Ciência Rural, Santa Maria, v.53:4, e20210616, 2023
http://doi.org/10.1590/0103-8478cr20210616
ISSNe 1678-4596
ANIMAL PRODUCTION

Performance and meat quality of Label Rouge chickens at different slaughter ages

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ABSTRACT: *This study evaluated the performance parameters, carcass characteristics, and meat quality of Label Rouge chickens raised under an alternative system as a function of age at slaughter. The design was completely randomized with a 5×2 factorial arrangement, with slaughtering at five ages (70, 90, 120, 150, and 180 days) and two sexes. A total of 240 birds (Pescoço Pelado strain) were used, including 120 females and 120 males. Performance, carcass, physicochemical, proximate composition, and muscle fiber traits were evaluated. Rearing time and sex had significant effects on performance-related traits, with better results for males. The interaction between slaughter age and sex had a significant effect on the carcass and physicochemical parameters, which cause different responses in males and females with increasing slaughter age. For the proximate composition and muscle fiber analysis, the interaction between the parameters studied only had a significant effect on ether extract in the breast. The increase in age resulted in chickens with higher live and carcass weight at slaughter but lower performance indices. Females had lower carcass yield and greater deposition of abdominal fat. Females had lower tenderness in the drumstick and males in the breast with increasing slaughter age, and both cuts had more intense color and redness and reduced lightness starting at the slaughter age of 90 days.*
Key words: *feed conversion, free-range chicken, muscle.*

Parâmetros de produção e qualidade da carne de frangos Label Rouge em diferentes idades de abate

RESUMO: *O objetivo deste estudo foi avaliar os parâmetros de desempenho e as características de carcaça e qualidade da carne de frangos Label Rouge criados em sistema alternativo em função do aumento da idade de abate. O delineamento foi inteiramente casualizado (DIC) disposto em esquema fatorial (2x5), sendo dois sexos (macho e fêmea) e cinco idades de abate (70, 90, 120, 150 e 180 dias). Foram utilizadas 240 aves (Pescoço Pelado), sendo 120 fêmeas e 120 machos, sendo avaliados os parâmetros de desempenho, carcaça, físico-químicos, composição centesimal e fibra muscular. Com o aumento no tempo de produção houve efeitos dos períodos de produção e sexo em relação a variáveis de desempenho, com melhores resultados para os machos. Para os parâmetros de carcaça e físico-químicos, houve interação entre sexo e idade de abate, revelando comportamento diferenciado para machos e fêmeas com aumento da idade de abate. Para a composição centesimal e análise das fibras musculares, somente para extrato etéreo no peito foi verificado interação entre os fatores estudados. O aumento da idade proporcionou a obtenção de frangos com maiores pesos vivos e de carcaça ao abate com consequente redução dos índices de desempenho, além de menor rendimento de carcaça e maior deposição de gordura abdominal nas fêmeas. As fêmeas apresentam menor maciez na coxa e os machos no peito com aumento da idade de abate e, em ambos os cortes, ocorreu maior intensificação da cor, índice de vermelho e redução do brilho a partir de 90 dias ou em maiores idades de abate.*
Palavras-chave: *conversão alimentar, frango caipira, músculo.*

INTRODUCTION

The production of broiler chickens in an alternative system is a strategy used by poultry farmers seeking to offer a product with characteristics different from those offered by the intensive poultry production system (TAVARES et al., 2015; BRITO et al., 2021). The birds raised with access to vegetation, are not given growth promoters, and are slaughtered at older ages. The Brazilian Ministry of Agriculture, Livestock, and Food Supply (MAPA) regulates poultry farming in an alternative system through Circular Letter No. 73 of 09/04/2020 (BRAZIL, 2020), establishing a minimum age at the slaughter

Received 08.22.21 Approved 04.12.22 Returned by the author 06.14.22
CR-2021-0616.R2
Editors: Rudi Weiblen Amanda D'avila Verardi

of 70 days for free-range chicken. According to the legislation, slow-growing birds of specific lines should be used for this purpose and should be slaughtered at 120 days at the oldest. In general, studies have evaluated the effect of slaughter age on performance, carcass (SURYANTO et al., 2009; FARIA et al., 2010; MICHALCZUK et al., 2016), and meat quality characteristics (FARIA et al., 2009; SOUZA et al., 2012), but these studies evaluated the effects of slaughter age up to 110 days at most. The maximum age at slaughter established by MAPA (BRAZIL, 2020) for these chickens could be increased, since the weights of carcasses and cuts increase with age, which could be exploited for the sale of portions to consumers. Meat quality attributes also improve with age, in the form of a firmer texture and darker and yellower color, which are associated with the physiological changes in these birds with increased slaughter age (FARIA et al., 2009; SURYANTO et al., 2009; POLTOWICZ & DOKTOR, 2012; SOUZA et al., 2012).

Here, we determined the behavior of the variables associated with performance, carcass parameters, and meat quality of broilers of different sexes raised in an alternative system as a function of age at slaughter.

MATERIALS AND METHODS

For the experiment, 240 Label Rouge birds were used, including 120 females and 120 males. The animals were vaccinated against Marek's disease in the hatchery and, at 28 days of age, against infectious bronchitis, Gumboro, and Newcastle disease by the ocular route and against avian pox via a the wing membrane. The birds received a diet formulated according to the nutritional requirements indicated by the Management Manual of Colonial Chickens (GLOBOAVES, 2015) in each rearing phase (Table 1). Rearing was divided into a starter phase (1 to 28 days); a growth phase (I - 29 to 55 days, and II – 50 to 70 days); and a final phase, day 70 until slaughter (70, 90, 120, 150, or 180 days), with management adjusted according to the rearing phase. In starter phase, the animals received water and balanced feed for chickens *ad libitum*, without access to the grazing area, while in the growth and final phases, the birds were housed in the experimental rearing area at a density of one bird per 3 m² (BRASIL, 2020).

The birds were distributed in 10 paddocks, five for each sex, with a total of 24 birds per paddock. To evaluate performance, the experimental unit consisted of one paddock with 24 birds of the same sex, and performance was evaluated per rearing period. The performance characteristics were live weight, mean weight gain per bird, mean feed intake and feed conversion, mean daily weight gain, and mean daily intake in each rearing period. A completely randomized design was used for the evaluation, with a 5×2 factorial arrangement with five breeding periods (1 to 70 days; 1 to 90 days; 1 to 120 days; 1 to 150 days; and 1 to 180 days) and two sexes, totaling 10 treatments, each with five replicates.

For the evaluations of the carcass and meat quality parameters, 9 females and 9 males were randomly chosen for slaughter according to the mean weight at each slaughter age (70, 90, 120, 150, and 180 days) totaling 18 birds slaughtered per period and 90 in the total experiment. Thus, a 5×2 factorial completely randomized design was applied, with five slaughter ages and two sexes, totaling 10 treatments, each with three replicates (one replicate consisted of the mean of the parameters evaluated in three birds slaughtered at each age).

The birds were slaughtered by stunning and exsanguination, followed by scalding, plucking, and evisceration, under humane conditions. After evisceration, the birds were packaged, labeled, cooled to 0 °C, and then cut to determine yields. The carcass straits evaluated were the live weight at slaughter and the weights and yields of the carcass, cuts (drumstick, thigh, breast, back, neck, and wing), edible viscera (liver, gizzard and heart), foot, head, and abdominal fat.

Samples of breast and drumstick were taken for physicochemical, proximate composition, and histomorphometric analyses (muscle fiber diameter and area). The final pH was measured after the cooling period of the cuts, at 5°C, using a digital pH meter (Hanna Instruments®, Model HI 99163). The color analysis was performed using a Konica Minolta® CM-700 colorimeter operating in the CIE $L^*a^*b^*$ system, where L^* represents lightness, a^* represents the red content, and b^* represents the yellow content. From these values, the chroma index (C^*) and hue angle (h°) were calculated (RAMOS & GOMIDE, 2017). To determine cooking loss, the samples were weighed on an analytical scale, wrapped in aluminum foil, and then cooked on an electric grill until reaching 72 °C (FARIA et al., 2009). After cooking, the samples were cut into 1.0×1.0-cm pieces by first cutting along the long axis of the muscle fibers, and then the samples were sectioned in the transverse direction of the muscle fibers using a texturometer (Extralab, model TA. XT Plus®). The results are expressed in kgf (FRONING & UIJTTENBOOGARTE, 1988).

To perform the analysis of collagen, the samples were weighed and ground with extraction

Table 1 - Ingredients and composition of the starter, growth (I and II), and final diets provided to the Label Rouge chickens up to 180 days.

Ingredients (kg)	Starter feed (1 to 28 days)	Growth I feed (29 to 49 days)	Growth II feed (50 to 70 days)	Final feed (71 to 180 days)
Corn	64.70	69.10	72.75	73.45
Soybean meal	31.70	27.70	23.85	22.80
Degummed soybean oil	0	0	0.2	0.9
Kaolin	0	0	0.2	0.2
Calcitic limestone	0.10	0.20	0	0.15
Compound feed for free-range chickens*	3.5	3.0	3.0	2.5
----------Calculated values----------				
Metabolizable energy (kcal/kg)	2949.20	2996.13	3047.97	3098.19
Crude protein (%)	20.07	18.50	17.01	16.50
Calcium (%)	1.05	0.91	0.87	0.79
Available phosphorus (%)	0.41	0.36	0.36	0.31
Methionine + Cystine (%)	0.69	0.64	0.64	0.57
Lysine (%)	0.96	0.87	0.78	0.75
Threonine (%)	0.68	0.63	0.57	0.55
Tryptophan (%)	0.23	0.21	0.19	0.18
Choline (mg/kg)	1153.96	1059.73	994.67	945.74
Sodium (mg/kg)	1848.39	1613.59	1611.59	1375.69
Chlorine (mg/kg)	3103.34	2744.98	2746.98	2381.02

[1]Core guarantee levels for free-range chickens: folic acid (min.) 23.33 mg/kg, pantothenic acid (min.) 333.33 mg/kg, BHT (min.) 500 mg/kg, biotin (min.) 0.5 mg/kg, calcium (min.) 240 g/kg, calcium (max.) 270 g/kg, copper (min.) 333 mg/kg, choline (min.) 6,000 mg/kg, iron (min.) 1.677 mg/kg, fluorine (max.) 497.8 mg/kg, phosphorus (min.) 51 g/kg, iodine (min.) 28.33 g/kg, lysine (min.) 10 g/kg, manganese (min.) 2.333 mg/kg, methionine (min.) 40 g/kg, niacin (min.) 1,000 mg/kg, selenium (min.) 10 mg/kg, sodium (min.) 47.28 g/kg, vitamin A (min.) 159 IU/kg, vitamin B1 (min.) 33.33 mg/kg, vitamin B12 (min.) 333.33 mcg/kg, vitamin B2 (min.) 133.33 mg/kg, vitamin B6 (min.) 66.67 mg/kg, vitamin D3 (min.) 50,000 IU/kg, vitamin E(min.) 266.667 IU/kg, vitamin K3 (min.) 53.33 mg/kg, zinc (min.) 2,000 mg/kg.

solution, and after separation of the fractions, the collagen content was quantified by determining the content of the amino acid hydroxyproline as described by RAMOS & GOMIDE (2017). The moisture, protein, ash, and ether extract contents were determined in duplicate (AOAC, 2005).

For the histomorphometric analysis, samples of the breast (*pectoralis major*) and leg muscle (*iliotibialis lateralis*) were collected. The muscle fragments were cross-sectioned perpendicular to the orientation of the fibers in the middle portion of both muscles. The samples were fixed in 10% formalin and routinely processed to obtain histological sections. Then, they were dehydrated in an increasing ethanol series, diaphanized in xylol, and embedded in paraffin, and 6-µm-thick sections were sliced and stained with hematoxylin and eosin. Digitized images were acquired using an image capture and analysis system consisting of a CX31 trinocular microscope (Olympus Optical do Brasil Ltda, São Paulo, SP) and camera (SC30 Color CMOS Camera for Light Microscopy, Olympus Optical do Brasil Ltda, São Paulo, SP). Approximately 100 muscle fibers of each muscle per animal were randomly imported into ImageJ software (NIH) to measure diameter and area in micrometers.

The data were analyzed with SISVAR® software. The performance variables showing significant responses in the analysis of variance (T-test, $P < 0.05$) or interaction effects were subjected to Tukey's means test ($\alpha = 0.05$), and regression analysis ($\alpha = 0.05$) was performed on the other evaluated parameters.

RESULTS AND DISCUSSION

The performance data revealed that among the evaluated parameters, there was an interaction effect between sex and period only on the variable daily weight gain (g/bird/day), with a difference between sexes in three rearing periods (1 to 90 days, 1 to 120 days, and 1 to 150 days) given the better gains observed for males (Table 2). Males showed a reduction in daily weight gain starting at 120 days, while females showed a reduction with increasing rearing time (Table 2). For the other variables analyzed and in all evaluated periods, males had better results, which was generally expected due to the anabolic effect of testosterone, which provides better efficiency in feed conversion, in addition to increased weight gain and higher weights at slaughter (DEL-CASTILHO et al., 2013; CRUZ et al., 2018a). All performance variables were influenced by rearing time, with worsening feed conversion rates, which was expected from another study (SURVANTO et al., 2009). This is caused by the change in tissue development with maturity and physiological development (LAWRENCE & FOWLER, 2002).

The evaluation of the carcass parameters revealed an interaction between sex and slaughter age ($P < 0.05$) for the variables slaughter weight, carcass weight and yield, and drumstick, neck, wing, abdominal fat, and edible viscera yield (Table 3). For slaughter weight and carcass weight, a linear increase was observed for both sexes, while for carcass yield, although the effect was linear, there was an increase for males and a decrease for females with increasing slaughter age. Drumstick yield linearly increased with increasing slaughter age in males, while in females there was no effect ($P = 0.472$). In males, there was no response in neck ($P = 0.144$) or abdominal fat yield ($P = 0.424$), whereas females showed a linear effect, with a reduction in neck yield and an increase in abdominal fat yield after 90 days (Table 3). For wing

Table 2 - Performance parameters of the chickens in the different experimental periods (up to 180 days).

Variable	Sex	-------------------------Period (days)------------------------					Mean	CV[1] (%)	-------------P-value*-------------		
		1 to 70	1 to 90	1 to 120	1 to 150	1 to 180			Sex (S)	Period (P)	S*P[2]
Weight gain (WG)(kg)	Male	2.50	3.21	3.38	3.66	3.80	3.31A	7.24	>0.001	>0.001	0.1107
	Female	2.40	2.62	2.96	3.26	3.66	2.98B				
	Mean	2.45d	2.91c	3.17bc	3.46ab	3.73a					
Feed intake (FI) (kg)	Male	6.10	9.26	12.47	15.82	19.82	12.69A	0.77	>0.001	>0.001	0.6619
	Female	5.95	9.11	12.32	15.67	19.78	12.57B				
	Mean	6.03e	9.19d	12.40c	15.75b	19.80a					
Mean final weight (kg)	Male	2.54	3.24	3.42	3.70	3.84	3.35A	7.14	>0.001	>0.001	0.1098
	Female	2.44	2.66	3.00	3.30	3.70	3.02B				
	Mean	2.49d	2.95c	3.21bc	3.50ab	3.77a					
Feed conversion (FI/WG)	Male	2.45	2.91	3.69	4.34	5.27	3.73B	7.70	>0.001	>0.001	0.1996
	Female	2.49	3.48	4.17	4.85	5.42	4.08A				
	Mean	2.47e	3.19d	3.93c	4.60b	5.34a					
Daily weight gain (g/bird/day)	Male	35.70Aa	35.20Aa	28.40Ab	24.90Ac	21.10Ad	29.1	6.23	>0.001	>0.001	0.0068
	Female	34.20Aa	28.80Bb	24.90Bc	22.20Bcd	20.30Ad	26.1				
	Mean	35.0	32.0	26.7	23.50	20.70					
Daily feed intake (g/bird/day)	Male	87.14	101.72	104.78	107.64	110.12	102.3A	0,92	>0,001	>0,001	0,2683
	Female	85.08	100.16	103.56	106.62	109.92	101.1B				
	Mean	86.11e	100.94d	104.20c	107.13b	110.02a					

*T-test (α = 0.05); [1]coefficient of variation; [2]Tukey's test (α = 0.05). Means followed by lowercase letters in the same row indicate differences between periods, and uppercase letters indicate differences between sexes.

Table 3 - Slaughter weight, carcass weight and yield, and yield of cuts, abdominal fat, and edible viscera of Label Rouge broilers according to slaughter age and sex.

Variable	Sex (S)	---------------------Age at slaughter (A)------------------					CV[2] (%)	----------------P-value[*]----------------		
		70d	90d	120d	150d	180d		S	A	S*A
Slaughter weight (kg)	Male	2.59	3.23	3.46	4.48	4.49	3,74	>0,001	>0,001	>0,001
	Female	2.16	2.67	2.99	3.26	3.69				
Regression[1]	$Y_{males} = 0.018x + 1.466$ ($R^2 = 0.93$; P =>0.001); $Y_{females} = 0.013x + 1.382$ ($R^2 = 0.97$; P = >0.001)									
Carcass(kg)	Male	1.97	2.42	2.72	3.60	3.59	4,82	>0,001	>0,001	>0,001
	Female	1.62	1.96	2.13	2.27	2.57				
Regression[1]	$Y_{males} = 0.016x + 0.954$ ($R^2 = 0.93$; P =>0.001); $Y_{females} = 0.008x + 1.160$ ($R^2 = 0.96$; P = >0.001)									
Carcass (%)	Male	76.13	75.05	78.64	80.33	79.96	2.23	>0.001	0.674	>0.001
	Female	75.17	73.34	71.00	69.45	69.49				
Regression[1]	$Y_{males} = 0.047x + 72.303$ (R^2= 0.79; P =>0.001); $Y_{females} = -0.054x + 78.232$ (R^2= 0.90; P = >0.001)									
Drumstick (%)	Male	14.42	14.76	15.97	16.53	16.46	2.70	>0.001	>0.001	>0.001
	Female	13.88	13.43	13.29	13.56	13.59				
Regression[1]	$Y_{males} = 0.021x + 13.099$ (R^2=0.88; P=>0.001); Females = 13.55 (P = 0.4724)									
Thigh (%)	Male	16.91	16.52	17.30	17.89	17.47	3.19	>0.001	0.098	0.100
	Female	16.58	15.94	15.57	16.14	16.31				
--Sex (Males = 17.22 and Females = 16.11)--										
Breast (%)	Male	25.33	26.65	25.70	25.84	25.34	3.63	>0.001	0.014	0.082
	Female	27.62	29.34	30.91	30.48	28.50				
--------------Sex (Males= 25.77 and Females= 29.37); [1]Age at slaughter ($Y = -0.001x^2 + 0.146x + 19.240$ (R^2= 0.95; P = 0.001))--------------										
Back (%)	Male	17.99	17.81	16.97	16.74	18.29	4.14	>0.001	>0.001	>0.001
	Female	18.40	19.02	18.79	18.94	21.05				
-------------Sex (Males= 17.56 and Females= 19.24); [1]Age at slaughter ($Y = 0.001x^2 – 0.086x + 22.666$ (R^2= 0.77; P = 0.003))----------------										
Neck (%)	Male	5.38	5.50	5.74	5.41	5.44	3.44	>0.001	0.002	0.003
	Female	5.16	5.36	4.88	4.54	4.75				
Regression[1]	Males= 5.50 (P = 0.144); $Y_{females} = -0.006x + 5.661$ (R^2= 0.66; P = >0.001)									
Wing (%)	Male	11.52	10.96	10.52	9.82	9.71	2.43	0.777	>0.001	0.015
	Female	11.17	10.47	10.44	10.22	10.11				
Regression[1]	$Y_{males} = -0.017x + 12.561$ (R^2= 0.95; P =>0.001); $Y_{females} = -0.008x + 11.475$ (R^2= 0.77; P = >0.001)									
Foot (%)	Male	5.22	4.72	4.46	4.40	4.12	4.95	>0.001	>0.001	0.997
	Female	4.28	3.72	3.50	3.46	3.12				
--------------------Sex (Males= 4.58 and Females= 3.62); [1]Age at slaughter ($Y = -0.009x + 5.181$ (R^2= 0.87; P = > 0.001))----------------------										
Head (%)	Male	3.21	3.07	3.33	3.37	3.16	6.62	>0.001	0.437	0.208
	Female	2.92	2.72	2.62	2.64	2.57				
---Sex (Males= 3.23 and Females= 2.69)--										
Abdominal fat (%)	Male	1.65	1.08	0.79	1.04	1.13	26.51	>0.001	0.064	0.002
	Female	1.66	3.11	3.00	2.92	4.12				
Regression[1]	$Y_{females} = 0.016x + 0.969$ (R^2= 0.69; P = >0.001); Males = 1.14 (P = 0.424)									
Edible viscera (%)	Male	4.38	3.82	3.49	2.82	2.94	4.87	0.002	>0.001	0.007
	Female	4.74	3.62	3.47	3.35	3.37				
Regression[1]	$Y_{males} = -0.014x + 5.149$ (R^2= 0.89; P =>0.001); $Y_{females} = -0.010x + 4.946$ (R^2= 0.59; P = >0.001)									

[*]T-test (α = 0.05); [1]with α = 0.05; [2]coefficient of variation.

and edible viscera yield, both sexes showed a linear reduction with increasing slaughter age.

The highest drumstick, foot, and head yields were observed in males and the highest back and breast yields in females (Table 3). Slaughter age did not affect the drumstick (P = 0.098) or head yield (P = 0.437). Increasing slaughter age had a quadratic effect on breast and back yield and caused a linear reduction in foot yield (Table 3).

The evaluation of the parameters related to breast meat quality revealed an interaction effect between sex and slaughter age ($P < 0.05$) on the variables lightness (L^*), red content (a^*), yellow content (b^*), hue angle (h°), cooking loss, and shear force (Table 4). There was a linear increase in a^* and shear force in both sexes, indicating an increase in red color and reduction in tenderness with increasing age at slaughter. In both sexes, a^* differed the most

Table 4 - Physicochemical parameters related to the breast meat quality of Label Rouge chickens as a function of slaughter age and sex.

Variable	Sex (S)	---------------------Age at slaughter (A)--------------------					CV^2 (%)	-------------P-value*------------		
		70d	90d	120d	150d	180d		S	A	S^*A
L^*	Male	54.01	58.82	58.93	55.80	53.41	2.63	>0.001	>0.001	0.013
	Female	56.35	58.95	59.16	59.68	59.41				
Regression[1]	$Y_{males} = -0.002x^2 - 0.375x + 36.405$ (R^2= 0.81; P =>0.001); Females= 58.71 (P = 0.0859)									
a^*	Male	1.26	9.05	6.27	7.99	8.73	14.46	0.002	>0.001	0.043
	Female	1.74	6.06	5.50	6.72	7.80				
Regression[1]	$Y_{males} = 0.046x + 1.043$ (R^2= 0.41; P =>0.001); $Y_{females} = 0.044x + 0.216$ (R^2= 0.71; P = >0.001)									
b^*	Male	13.76	9.05	11.23	11.38	11.17	6.85	>0.001	>0.001	0.031
	Female	14.52	13.15	12.79	13.64	13.95				
Regression[1]	$Y_{males} = 0.001x^2 - 0.144x + 19.900$ (R^2= 0.25; P = 0.006); Females= 13.61 (P = 0.1533)									
C^*	Male	13.82	10.00	12.86	13.93	14.19	7.73	>0.001	0.001	0.060
	Female	14.96	14.49	13.94	15.21	16.00				
------------Sex (Females = 14.92 and Males = 12.96); [1]Age at slaughter ($Y = 0.0004x^2 - 0.090x + 18.025$ (R^2= 0.60; P = 0.007))-------------										
h°	Male	84.82	64.86	60.92	55.11	51.94	3.96	>0.001	>0.001	0.005
	Female	83.18	65.43	66.67	63.75	60.97				
Regression[1]	$Y_{males} = -0.260x + 95.302$ (R^2= 0.80; P =>0.001); $Y_{females} = -0.156x + 87.061$ (R^2= 0.63; P = >0.001)									
CL (%)	Male	24.53	18.06	18.88	20.22	25.3	14.19	0.050	0.032	0.004
	Female	16.61	19.71	16.09	24.96	18.66				
Regression[1]	$Y_{males} = 0.002x^2 - 0.520x + 49.356$ (R^2= 0.87; P = 0.002); $Y_{females} = x^4$ (R^2= 1.00; P = 0.004)									
Final pH	Male	5.72	5.75	5.61	5.91	5.81	1.64	0.225	0.029	0.059
	Female	5.71	5.90	5.78	5.76	5.88				
---[1]Age at slaughter ($Y= 0.001x + 5.671$ (R^2= 0.33; P = 0.047))---										
SF(kgf)	Male	1.21	1.51	2.68	2.09	- -	23.37	0.064	>0.001	0.034
	Female	0.94	1.30	1.52	2.44	- -				
Regression[1]	$Y_{males} = 0.014x + 0.395$ (R^2= 0.55; P = 0.002); $Y_{females} = 0.016x - 0.341$ (R^2= 0.93; P = >0.001)									
TotalColl (mg/g)	Male	1.87	2.93	4.92	5.85	5.40	46.03	0.039	0.060	0.125
	Female	2.25	2.78	4.47	1.51	3.42				
---Sex (Females = 2.89 and Males = 4.19)---										
SolColl (%)	Male	38.55	44.60	31.14	32.39	20.56	35.65	0.023	0.001	0.325
	Female	39.68	38.17	18.22	9.07	16.14				
------------------Sex (Females = 24.26 and Males = 33.45); [1]Age at slaughter ($Y = -0.224x + 56.152$ (R^2= 0.86; P = >0.001))------------------										

*T-test (α = 0.05); [1]with α = 0.05;[2]coefficient of variation; CL- cooking loss; SF - shear force; TotalColl - total collagen; SolColl - soluble collagen; L^* - lightness; a^* - red index; b^* - yellow index; C^* - saturation index; h°- hue angle.

between animals slaughtered at 70 days and animals slaughtered at the other ages (Table 4). This result is due to the physiological development of the animals, as myoglobin accumulates in muscle tissue (GORDON & CHARLES, 2002) and collagen cross-linking forms in connective tissue (McCORMICK, 1994; TORNBERG, 2005), resulting in lower elasticity and greater resistance to cutting. Males showed a quadratic pattern for the variables L^*, b^*, and cooking loss as a function of slaughter age, while females showed no pattern ($P > 0.05$).

In both sexes there was a linear reduction in h° in the breast with increasing slaughter age, indicating a change in the color of the meat from yellow (70° to 100°) to orange (25° to 70°) (RAMOS & GOMIDE, 2017) (Table 4). This change occurred with greater intensity starting at 90 days of age in both sexes, at which time h° was below 70° and gradually fell up to 180 days. The chroma index (C^*), which evaluates color intensity, was higher for the breast meat of females and showed a quadratic response as a function of slaughter age (Table 4). This result is related to the increase in a^* and b^* values (RAMOS & GOMIDE, 2017) that occurred with slaughter age.

The amount of total collagen in the breast differed between the sexes, with higher values in males. Higher soluble collagen percentages were also observed in males (Table 4). The percentage of soluble collagen showed a linear reduction with increasing slaughter age in both sexes. This reduction in solubility is due to the formation of tropocollagen cross-linking (McCORMICK, 1994; SOUZA et al., 2012). In the present study, the higher shear force values of breast meat at 120 days in males and at 150 days in females were accompanied by lower amounts of soluble collagen, especially in females (Table 4).

The final pH of breast meat showed an increasing trend as a function of slaughter age, but with a low R^2 value (Table 4). The final pH of drumsticks showed no difference between sexes and showed a polynomial trend (X^4) as a function of slaughter age (Table 5).

In the drumstick, the interaction between sex and age at slaughter influenced the lightness values (L^*), with a linear reduction in shear force in both sexes. Females had higher h° values than males. There was a linear reduction in h° with increasing slaughter age, especially starting at 90 days of age, when it began its fall to values below 40°, without a change in the color, which was orange (25° to 70°) (RAMOS & GOMIDE, 2017). Although, there was no change in color, the color intensity (C^*) in the drumstick increased linearly in both sexes, together with the red index (a^*), as a function of slaughter age (Table 5). a^* and C^* both differed the most between birds slaughtered at 70 days and at the other ages, indicating a greater intensity of change in these parameters in this phase.

In the drumstick, the interaction between sex and slaughter age had a quadratic effect on b^* in females but led toa linear reduction in males. In general, this behavior is associated with the accumulation of carotenoid pigments as a function of sex (FARIA et al., 2012; CRUZ et al., 2021) and age at slaughter (FARIA et al., 2009; SOUZA et al., 2012). Females showed a tendency to have higher b^* values than males, which is associated with fat accumulation in this genus, as mentioned in other studies.

There was a linear increase in shear force in the drumstick, with different responses between males and females, indicating a reduction in meat tenderness with slaughter age (Table 5). Total collagen in the drumstick linearly increased in males but showed no polynomial trend in females. The amount of soluble collagen decreased as a function of slaughter age in each sex, with lower values observed in females (Table 5). Thus, there was a relationship between the amounts of total and soluble collagen in both cuts and lesser tenderness with advancing age at slaughter (PURSLOW, 2005), these values changing jointly with age (Tables 4 and 5).

Regarding the proximate composition parameters (Table 6), there was a linear increase in protein content of the breast, but the drumstick did not show any changes in the analyzed variables. The moisture content in both cuts differed between the sexes, being higher in males, though it linearly decreased with slaughter age in both sexes. There was an interaction effect between sex and age at on the ether extract of the breast, revealing a linear increase in females, while in males there was no polynomial trend. In the drumstick, females exhibited a higher mean ether extract than males, and no difference was observed as a function of slaughter age. These results are related to physiological development, as muscle development slows and thus lipid deposits grow, with a proportional reduction in moisture content (LAWRENCE & FOWLER, 2002). In addition, due to their lower anabolic rate and higher precocity than males, females have higher fat deposition (RIZZI et al., 2009; CRUZ et al., 2018b).

The ash content showed a linear increase in the breast, with higher means for females, while in the drumstick a quadratic effect was observed as a function of slaughter age, with no difference

Table 5 - Physicochemical parameters related to the drumstick meat quality of Label Rouge chickens as a function of slaughter age and sex.

Variable	Sex (S)	-----------------------Age at slaughter (A)--------------------					CV^2 (%)	-------------P-value*-------------		
		70d	90d	120d	150d	180d		S	A	S*A
L^*	Male	50.51	52.07	46.64	47.08	45.57	2.85	0.001	>0.001	0,020
	Female	52.08	52.17	46.55	52.41	48.14				
Regression[1]	$Y_{males} = -0.054x + 54.954$ (R^2= 0.74; P =>0.001); $Y_{females} = -0.027x + 53.546$ (R^2= 0.19; P = 0.008)									
a^*	Male	8.09	15.97	16.92	17.63	18.84	7.93	0.005	>0.001	0,020
	Female	7.92	13.84	16.79	13.35	16.78				
Regression[1]	$Y_{males} = 0.079x + 5.8778$ (R^2= 0.67; P =>0.001); $Y_{females} = 0.073x + 5.237$ (R^2= 0.62; P =>0.001)									
b^*	Male	14.43	13.75	13.51	13.39	12.18	6.15	0.998	0.112	0,019
	Female	14.14	12.51	13.47	12.75	14.38				
Regression[1]	Y_{males}= $-0.017x + 15.55$ (R^2= 0.88; P = 0.004); $Y_{females}$= $0.001x^2 – 0.11x +19.12$ (R^2= 0.62; P = 0.020)									
C^*	Male	16.55	21.08	21.67	22.14	22.44	5.66	0.019	>0,001	0,010
	Female	16.26	18.66	21.52	18.46	23.66				
Regression[1]	$Y_{males} = 0.044x + 15.465$ (R^2= 0.64; P =>0.001); $Y_{females} = 0.051x +13.467$ (R^2= 0.62; P = >0.001)									
h°	Male	60.75	40.76	38.56	37.22	32.87	6.15	0.015	>0,001	0,184
	Female	60.93	42.17	38.72	43.73	37.49				
------------------Sex (Females = 44.61 and Males = 42.03); [1]Age at slaughter (Y = $-0.177x + 64.908$ (R^2= 0.61; P = >0.001))------------------										
CL (%)	Male	32.27	28.07	29.17	34.63	36.25	5.78	0.001	>0.001	0.001
	Female	29.33	30.80	27.00	28.85	35.89				
Regression[1]	$Y_{males} = 0.002x^2 – 0.483x + 58.059$ (R^2= 0.62; P =>0.001); $Y_{females} = 0.002x^2 – 0.389x + 49.477$ (R^2= 0.79; P = >0.001)									
Final pH	Male	5.79	5.70	5.59	5.99	5.81	2.45	0.131	0,042	0,114
	Female	5.75	6.03	5.76	5.90	5.87				
--[1]Age at slaughter (Y = x^4 (R^2= 1.00; P = 0.006))--										
SF(kgf)	Male	1.64	1.80	1.54	3.30	- -	12.85	0.004	>0.001	>0.001
	Female	1.81	1.68	3.22	3.13	- -				
Regression[1]	$Y_{males} = 0.018x + 0.129$ (R^2= 0.59; P =>0.001); $Y_{females} = 0.021x + 0.226$ (R^2= 0.76; P = >0.001)									
TotalColl (mg/g)	Male	3.26	4.91	8.06	7.20	11.48	27.59	>0.001	>0.001	0.016
	Female	2.59	5.06	6.25	3.99	5.07				
Regression[1]	$Y_{males} = 0.047x + 72.303$ (R^2= 0.88; P =>0.001); Females= 4.59 (P = 0.1018)									
SolColl (%)	Male	37.05	35.34	31.51	17.84	21.44	23.31	0.007	>0.001	0.164
	Female	31.90	38.81	17.70	11.73	10.99				
Regression[1]	Sex (Females = 22.23 and Males = 28.64); [1]Age at slaughter (Y = $-0.212x + 51.346$ (R^2= 0.85; P = >0.001))									

*T-test (α = 0.05); [1]with α = 0.05;[2]coefficient of variation; CL - cooking loss; SF - shear force; TotalColl- total collagen; SolColl - soluble collagen; L^* - lightness; a^* - red index; b^* - yellow index; C^* - saturation index; h°- hue angle.

between sexes (Table 6). In both cuts there was a linear and gradual increase in the diameter and area of muscle fibers as a function of age at slaughter, which behavior was due to the process of muscle hypertrophy (NAKAMURA et al., 2004). Females showed higher values in the breast, but there was no difference between the sexes in the drumstick, which may explain why females had higher breast yields in the present and previous studies (CRUZ et al., 2018 a, b; CRUZ et al., 2020).

Overall, male and female Label Rouge chickens respond differently to advancing slaughter age, affecting their performance. The carcass and meat quality parameters followed polynomial a polynomial trend with slaughter age, which can be used to choose the slaughter time to obtain better product characteristics for consumers.

Table 6 - Parameters related to the proximate and muscle fiber composition of the breast and drumstick of Label Rouge chickens as a function of slaughter age and sex.

Cut	Variable	Sex (S)	---------------Age at slaughter (A)------------					CV^2 (%)	----------P-value*---------		
			70d	90d	120d	150d	180d		S	A	S*A
Breast	Protein (%)	Male	22.31	25.03	24.21	23.94	25.29	4.60	0.379	0.018	0.487
		Female	24.07	24.80	24.73	23.51	25.52				
	------------------------------------[1]Age at slaughter (Y= 0.0108x + 23.019 (R^2= 0.36; P = 0.048))-----------------------------------										
	Moisture (%)	Male	76.17	74.95	75.86	74.91	74.61	0.87	0.001	0.007	0.083
		Female	74.73	75.11	74.34	74.80	73.18				
	----------Sex (Females = 74.43 and Males = 75.30); [1]Age at slaughter (Y = -0.012x + 76.293 (R^2= 0.79; P = 0.001))-----------										
	Ether extract (%)	Male	0.78	1.00	0.74	0.93	0.65	26.94	0.109	0.015	>0.001
		Female	0.72	0.53	0.81	1.02	1.76				
	Regression[1]	Males= 0.82 (P = 0.4052); $Y_{females}$ = 0.009x – 0.182 (R^2= 0.78; P = >0.001)									
	Ash (%)	Male	1.25	1.03	1.09	1.48	1.21	9.06	0.006	>0.001	0.376
		Female	1.36	1.05	1.33	1.71	1.26				
	-------------Sex (Females = 1.34 and Males = 1.21); [1]Age at slaughter (Y = 0.002x + 1.078 (R^2= 0.13; P = 0.006))-------------										
	Muscle fiber diameter (µm)	Male	19.16	23.86	28.38	27.70	28.07	5.92	0.022	>0.001	0.470
		Female	22.08	24.51	28.18	29.32	30.11				
	-----------Sex (Females = 26.84 and Males = 25.44); [1]Age at slaughter (Y= 0.074x + 17.118 (R^2= 0.81; P = >0.001))----------										
	Muscle fiber area (µm²)	Male	258.46	402.46	517.78	468.95	503.77	12.13	0.039	>0.001	0.172
		Female	356.86	374.61	504.12	550.91	585.19				
	------Sex (Females = 474.34 and Males = 430.28); [1]Age at slaughter (Y = 1.903x + 198.125 (R^2= 0.64; P = >0.001))------										
Drumstick	Protein (%)	Male	21.81	24.36	24.01	23.11	24.26	4.50	0.348	0.058	0.433
		Female	23.43	24.49	23.34	23.89	24.27				
	-										
	Moisture (%)	Male	77.52	76.41	77.29	76.41	76.17	0.82	0.006	0.005	0.285
		Female	77.03	76.46	75.74	75.88	75.19				
	---------Sex (Females = 76.06 and Males = 76.76); [1]Age at slaughter (Y = -0.012x + 77.892 (R^2= 0.85; P = >0.001))---------										
	Ether extract (%)	Male	2.14	2.54	1.75	2.06	1.55	26.23	0.034	0.121	0.074
		Female	1.72	2.36	2.86	3.35	2.22				
	---Sex (Females = 2.50 and Males = 2.01)--										
	Ash (%)	Male	1.02	0.93	1.09	1.13	0.95	7.61	0.871	0.010	0.789
		Female	1.02	0.96	1.07	1.08	1.01				
	-----------------------------[1]Age at slaughter (Y = $-0.00003x^2$ + 0.007x + 0.605 (R^2= 0.36; P = 0.027))-----------------------------										
	Muscle fiber diameter (µm)	Male	17.16	22.00	25.68	28.83	27.42	7.11	0.096	>0.001	0.337
		Female	20.24	23.19	24.52	29.39	29.34				
	-----------------------------------[1]Age at slaughter (Y = 0.091x + 13.698 (R^2= 0.88; P = >0.001))-----------------------------------										
	Muscle fiber area (µm²)	Male	225.59	316.88	449.61	532.51	529.80	13.59	0.248	>0.001	0.913
		Female	273.17	360.81	447.16	536.60	561.55				
	-----------------------------------[1]Age at slaughter (Y = 2.780x + 84.168 (R^2= 0.93; P = > 0.001))-----------------------------------										

*T-test (α = 0.05); [1]with α = 0.05;[2]coefficient of variation.

CONCLUSION

Increasing the slaughter age allows higher live and carcass weights at slaughter to be obtained from chickens of both sexes, with a consequent reduction in performance indices, in addition to lower carcass yield and greater deposition of abdominal fat in females.

Females have lower tenderness in the drumstick and males in the breast with increasing slaughter age, especially after 120 days. The breast and drumstick have different color characteristics between sexes, and in both cuts, there is greater color intensification, greater red index, and reduced brightness with increasing slaughter age starting at 90 days.

ACKNOWLEDGEMENTS

The authors are thankful for the funding received from Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) process no. CVZ-APQ-03268-16; and for the scholarship granted and finance code 001 by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). The authors also thank the Instituto Federal de Minas Gerais (IFMG) Bambuí Campus, and Vaccinar Nutrição Animal® for providing resources for the study.

BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

This study was approved by the Comitê de Ética no Uso de Animais (CEUA) of Instituto Federal de Minas Gerais (IFMG), Campus Bambuí, under protocol number 04/2019.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

Conceptualization and data curation: Peter Bitencourt Faria; Methodology: José Rafael Miranda, Joanna Oliveira Marçal, Giulia Piva Oliveira, Larissa Faria Silveira Moreira, Alexander Alexandre de Almeida, Rosiane de Souza Camargos; Supervision: Adriano Geraldo. Writing and editing: Peter Bitencourt Faria. All authors critically reviewed and approved the final version the manuscript.

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