p<0.05) was found for feed consumption, with a minimum of 2,912.5 kcal/kg. In addition, an interaction effect (p<0.05) was found for the factors studied (ME × sex) in terms of feed conversion, with females showing a quadratic response at a maximum ME of 2,929.55 kcal/kg and males showing a negative linear response to the increasing levels of ME.

Table 3. Growth performance of slow-growing chickens fed diets containing different metabolizable energy (ME) levels during the starter phase corresponding to the period from 1–56 days of age.

Growth performance variables				
ME (kcal/kg)	Live weight (g)*	Weight gain (g\ bird\day)*	Feed consumption (g/ bird/ period)*	Feed conversion*
2.725	2,422	42.55	4,979[a]	2.225
2.850	2,353	41.32	4,790[b]	2.219
2.975	2,393	42.03	4,857[b]	2.247
3.100	2,386	41.92	4,815[b]	2.206
Sex				
Male	2,637[a]	46.39[a]	5,100[a]	2.166[b]
Female	2,140[b]	37.51[b]	4,621[b]	2.283[a]
p-value				
ME	0.361	0.369	0.015	0.259
Sex	<0.0001	<0.0001	<0.0001	<0.0001
ME × sex	0.108	0.108	0.599	0.007
CV (%)	2.72	2.77	1.94	1.55
Regression				
Feed consumption		p=<0.0001	R^2=0.48	CV (%)=5.64
Female feed conversion		p=0.046	R^2=0.159	CV (%)=2.10
Male feed conversion		p=0.009	R^2=0.228	CV (%)=1.05

*Means in the same column followed by different lowercase letters differ (P<0.05) based on Tukey's test. CV = Coefficient of Variation. Feed consumption: Y = 5.8009476 – 0.0003385x + 2.3449 e–6x2; Female feed conversion: Y = 2.0863803 + 8.0866 e–5x – 2.2167 e–6x2; Male feed conversion: Y = 2.6037351 – 0.00015x.

The results were similar to those obtained by Mendonça *et al.* [5] and Mendonça *et al.* [10], who observed that increasing ME levels (2,600, 2,750, 2,900, 3,050, and 3,200 kcal/kg) improved feed conversion and reduced feed consumption in slow-growing broilers during the starter, growth, and final phases. During the starter phase, the birds that consumed diets with higher ME levels had better live weight, weight gain, and corrected feed conversion. According to Sakomura *et al.* [11], improvement in the feed conversion of birds may be associated with greater fat supplementation in diets with higher ME levels, generating a lower increase in calories, resulting in better energy efficiency by increasing the net energy of the diet.

Despite improvements in feed conversion and feed consumption, the final live weights showed no improvements, as, in this study, we only evaluated the effects of increasing ME levels with fixed crude protein levels in the feed. Thus, the energy: protein ratios of the experimental diets containing 2,725, 2,850, 2,975, and 3,100 kcal ME/kg were 143, 150, 156, and 163, respectively, higher than the values recommended for this strain.

In a study with slow-growing chickens fed diets with different ME levels of 2,600, 2,750, 2,900, 3,050, and 3,200 kcal/kg with the energy: protein ratios of 121, 128, 135, 142, and 149, respectively, Mendonça *et al.* [10] reported that the optimal energy: protein ratio for optimal zootechnical performance is 128 in the starter phase.

Regarding carcass yield, no interaction (p>0.05) was found between the factors studied during the period from one to 56 days (Table 4). However, differences were found between sexes for fat percentage, which was higher in males, and breast meat yield, which was higher in females. These results suggest that slow-growing chickens do not respond to increasing ME levels in terms of carcass yield, and this may be associated with genetic factors.

Table 4. Carcass and prime cut yields of slow-growing chickens fed diets containing different metabolizable energy (ME) levels during the starter phase until 56 days of age.

			Variáveis		
EM (kcal/kg)	RC (%)	% G	RP (%)	RCS (%)	RA (%)
2.725	72,21	3,31	23,45	34,78	12,51
2.850	70,80	3,41	22,84	35,99	12,42
2.975	71,46	3,3	24,74	36,15	12,73
3.100	71,32	3,64	23,04	35,28	12,38
Sexo					
Macho	71,85	3,79 a	22,23 b	36,05	12,52
Fêmea	71,05	3,04 b	24,81 a	35,05	12,51
			Valor de P		
	RC (%)	% G	RP (%)	RCS (%)	RA (%)
Energia	0,555	0,799	0,150	0,496	0,821
Sexo	0,267	0,011	0,0001	0,167	0,964
EM x Sexo	0,832	0,266	0,560	0,806	0,776
CV (%)	3,35	26,89	8,61	6,75	7,40

CV = Coefficient of variation. CY: Carcass yield; FC: Fat content; BY: Breast yield; TDY: Thigh and drumstick yield; WY: Wing yield; MDM, metabolizability of dry matter. *Means in the same column followed by different lowercase letters differ (P<0.05) based on Tukey's test.

Regarding the differences in fat content percentage between males and females, males stored excess energy as body fat. According to Boekholt *et al.* [12], when ME intake is high, more energy is retained as fat and less as protein. Regarding prime cut yield during the period from one to 56 days (Table 4), no interaction (p>0.05) was found between ME levels and sex.

Differences were found between sexes for breast weight, with females showing higher breast yields than males. The data showed no regression effects on yield variables with increasing ME levels in the starter feed for both male and female chicks (p>0.05). Similar results were found by Oliveira Neto *et al.* [13], Sakomura *et al.* [11], Mendes *et al.* [14], and Duarte *et al.* [15], where prime cut yields were not influenced by increasing ME levels (between 2,900 and 3,600 kcal/kg) in fast-growing broilers.

However, the results differ from those found by Oliveira Neto *et al.* [16], who studied ME levels in the growth feed of fast-growing chickens (3,000, 3,075, 3,150, 3,225, and 3,300 kcal/kg) and found effects on carcass yield, with a positive quadratic effect for absolute drumstick weight with a maximum of 3,150 kcal/kg for ME levels in the diets. In another study, Copat *et al.* [2] found lower carcass weight as ME levels increased, which may be associated with lower feed and nutrient consumption by free-range chickens.

As with carcass yields, slow-growing birds showed no improvements in prime cut yields in response to increasing ME levels in the starter phase, as genetic selection in these birds is less intense and has a different purpose than in fast-growing birds, prioritizing a reduction in fattening rate, hardiness, and adaptability. These slow-growing birds could have responded with improved carcass and prime cut yields if the energy: protein ratios of the experimental diets had been adjusted, as an imbalance in this ratio limits the growth of lean tissue, which may have affected yield [17].

Regarding the differences observed between males and females in terms of prime cut yields, the results corroborate those found by Mendes *et al.* [14], when evaluating increasing levels of ME (2,900, 2,960, 3,020, 3,080, 3,140, and 3,200 kcal/kg) in fast-growing chickens, where they observed that males obtained better results for thigh and drumstick yields, while females showed better breast yields.

Dourado *et al.* [18] and Takahashi *et al.* [19] also had similar results when evaluating slow-growing broiler strains subjected to different rearing systems (confined/ semiconfined), with females showing better breast yields and males better yields in other prime cuts. As for nutrient metabolizability during the period from 17 to 21 days, no interaction (p>0.05) was found between ME and sex (Table 5).

Table 5. Nitrogen balance (NB), ether extract balance (EEB), the coefficient of metabolizability of nitrogen (CMN), the coefficient of metabolizability of ether extract (CMEE), and the coefficient of metabolizability of dry matter (CMDM) of slow-growing broilers fed diets containing different metabolizable energy (ME) levels during the starter phase.

Nutrient balance and metabolizability					
ME (kcal/kg)	NB*	EEB*	CMN*	CMEE*	CMDM*
2,725	50.33[a]	7.48[d]	66.63[a]	72.28[b]	72.57[b]
2,850	42.30[bc]	10.42[c]	63.11[ab]	84.38[a]	74.37[ab]
2,975	39.21[c]	12.57[b]	60.84[b]	85.52[a]	74.22[ab]
3,100	46.20[ab]	13.64[a]	64.69[ab]	83.08[a]	75.40[a]
Male	44.56	11.22	62.91b	82.05	73.71
Female	44.46	10.84	64.95a	83.08	74.57
p-value					
ME	<0.0001	<0.0001	0.003	<0.0001	0.019
Sex	0.940	0.148	0.033	0.150	0.158
ME × sex	0.279	0.087	0.721	0.241	0.657
CV (%)	8.67	6.41	4.41	2.39	2.24
Regression					
p-value	<0.0001	<0.0001	0.0014	<0.0001	<0.0001
R^2	0.4	0.007	0.038	0.47	0.22
CV	8.64	8.1	4.61	2.48	2.22

*Means in the same column followed by different lowercase letters differ (P<0.05) based on Tukey's test. CV = Coefficient of variation. NB: Y = 75.884447 – 0.0123833x + 0.0002404x2; EEB: Y = 37.05225 + 0.01651x; CMN: Y = 80.419269 – 0.006488x + 0.0001178x2; CMEE: Y = 42.362533 + 0.0148299x – 0.0001528x2; and CMDM: Y = 54.7439 + 0.006661x.

However, differences were found (p<0.05) between males and females for the nitrogen metabolizability coefficient. In addition, a regression effect was found for increasing ME levels in the feed for all variables analyzed (Table 5). For nitrogen balance and the nitrogen metabolizability coefficient, a quadratic regression effect was observed (p<0.05), with a minimum of 2,912.5 kcal/kg. These results corroborate those of Oliveira Neto *et al.* [(13)], who observed an increase in nitrogen balance and nitrogen metabolizability coefficient with an increase in ME in the diet of fast-growing chickens. However, Cançado and Baião (20) reported no effects of increasing ME levels in the feed of fast-growing broilers during their starter phase on these variables.

A positive linear regression was found (p<0.05) for ether extract balance, i.e., birds that consumed feed containing higher ME levels exhibited higher ether extract balance. The CMEE showed a quadratic regression effect (p<0.05), with a maximum of 2,912.5 kcal/kg.

These results are similar to those obtained by Oliveira Neto *et al.* [(13)] when studying the effects of increasing ME levels (between 2,900 and 3,300 kcal/kg) in feed for fast-growing broilers on nutrient digestibility. According to Singh *et al.* [(21)], AME in slow-growing chickens may be used for physical activity, which may be responsible for lower weight gain than in fast-growing chickens.

As for CMDM, a positive linear regression effect was found (p<0.05). The values increased with increasing ME levels in the feed. In addition, a difference was found (p<0.05) between males and females for this variable, with females showing higher values. Regarding AME and AMEn (Table 6), a positive linear regression effect was found (p<0.05), i.e., an increase in ME in the feed resulted in an increase in

AME and AMEn. The ME of the diet is directly affected by the composition of the feed, and increasing the ME levels of the feed by including oil (a traditional source of energy) leads to higher AME and AMEn values as the inclusion of this product in the diet increases.

Table 6. Apparent metabolizable energy (AME) and the AME corrected for nitrogen balance (AMEn) of slow-growing broilers fed diets containing different metabolizable energy (ME) levels during the starter phase.

	Nutrient metabolizable energy	
ME (kcal/kg)	AME*	AMEn*
2,725	3,302.2[c]	3,113.1[d]
2,850	3,372.4[c]	3,216.6[c]
2,975	3,471.8[b]	3,324.6[b]
3,100	3,674.4[a]	3,507.2[a]
Male	3,468.9	3,279.5
Female	3,441.6	3,301.2
	p-value	
Sex	<0.0001	<0.0001
ME × sex	0.245	0.313
CV (%)	0.869	0.782
	Regression	
p-value	0.022	<0.0001
R2	0.16	0.13
CV (%)	2.02	1.81

*Means in the same column followed by different lowercase letters differ (P<0.05) based on Tukey's test. CV = Coefficient of variation. AME: Y = 621.54247 + 0.972944x; and AMEn: Y = 283.2756 + 1.032494x.

A comparative analysis of the data obtained in the two experiments revealed that at the end of the starter phase, i.e., at 28 days, both slow-growing males and females responded to increasing ME levels. The birds showed a linear improvement in corrected feed conversion and better live weight and weight gain up to the level of 2,915.22 kcal/kcal, a value close to that obtained by Massi *et al.* [(22)] of 3,046 kcal/kcal for the best feed conversion result.

High levels did not yield significant results and could be harmful, as noted in the metabolizability test, where very high levels of ME led to a decrease in the nitrogen balance and nitrogen metabolizability coefficient from 2,912.5 kcal/kg, impairing protein utilization and lean tissue deposition.

Starting from 21 days of age, it is clear that slow-growing male and female chicks develop differently physiologically, with males outperforming females in growth. Therefore, slow-growing chicks must be separated based on sex and reared in separate flocks to reduce competition between males and females when reared in different houses and improve flock performance.

4. Conclusion

It is concluded that feed with ME levels of 2,900–2,930 kcal/kg during the starter phase is recommended for broiler chickens, regardless of gender, during the period from 1–28 days.

Declaration of conflict of interest

The authors declare no conflicts of interest.

Data availability statement

The data will be provided upon request.

Author contributions

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