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ANIMAL SCIENCE

Formulation of diets for slow-growing broilers slaughtered at different ages on carcass characteristics and composition of commercial cuts

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Abstract: This study was conducted to examine the effects of a diet formulated with industrial amino acids and a commercial vitamin-mineral mixture on the characteristics of carcass and meat cuts of slow-growing broilers slaughtered at different ages. The experiment involved 600 one-day-old male and female white Naked Neck chicks. The chicks were allotted randomly to a 2 × 3 factorial arrangement consisting of two diets and three slaughter ages, in a completely randomized experimental design with five replicates of 20 birds each. The experimental period was 84 days. Six chicks were selected and slaughtered on the first day, and then at 56, 70 and 84 days of age 10 birds unit was selected and slaughtered per experimental period. Weight and yield of carcass, abdominal fat and breast, thigh and drumstick meat were determined. Additionally, moisture, protein, fat and mineral matter contents and protein and fat deposition in the breast, drumstick and thigh muscles were determined. The diet did not influence the yields of carcass, abdominal fat, or meat cuts or the nutritional composition of meat. Slaughter age influenced the yields of breast and thigh meat and abdominal fat; the protein content of breast meat; and the moisture, crude protein, fat, and mineral matter contents of drumstick and thigh meat. There was an interaction effect between diet and slaughter age for protein deposition in breast meat. The age factor influenced fat deposition in the drumstick muscles. Protein deposition in the thigh muscles was influenced by the diet. Moreover, a difference was observed between the ages for protein and fat deposition in the thigh muscle. In conclusion, the use of a commercial mixture in the diet results in decreased protein deposition in the breast and thigh muscles, although this difference does not affect the characteristics of carcass or meat cuts. Birds slaughtered at 70 days exhibit similar carcass characteristics to those of birds slaughtered at 84 days, indicating the possibility of an earlier slaughter age.

Key words: carcass yield, naked neck, nutritional composition, slaughter age.

INTRODUCTION

Slow-growing birds have peculiar characteristics, commonly exhibiting different growth curves and rates than commercial poultry lines. Despite their lower production performance and prime-cut yields, the preference of the consumer market for distinguished meat quality attributes such as desirable texture and a more intense color warrants their production (Santos et al. 2005, Attia et al. 2009, 2011, 2017, Dilelis et al. 2019).

The farming of slow-growing chicken thus emerges as an alternative due mainly to the lower necessary investment in facilities and equipment and higher hardiness of those lines, which allow for adjustments in the rearing system (Mutibvu et al. 2017). Research has shown that the husbandry system (intensive or semi-intensive) does not influence performance or meat characteristics (Cruz et al. 2018, Takahashi et al. 2012).

Because it is a viable activity in that it exploits a market niche that seeks differentiated products, it does not compete with the industrial chicken in production scale and cost, but rather in meat quality. Moreover, this segment has shown to be promising, considering that production is viable for small- and medium-sized producers as well as on a commercial scale (Veloso et al. 2014, Moreira et al. 2012).

The use of premix has become the main strategy to meet the nutritional requirements of vitamins and mineral for animals, especially by small farmers. This practice may, however, contribute to inadequate nutrient supply, given the possibility of excess or even lack of the supplied nutrients, which may culminate in production losses.

On the other hand, diets formulated with industrial amino acids properly meet the animal's requirements, preventing nutrient excesses or deficiencies, providing adequate poultry performance and preventing wastage. However, the high costs of those ingredients may render their use economically unfeasible.

In this scenario, the present study proposes to examine the effect of a diet formulated with industrial amino acids and a commercial vitamin-mineral mixture on the characteristics of carcass and meat cuts of slow-growing broilers slaughtered at different ages.

MATERIALS AND METHODS

The study was developed at the Experimental Laboratory of Poultry Science at the Faculty of Veterinary Medicine and Animal Science of the Federal University of Mato Grosso do Sul, under the approval of the Ethics Committee on Animal Use (CEUA/UFMS; approval no. 996/2018)

Six hundred 1-day-old male and female (mixed lot) white Naked Neck chicks were allotted to a 2 × 3 factorial arrangement consisting of two diets and three slaughter ages in a completely randomized design with five replicates of 20 birds each, totaling 30 experimental units. The birds were grouped by weight (±10% of the average weight of the lot) so that all experimental units would have similar weights.

The experimental diets were based on corn and soybean meal. One of them was formulated to meet the nutritional requirements of brown egg-laying replacement birds, following Rostagno et al. (2017), and including industrial amino acids, while the other included a commercial mineral-vitamin mixture at the levels recommended by the manufacturer (Table I).

The birds were housed in a conventional shed covered by fiber-cement tiles and divided into thirty 2.5-m^2 cages on earthen floor covered with pine shavings litter which had been used by a brood. The cages were equipped with electric brooders containing two 100-W incandescent light bulbs for heating, a trough-type feeder and pendulum-type drinkers. Form of feed and water were available *ad libitum*. After 14 days of age the birds were subjected to 12 hours of natural light. The experiment lasted 84 days.

Six chicks were selected and slaughtered on the first day, and then at 56, 70 and 84 days of age 10 birds whose live weight was similar to the average weight (±10%) of the experimental unit was selected and slaughtered per experimental

Table I. **Composition and calculated values of the experimental diets.**

	Starter (1 to 28 days)		Grower (29 to 56 days)		Finisher (57 to 84 days)	
Ingredient (%)	Formulated	Mixture	Formulated	Mixture	Formulated	Mixture
Corn	59.44	60.00	63.23	66.20	72.63	70.00
Soybean oil 46	34.41	35.00	30.71	28.80	24.33	25.00
Soybean oil	0.05	-	0.05	-	-	-
Kaolin	2.28	-	1.93	-	-	-
Dicalcium phosphate	1.79	-	1.80	-	1.62	-
Limestone	1.00	-	0.98	-	0.91	-
Sal	0.42	-	0.38	-	0.35	-
DL-methionine	0.27	-	0.24	-	-	-
L-lysine HCl	0.13	-	0.07	-	-	-
L-threonine	0.05	-	0.02	-	-	-
Min. supplement[1]	0.05	-	0.05	-	0.05	-
Vit. supplement[2]	0.10	-	0.10	-	0.10	-
Commercial mixture[3]	-	5.00	-	5.00	-	5.00
Nutritional composition						
Metabolizable energy (kcal)	2850	2857	2850	2887	3004	2930
Crude protein (%)	20.98	20.99	19.50	18.62	17.05	17.15
Dig. met +cys. (%)	0.842	0.580	0.767	0.517	0.532	0.485
Dig. lys. (%)	1.138	1.024	0.959	0.860	0.771	0.770
Dig. thr. (%)	0.762	0.724	0.675	0.634	0.591	0.584
Calcium (%)	0.950	1.315	0.930	1.283	0.840	1.212
Phosphorus (%)	0.440	0.340	0.430	0.515	0.390	0.450
Sodium (%)	0.180	0.173	0.170	0.179	0.160	0.179

Levels per kg of feed, [1]Mineral supplement: 11.00 mg Zinc; 3.04 mg Pantothenic Acid; 0.22 mg Iodine; 0.06mg Selenium; 8.48 mg Iron; 2.64 mg Copper; 15.15 mg Manganese, 2660. Levels per kg of feed. [2]Vitamin supplement: 2,400 IU Vitamin A; 480 IU Vitamin D3; 0.32 mg Vitamin K3; 0.51 mg Vitamin B1, 1.38 mg Vitamin B2; 0.64 mg Vitamin B6; 2.88 mg Vitamin B12; 3.00 mg Vitamin E; 7.12 mg Niacin. Guarantee levels of the initial Core[3]: Calcium (min-max): 177g / kg; Phosphorus (min): 46g / kg; Fluorine (max): 460mg / kg; Sodium (min): 32g / kg; Choline (min): 5.220g / kg; Vitamin A (min): 220,000 IU / kg; Vitamin D3 (min): 40,000 IU / kg; Vitamin E (min): 320UI / kg; Vitamin K3 (min): 30mg / kg; Vitamin B1 (min): 24mg / kg; Vitamin B2 (min): 90mg / kg; Vitamin B6 (min): 160mg / kg; Vitamin B12 (min): 320mcg / kg; Niacin (min): 700mg / kg; Pantathenic Acid (min): 184mg; Cyanine (min): Folic Acid (min): 8mg / kg; Biotin (min): 1.2mg / kg; Iron (min): 600mg / kg; Copper (min): 180mg / kg; Manganese (min): 1,200mg / kg; Zinc (min): 1,200mg / kg; Iodine (min): 20mg / kg; Selenium (min): 5mg / kg. Growth nucleus: Calcium (min-max): 117-176g / kg; Phosphorus (min): 42g / kg; Fluorine (max): 420mg / kg; Sodium (min): 32g / kg; Choline (min): 4.220g / kg; Vitamin A (min): 180,000 IU / kg; Vitamin D3 (min): 32,000 IU / kg; Vitamin E (min): 280UI / kg; Vitamin K3 (min): 30mg / kg; Vitamin B1 (min): 20mg / kg; Vitamin B2 (min): 80mg / kg; Vitamin B6 (min): 75mg / kg; Vitamin B12 (min): 240mcg / kg; Pantathenic Acid (min): 165.5mg; Cyanine (min): 600mg / kg; Folic Acid (min): 6mg / kg; Biotin (min): 1mg / kg; Iron (min): 600mg / kg; Copper (min): 180mg / kg; Manganese (min): 1,200mg / kg; Zinc (min): 1,200mg / kg; Iodine (min): 20mg / kg; Selenium (min): 5mg / kg. Final Core: Calcium (min-max): 111-166g / kg; Phosphorus (min): 36g / kg; Fluorine (max): 370mg / kg; Sodium (min): 32g / kg; Choline (min): 2.610g / kg; Vitamin A (min): 54,000 IU / kg; Vitamin D3 (min): 9,000 IU / kg; Vitamin E (min): 90 IU / kg; Vitamin K3 (min): 9mg / kg; Vitamin B1 (min): 5.4mg / kg; Vitamin B2 (min): 18mg / kg; Vitamin B6 (min): 7mg / kg; Vitamin B12 (min): 54mcg / kg; Niacin (min): 90mg / kg; Pantathenic Acid (min): 66.2mg; Biotin (min): 0.27mg / kg; Iron (min): 600mg / kg; Copper (min): 180mg / kg; Manganese (min): 1,200mg / kg; Zinc (min): 1,200mg / kg; Iodine (min): 20mg / kg; Selenium (min): 3.6mg / kg.

period to obtain data of body composition and nutrient deposition in the carcass.

The selected birds were placed in cages and deprived of solid feed for 6 h for a complete emptying of their gastrointestinal tract. Subsequently, the birds were weighed individually, stunned by cervical displacement and slaughtered by exsanguination. Thereafter, they were plucked and eviscerated and then their carcass, abdominal fat, head and feet were weighed.

After 24 h of refrigeration, the cuts were deboned, weighed individually, packed in labeled plastic bags and frozen for later processing and to obtain the laboratory samples.

Carcass yield (%) was calculated as the ratio between cold carcass weight and bird weight after fasting, before slaughter: Carcass yield (%) = cold carcass weight (g) × 100 ÷ bird weight before slaughter. Abdominal fat percentage was calculated as the ratio between fat weight and bird weight after fasting, before slaughter: Abdominal fat percentage (%) = Fat weight (g) × 100 ÷ Bird weight before slaughter. The yields of meat cuts were calculated as the ratio between the weight of the deboned cut and cold carcass weight: Meat cut yield (%) = Deboned cut weight × 100 ÷ Cold carcass weight.

The frozen deboned cuts were ground through an industrial meat grinder to obtain homogeneous samples. An aliquot of 60 to 80 g was taken from the total sample and placed on glass petri dishes, pre-dried in a forced-air oven at 105 ºC for 72 h and then processed through a ball mill to obtain a finely ground material for the analyses of definitive dry matter, crude protein, ether extract and mineral matter.

The methodologies described by Silva & Queiroz (2002) were adopted for all centesimal analyses performed in this study. The crude protein values of the samples were obtained by the KJELDAHL method, whereas the ether extract contents were determined by extracting the fat with petroleum ether, using an ANKOM instrument. The ash content was determined after burning the sample in a muffle furnace at 600 ºC for 6 h.

Data were subjected to analysis of variance using SAS software version 9.0, according to statistical model.

$$Y_{ijk} = \mu + D_i + S_j + (D*S)_{ij} + e_{ijk}$$

Y_{ijk} = observation of the characteristic in the birds of the experimental unit k, of diet I and slaughter ages j;

μ = constant common to all experimental units;

D_i = effect of i-th diet (i=1,2);

S_j = effect of j-th slaughter ages (j=1, 2, 3);

DS_{ij} = interaction effect do i-th diet and j-th slaughter ages;

e_{ijk} = error associated with observation Y_{ijk}; $e_{ijk} \sim N(0, \sigma^2)$

When significant differences were detected, means were compared by Tukey's test at the 5% probability level.

RESULTS AND DISCUSSION

The interaction effect between the diet and slaughter age factors was not significant for the carcass and meat characteristics (Table II). The diets provided to the broilers did not elicit changes ($P>0.05$) in carcass characteristics, probably because they sufficiently met the nutritional requirements of the animals. The nutritional requirements for slow growing birds are not well known. Therefore, it is possible for these strains to take advantage of food nutrients differently from fast-growing birds (Dilelis et al. 2019). Because they are birds with a lower rate of body development, they have a greater proportion of the gastric compartment (Morais et al. 2015), and this anatomical feature can contribute to greater energy use of food, helping the different diets provided in the better adaptation of these strains (Santos et al. 2014). Slaughter age, however, influenced ($P<0.05$) the

Table II. Weights and yields of cold carcass, meat cuts and abdominal fat of slow-growing broilers slaughtered at different ages.

Characteristic	Age (days)	Diet		Mean	CV (%)	P-value		
		Formulated	Mixture			Diet	Age	Diet × Age
Carcass, g	56	1270	1260	1265^C	7.46	0.0059	<0.0001	0.0932
	70	1680	1620	1650^B				
	84	2010	1880	1945^A				
	Mean	1653	1587					
Breast, g	56	291	293	292^C	9.81	0.7674	<0.0001	0.8999
	70	405	404	404^B				
	84	481	474	478^A				
	Mean	392	390					
Drumstick, g	56	146	142	144^C	8.98	0.0596	<0.0001	0.2366
	70	191	186	188^B				
	84	241	217	229^A				
	Mean	193	182					
Thigh, g	56	188	182	185^C	9.92	0.4937	<0.0001	0.4525
	70	275	282	278.5^B				
	84	326	312	319^A				
	Mean	263	259					
Abdominal fat, g	56	33	32	32.53^C	8.42	0.0739	<0.0001	0.3284
	70	58	64	61.00^B				
	84	93	98	95.30^A				
	Mean	61.38	64.50					
Carcass (%)	56	71.45	71.12	71.29	13.24	0.5201	0.2317	0.8745
	70	71.74	71.88	71.81				
	84	71.84	71.22	71.53				
	Mean	71.68	71.41					
Breast (%)	56	22.97	23.16	23.07^B	9.06	0.0934	0.0046	0.6244
	70	24.16	24.93	24.55^A				
	84	24.04	25.26	24.65^A				
	Mean	23.72	24.45					
Drumstick (%)	56	11.50	11.32	11.41	9.01	0.5009	0.3797	0.5860
	70	12.44	11.50	11.97				
	84	11.91	11.54	11.73				
	Mean	11.95	11.45					
Thigh (%)	56	14.85	14.41	14.63^B	10.46	0.3410	<0.0001	0.2391
	70	16.41	17.33	16.87^A				
	84	17.60	16.61	17.11^A				
	Mean	16.29	16.12					
Abdominal fat (%)	56	1.85	1.83	1.84^C	39.12	0.7564	<0.0001	0.8390
	70	2.63	2.87	2.75^B				
	84	3.37	3.34	3.35^A				
	Mean	2.62	2.68					

Means followed by different uppercase letters in the column differ from each other according to Tukey's test (P<0.05).

carcass characteristics, except for cold carcass yield and drumstick meat yield.

A significant increase was observed for the weight of all components as the birds aged. The increase observed between 56 and 70 days was likely because the animals were in the grower phase, which, in slow-growing chickens, ends at around 70 days. After this period, the protein synthesis and degradation rates are similar, meaning reduced muscle deposition. However, after the growth peak, there is an increase intramuscular fat deposition, which might have contributed to the weight gain observed between 70 and 84 days.

Mueller et al. (2018) observed similar values for the weights of carcass, breast meat, leg meat and abdominal fat in slow-growing broilers slaughtered at 63 days (1677, 335, 687 and 40.8 g, respectively). Siekmann et al. (2018) reported similar weights of carcass, breast meat and leg meat in slow-growing broilers slaughter at 75 days to those obtained in the current study (1799.1, 364.35 and 518.9 g).

The highest yields (P<0.05) of breast and thigh meat were observed at 70 and 84 days. No difference was detected between the results of those days for either cut; however, these values were higher than the yields obtained at 56 days. The lower yield observed at 56 days for breast and thigh meat may be explained by the fact that the animals were still under development and had thus not yet reached maximum growth.

The present results partially agree with those described by Dal Bosco et al. (2014), who observed no influence of slaughter age on the carcass yield of Naked Neck broilers slaughtered at 70 and 84 days. Conversely, Poltowicz & Doktor (2012) observed an increase in the yields of carcass (66.29, 69.07 and 70.66%) and leg meat (19.56, 20.64 and 21.24%) of slow-growing chickens. The lowest values were found at 56 days, and no significant difference was detected between 70 and 84 days.

According to Gordon & Charles (2002), the inflection point for the growth of slow-growing broilers occurs at around the eighth week of age (70 days). Thereafter, protein deposition decreases, which may explain the similar values for the yields of breast and thigh meat at 70 and 84 days. Additionally, the fact that the animals were reared in an intensive system might have reduced stimulus to muscle hypertrophy mainly in the drumstick and thigh, due to little locomotor activity (Lawrie & Ledward 2006, Vieira et al. 2017).

There was a significant increase in the percentage of abdominal fat as slaughter age increased. This may be explained by the higher lipid deposition in older animals, as it increases naturally throughout the growth process, and because fat accumulates later in the abdominal region. In birds, fat is firstly deposited in the neck and gizzard regions, and then in the coelomic cavity (Gonzales & Sartori 2002). Moreover, the rearing system can influence the percentage of abdominal fat due to the higher or lower possibility of the animal performing exercise (Madeira et al. 2010).

No interaction effect was detected (P>0.05) between diet and slaughter age for the centesimal composition of breast meat; differences were only found between the ages, for the protein content of meat (Table III). The highest amount of protein in breast meat was observed at 56 days. At 70 and 84 days, the values for this variable did not differ. No difference was observed for the moisture, fat, or mineral matter contents of breast meat.

Faria et al. (2009) found a decrease in the moisture (74.41, 74.22, 73.55 and 73.28%) and protein (23.30, 23.18, 23.03 and 22.56%) contents and an increase in the fat (0.45, 0.60, 0.74 and 0.77%) and mineral matter (1.06, 1.08, 1.10 and 1.22%) contents of breast meat in Naked Neck chickens slaughtered at 65, 75, 85 and 95 days of age, respectively. Castellini et al. (2002) observed no differences in chickens slaughtered at 56 and 85 days of age for the moisture (75.54 and 74.85%), protein (22.39 and 22.34%), fat (1.46 and 2.37%) and mineral matter (0.61 and 0.64%) contents.

The decrease in the protein content of the meat cuts with the advance of age was expected, since younger animals have higher amounts

Table III. Centesimal composition of breast meat from slow-growing broilers slaughtered at different ages.

Variable (%)	Age (days)	Diet		Mean	CV (%)	P-value		
		Formulated	Mixture			Diet	Age	Diet × Age
Moisture	56	73.51	73.87	73.69	0.027	0.814	0.153	0.584
	70	72.92	73.63	73.27				
	84	72.48	71.59	72.04				
	Mean	72.97	73.03					
Protein	56	21.77	21.60	22.20^{A}	2.752	0.7906	<.0001	0.5498
	70	21.32	20.46	20.89^{B}				
	84	22.13	22.28	21.69^{B}				
	Mean	21.74	21.45					
Fat	56	1.86	1.41	1.63	24.684	0.1046	0.1305	0.4546
	70	1.94	1.94	1.94				
	84	2.45	2.09	2.27				
	Mean	2.08	1.81					
Mineral matter	56	1.03	1.05	1.04	11.574	0.2268	0.9576	0.0534
	70	1.08	0.99	1.04				
	84	1.06	1.22	1.14				
	Mean	1.06	1.09					

Means followed by different uppercase letters in the column differ from each other according to Tukey's test (P<0.05).

of protein in the muscle and, consequently, in the meat, due to the higher protein synthesis that takes place during this phase. As the bird ages, its protein synthesis rate declines until it reaches basal levels (Schiaffino et al. 2013, Attia et al. 2017).

No increases were observed for the breast meat fat content, which is probably due to the predominant type of fiber in the meat of this cut. Type-IIB fibers have energy utilization pathways that depend on the use of carbohydrate and utilize glycogen as an energy substrate. Therefore, they do not store fat, which results in a lower lipid content in breast meat (Vieira 2014, Vieira et al. 2017).

There was no interaction effect (P>0.05) between the factors for the any of the variables evaluated in the analysis of centesimal composition of drumstick meat. However, slaughter age influenced (P<0.05) its moisture, crude protein, ether extract and mineral matter contents (Table IV).

Moisture and mineral matter contents decreased as the birds aged. The opposite response was shown by the protein and fat contents in the meat at 70 days, which decreased and increased, respectively. However, an unexpected response was seen at 84 days, when the protein content increased and the lipid content did not differ in comparison to the other ages.

Overall, the protein and lipid contents of muscle are expected to decrease and increase, respectively, as the bird ages. This is due to the different growth rates of body tissues, with older animals showing higher fat and lower protein deposition rates.

Santos et al. (2012) observed an increase in the lipid content of drumstick meat of slow-growing broilers slaughtered at 75, 85 and 110 days (2.23, 2.32 and 2.68%). However, the protein (19.94, 19.43 and 19.62%) and mineral matter (1.00, 1.00 and 0.93%) contents did not differ between the ages. Additionally, meat moisture decreased (77.42, 76.62 and 76.69%).

Table IV. Centesimal composition of the drumstick meat from slow-growing broilers slaughtered at different ages.

Variable (%)	Age (days)	Diet		Mean	CV (%)	P-value		
		Formulated	Mixture			Diet	Age	Diet × Age
Moisture	56	75.39	77.00	76.19^{A}				
	70	74.26	73.27	73.76^{B}	0.028	0.854	0.001	0.327
	84	73.06	72.82	72.94^{B}				
	Mean	74.24	74.36					
Protein	56	16.99	16.04	16.52^{B}				
	70	17.40	17.02	17.21^{B}	5.342	0.3083	0.0094	0.2598
	84	18.77	18.70	18.74^{A}				
	Mean	17.72	17.25					
Fat	56	3.90	3.35	3.62^{B}				
	70	4.65	6.03	5.34ª	13.218	0.6521	0.0059	0.1222
	84	5.07	3.95	4.51^{AB}				
	Mean	6.54	6.45					
Mineral matter	56	0.93	1.41	1.17^{A}				
	70	0.97	0.76	0.86^{AB}	18.827	0.0021	0.0236	0.1839
	84	0.87	0.77	0.82^{B}				
	Mean	0.92	0.98					

Means followed by different uppercase letters in the column differ from each other according to Tukey's test (P<0.05).

There was no interaction effect (P>0.05) between diet and slaughter age on the composition of thigh meat (Table V). The lowest (P<0.05) values for moisture, crude protein and mineral matter were observed at 84 days of age. However, similar values were found at 56 and 70 days. The lowest (P<0.05) fat content in thigh meat was observed at 70 days, whereas no difference was detected for this variable between 56 and 84 days.

Castellini et al. (2002), on the other hand, observed no influence of slaughter age on the moisture (76.02 and 75.39%), protein (19.01 and 19.06%), fat (4.46 and 5.01) and mineral matter (0.51 and 0.54%) contents of thigh meat from slow-growing broilers slaughtered at 56 or 81 days of age.

The observed increase in fat content in drumstick and thigh meat with the advance of age may be a favorable finding, since intra- or intermuscular fat is associated with greater juiciness and tenderness of meat (Warris 2000, Attia et al. 2011, Vieira 2014). Fat deposition is highly marked in the thigh and drumstick, as these are regions where fat storage is important. This is mainly because of their locomotor function, which leads to a predominance of type-I fibers in those limbs (Vieira 2014).

There was an interaction effect (P<0.05) between the diet and age factors for protein deposition in breast meat. However, no significant differences were detected for fat deposition in that meat cut (Table VI). The formulated diet provided the highest protein deposition at 56 and 84 days. At 70 days, no difference was observed between the diets. When the broilers received the formulated diet, no differences were observed for protein deposition at the three ages. By contrast, in the diet containing the mineral-vitamin mixture, protein deposition

Table V. Centesimal composition of thigh meat from slow-growing broilers slaughtered at different ages.

Variable (%)	Age (days)	Diet		Mean	CV (%)	P-value		
		Formulated	Mixture			Diet	Age	Diet × Age
Moisture	56	70.84	70.39	70.62^{A}	0.038	0.301	<0.0001	0.842
	70	71.97	70.17	71.07^{A}				
	84	61.81	61.18	61.50^{B}				
	Mean	68.21	67.25					
Protein	56	17.01	17.38	17.19^{B}	5.598	0.1799	0.0001	0.3792
	70	17.85	18.02	17.93^{B}				
	84	20.69	20.19	20.44^{A}				
	Mean	18.52	18.53					
Fat	56	6.24	6.17	6.21^{A}	8.299	0.2951	<0.0001	0.1439
	70	5.39	6.66	5.03^{B}				
	84	7.00	5.69	6.34^{A}				
	Mean	11.21	11.17					
Mineral matter	56	0.91	0.80	0.85^{A}	16.220	0.9038	0.0003	0.6369
	70	0.85	0.91	0.88^{A}				
	84	1.00	0.96	0.98^{B}				
	Mean	0.92	0.89					

Means followed by different uppercase letters in the column differ from each other according to Tukey's test (P<0.05).

Table VI. Protein and fat deposition in breast meat from slow-growing broilers slaughtered at different ages.

Variable[1]	Age (days)	Diet		Mean	CV (%)	P-value		
		Formulated	Mixture			Diet	Age	Diet × Age
Protein (g/day)	56	4.76^{Aa}	4.47^{Ab}	4.62		0.7705	0.0699	0.0484
	70	4.80^{Aa}	5.31^{Aa}	5.06	8.50			
	84	4.95^{Aa}	4.59^{Ab}	4.77				
	Mean	4.84	4.79					
Fat (g/day)	56	0.41	0.29	0.35		0.2588	0.0537	0.1765
	70	0.44	0.51	0.48	28.72			
	84	0.54	0.42	0.48				
	Mean	0.46	0.41					

Means followed by different uppercase letters in the row and lowercase letters in the column differ from each other according to Tukey's test (P<0.05). [1]Values based on natural matter.

was highest at 70 days, whereas no difference was observed between 56 and 84 days, whose results did not differ from each other. There was no significant difference for fat deposition in breast meat.

The interaction effect between diet and slaughter age was not significant for protein and fat deposition in thigh meat (Table VIII). Protein deposition in thigh meat was highest (P<0.05) at 70 days, with similar values detected between 56 and 84 days. Fat deposition rose with age, with the lowest deposition observed at 56 days and the highest at 84 days. At 70 days, the results did not differ from those observed at the other days.

Table VII. Protein and fat deposition in drumstick meat from slow-growing broilers slaughtered at different ages.

Variable¹	Age (days)	Diet		Mean	CV (%)	P-value		
		Formulated	Mixture			Diet	Age	Diet × Age
Protein (g/day)	56	1.86	1.86	1.86	11.389	0.2200	0.8140	0.7185
	70	1.91	1.76	1.84				
	84	1.87	1.74	1.80				
	Mean	1.88	1.79					
Fat (g/day)	56	0.64	0.617	0.63^B	18.13	0.679	0.0153	0.139
	70	0.73	0.83	0.78^A				
	84	0.69	0.56	0.63^B				
	Mean	0.69	0.67					

Means followed by different uppercase letters in the column differ from each other according to Tukey's test (P<0.05). ¹Values based on natural matter.

Table VIII. Protein and fat deposition in thigh meat from slow-growing broilers slaughtered at different ages.

Variable¹	Age (days)	Diet		Mean	CV (%)	P-value		
		Formulated	Mixture			Diet	Age	Diet × Age
Protein (g/day)	56	2.13	1.95	2.04^B	10.34	0.0149	<0.0001	0.9507
	70	2.64	2.40	2.52^A				
	84	2.18	1.95	2.06^B				
	Mean	2.32^a	2.10^b					
Fat (g/day)	56	1.28	1.15	1.21^B	14.55	0.1300	0.0286	0.2558
	70	1.24	1.29	1.27^{AB}				
	84	1.57	1.32	1.45^A				
	Mean	1.36	1.26					

Means followed by different uppercase letters in the column differ from each other according to Tukey's test (P<0.05). ¹Values based on natural matter.

Considering that the peak growth of slow-growing broilers occurs at around 70 days, greater protein deposition is expected in this phase, as observed in this study for the breast and thigh cuts. However, the birds fed the formulated diet showed greater protein deposition in those muscles, which is likely a result of the adequate nutritional supply from that diet, which met the animals' requirements.

The association between the diet and slaughter age factors did not influence (P>0.05) the deposition of protein or fat in drumstick meat (Table VII). Protein deposition in breast meat was similar at the different ages, but fat deposition was highest (P<0.05) at 70 days.

The fat present in the muscle is deposited at a faster rate after peak muscle development, since intermuscular fat deposition is highest in the period preceding this peak. After the peak, intramuscular fat deposition increases (Lawrie & Ledward 2006), as observed for the deposition of fat in thigh meat. No difference was observed for fat deposition in breast meat, probably because the fibers that predominate in this cut are type-II and thus store a small amount of fat.

CONCLUSION

Dietary inclusion of a commercial mineral-supplement mixture reduces protein deposition in the breast and thigh muscles; however, this difference does not affect the characteristics of carcass or meat cuts. Birds slaughtered at 70 days have similar carcass characteristics to those of birds slaughtered at 84 days, indicating the possibility of an earlier slaughter age.

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REFERENCES

ATTIA YA, ABD-ELHAMID AE, MUSTAFA M, AL-HARTHI MA & MUHAMMAD M. 2017. Response of slow-growing chickens to feed restriction and effects on growth performance, blood constituents and immune markers. Rev Mex de Cienc Pecuarias 8: 175-184.

ATTIA, YA, HASSAN, RA & QOTA EMA. 2009. Recovery from adverse effects of heat stress on slow-growing chicks in the tropics 1: Effect of ascorbic acid and different levels of betaine. Trop Anim Health Prod 41: 807-818.

ATTIA YA, ZEWEIL HS, ALSAFFAR AA & EL-SHAFY AS. 2011. Effect of non-antibiotic feed additives as an alternative to flavomycin on productivity, meat quality and blood parameters in broilers. Arch Geflügelk 75: 40-48.

CASTELLINI C, MUGNAI C & DAL BOSCO A. 2002. Effect of organic production system on broiler carcass and meat quality. Meat Sci 60: 219-225.

CRUZ FL, SILVA AA, MACHADO IFM, VIEIRA LC, ESTEVES C, PASSANI EJ & FARIA PB. Meat quality of chicken of different crossings in alternative system. Arq Bras Med Vet Zootec 70: 254-262.

DAL BOSCO A, MUGNAI C, GUARINO M, AMATO LP, CARTONI A & CASTELLINI C. 2014. Effect of slaughtering age in different commercial chicken genotypes reared according to the organic system: 1. Welfare, carcass and meat traits. Ital J Ani Sci 13: 467-472.

DILELIS F, GOMES AVC, DE LIMA CAR, CORRÊA DCB & REIS TL. 2019. Metabolizable energy of rice bran, cottonseed meal and wheat bran for slow-growing broilers at two ages. Cienc Anim Bras 20: 1-10.

FARIA PB, BRESSAN MC, SOUZA XR, RODRIGUES EC, CARDOSO GP & GAMA LT. 2009. Composição proximal e qualidade da carne de frangos das linhagens Paraíso Pedrês e Pescoço Pelado. Rev Bras Zootec 38: 2455-2464.

GONZALES E & SARTORI JR. 2002. Crescimento e metabolismo muscular. In: Macari M, Furlan RL & Gonzales E. 2002. Fisiologia Aviária Aplicada a Frangos de Corte, Jaboticabal: FUNEP, Jaboticabal, Brasil, p. 279-298.

GORDON SH & CHARLES DR. 2002. Niche and organic chicken products, Nottingham: CRC Press, Nottingham, UK, 320 p.

LAWRIE RA & LEDWARD DA. 2006. Lawrie's meat Science, New York: CRC Press. New York, USA, 464 p.

MADEIRA LA, SARTORI JR, ARAUJO PC, PIZZOLANTE CC, SALDANHA ESPB & PEZZATO AC. 2010. Avaliação do desempenho e do rendimento de carcaça de quatro linhagens de frangos de corte em dois sistemas de criação. Rev Bras Zootec 39: 2214-2221.

MORAIS J, FERREIRA PB, JACOME IMTD, MELLO R, BREDA FC & RORATO PRN. 2015. Curva de crescimento de diferentes linhagens de frango de corte caipira. Cienc Rural 45: 1872-1878.

MOREIRA AS, SANTOS MSV, VIEIRA SS, TAVARES FB & MANNO MC. 2012. Desempenho de frangos caipiras alimentados com rações contendo diferentes níveis de energia metabolizável. Arq Bras Med Vet Zoot 64: 1009-1016.

MUELLER S, KREUZER M, SIEGRIST M, MANNALE K, MESSIKOMMER RE & GANGNAT IDM. 2018. Carcass and meat quality of dual-purpose chickens (Lohmann Dual, Belgian Malines, Schweizerhuhn) in comparison to broiler and layer chicken types. Poult Sci 97(9): 3325-3336.

MUTIBVU T, CHIMONYO M & HALIMANI TE. 2017. Respostas fisiológicas de galinhas de crescimento lento sob temperatura de ciclo diurno em ambiente quente. Rev Bras Cienc Avic 19(4): 567-576.

POŁTOWICZ K & DOKTOR J. 2012. Effect of slaughter age on performance and meat quality of slow-growing broiler chickens. Ann Ani Sci 12(4): 621-631.

ROSTAGNO HS ET AL. 2017. Tabelas brasileiras para aves e suínos. Composição de alimentos e exigências nutricionais, 4th ed., Viçosa: UFV, 488 p.

SANTOS AL, SAKOMURA NK, FREITAS ER, FORTES CML S, CARRILHO ENVM & FERNANDES JBK. 2005. Estudo do Crescimento, Desempenho, Rendimento de Carcaça e Qualidade de Carne de Três Linhagens de Frango de Corte. Rev Bras Zootec 34(5): 1589-1598.

SANTOS FR, STRINGHINI JH, MINAFRA CS, ALMEIDA RR, OLIVEIRA PR, DUARTE EF, SILVA RB & CAFÉ MB. 2014. Formulação de ração para frangos de corte de crescimento lento utilizando valores de energia metabolizável dos ingredientes determinada com linhagens de crescimento lento e rápido. Arq Bras Med Vet Zootec 66(6): 1839-1846.

SANTOS XR, FARIA PB & BRESSAN MC. 2012. Qualidade da carne de frangos caipiras abatidos em diferentes idades. Arq Bras Med Vet Zootec 64(2): 479-487.

SCHIAFFINO S, DYAR KA, CICILIOT S, BLAAUW B & SANDRI M. 2013. Mechanisms regulating skeletal muscle growth and atrophy. The FEBS Journal 280(17): 34-55.

SIEKMANN L, MEIER-DINKEL L, JANISCH S, ALTMANN B, KALTWASSER C, SÜRIE C & KRISCHEK C. 2018. Carcass Quality, Meat Quality and Sensory Properties of the Dual-Purpose Chicken Lohmann Dual. Foods 7(10): 156-172.

SILVA DJ & QUEIROZ AC. 2002. Análise de alimentos: métodos químicos e biológicos, 1st, ed., Viçosa: UFV, 235 p.

TAKAHASHI SE, MENDES AA, MORI C, PIZZOLANTE CC, GARCIA RG, PAZ ICA, PELÍCIA K, SALDANHA SLPB & ROÇA JRO. 2012. Qualidade da carne de frangos de corte tipo colonial e industrial. Rev Cient Elet Med Vet 9(18).

VELOSO RC, PIRES AV, TORRES FILHO RA, PINHEIRO SRF, WINKELSTROTER LK, ALCÂNTARA DC & CRUZ CCDCS. 2014. Parâmetros de desempenho e carcaça de genótipos de frangos tipo caipira. Arq Bras Med Vet Zootec 66(4): 1251-1259.

VIEIRA BS, WEBER ALFL, SOARES CES, OLIVEIRA CFS & DAHLKE F. 2017. Crescimento Muscular. In: MACARI M & MAIORKA A. Fisiologia Das Aves Comerciais, Jaboticabal: FUNEP, Jaboticabal, Brasil, p. 532-593.

VIEIRA SL. 2014. Considerações sobre as características de qualidade de carne de frango e fatores que podem afetá-la. In: XV SIMPÓSIO BRASIL SUL DE AVICULTURA E VI BRASIL SUL POULTRY FAIR, Chapecó. Anais... Chapecó: Nucleovet, p. 1-10.

WARRIS PD. 2000. The growth and body composition of animals. In: WARRIS PD. Meat Science: An Introductory Text, Wallingford: CABI, Wallingford, UK, p. 9-25.

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