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ANIMAL SCIENCE

Cut yield and meat quality of brown eggshell laying hens housed in an alternative system and submitted to different feeding volumes

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Abstract: The aim was to evaluate the effect of different feeding volumes on the cut yield and meat quality of brown eggshell laying hens strain Embrapa 051 (E051) during the laying cycle, reared in an alternative system and slaughtered at 73 weeks, with reference to the lineage *Lohmann Brown* (LB). 600 hens E051 and 200 hens LB were used in an entirely randomized experimental design totalizing 5 replicates with 40 birds each. The treatments were: Control (LB fed with 100% of their dietary requirements), E051 fed with 93% of the control diet, E051 fed with 100% of the control diet, and E051 fed with 107% of the control diet. Birds were supplemented daily with 30g of ground grasses. Different feeding volumes did not alter the physicochemical quality of the meat and the cut yield. Body and cold carcass weight were greater in the E051 fed with 107% of the reference feed compared to the LB or the E051 fed with 7% less than the control diet. Yellow color intensity was greater in the E051 than in LB. The results demonstrated that, at the end of their productive cycle, the E051 without a restricted diet presents good carcass characteristics and potential for industrialized development.

Key words: dual purpose, feed supply, laying hen, meat quality.

INTRODUCTION

New consumer demands about food security and animal welfare have brought about increased demand for more natural products produced in alternative systems to the conventional cage system. The free-range production model, in which birds have more freedom and access outdoor areas are perceived as natural, ecological and animal welfare-friendly (Husak et al. 2008). The majority of consumers believe that raising birds in conventional systems of confinement cause stress and harmful physiological responses and behaviors in the animal and result in worse productive performance (Li et al. 2017).

There is also a low acceptance of laying hens alive birds by the industry, especially those raised in cages. This has been reported by farmers as major problem for the feasibility of commercial laying. However, in Brazil there is the commercial lineage of free-range laying hens Embrapa 051 (E051), a hybrid crossbreed of the *Rhode Island Red* and *Plymouth Rock White*. As a rustic bird, it adapts well to less intensive systems (Avila et al. 2006), as well as being the only Brazilian lineage available for small and medium-sized farmers (Miele et al. 2008).

The E051, according to Embrapa recommendations, is ideal for alternative housing, as its performance presents a high egg production capacity and, as a bird considered to be dual purpose, the carcass can be consumed at the end of the productive cycle. One feasible alternative is the slaughter of these birds in commercial slaughterhouses when they reach the end of their laying cycle. Therefore, producing this meat through deboning and tenderizing methods is an option for Brazilian poultry farming (Sanfelice et al. 2010). One form of commercialization generally used for hen meat is the preparation of mechanically separated meat (MSM), used in the composition of most meat emulsions such as frankfurters, mortadella (Trindade et al. 2004) canned meats, or can even be commercialized in the form of whole carcass which are used to make aromatic broths and other soups (Kokoszyński et al. 2016).

Meeting all the quality specifications is one of the main challenge of the meat industry, being important to know the physicochemical, microbiological and sensory properties, as well as whether such attributes determine the quality of the product, essential for obtaining well-accepted commercial products. The objective of this work, therefore, was to evaluate the cut yield and physicochemical quality of layer hen breast meat (*Pectoralis major*) submitted to different feeding volumes and housed in an alternative system.

MATERIALS AND METHODS

The methods and protocols for this experiment were approved by the Commission for Ethics in Animal Experimentation (CEEA) of the Federal University of Pelotas, RS, Brazil, under registration number 8469/2016.

Location, animals, diets, experimental design

The experiment was carried out at a commercial laying hen house in the town of Ouro, Santa Catarina, Brazil, in partnership with Embrapa Swine and Poultry research institute. A total number of 800 laying hens were housed, 600 of the hybrid lineage Embrapa 051 (E051) and 200 of the commercial lineage *Lohmann Brown* (LB). The birds were distributed in 20-floor pens with 40 birds each, at a density of 6.6 birds m^2, in an entirely randomized experimental design. For each pen, the floor was covered with pine shavings lay of eight centimeters and individually connected to a 5.6 m^2 external area, covered with eight centimeters of sand, aiming for an alternative enriched rearing system. The ambient temperature and relative air humidity were recorded using a datalogger, obtaining a mean temperature along the experimental period of 21.3°C and a relative air humidity of 82.1%. The aviary lighting was provided through fluorescent lamps and controlled by a timer to provide a total of 16 hours of daily light.

The birds were fed from the age of 18 to 73 weeks with a corn and soybean meal-based experimental diet, formulated to meet the maintenance and egg production nutritional requirements, according to the *Lohmann Brown* manual for the reference lineage (Lohmann do Brasil 2011), following the ideal protein profile recommended by the Brazilian Tables for Poultry and Swine (Rostagno et al. 2011). Table I presents the compositions of the experimental diets used in the different bird development phase.

Daily caloric requirements have been used in laying hens to establish daily feed intake. Understanding the energy ingestion of the Embrapa 051 laying hen has become important to improve the energy use efficiency of the feed and to control feeding costs. For this reason, a volume-based feeding protocol for E051 was designed to adjust the feed intake in relation to the other genetic line, broadly accepted by the production chain. The hypothesis was that by varying the volume of food at a range of ±7% of Lohmann brown's requirement we would find the best feeding strategy for Embrapa 051. This

Table I. Ingredients and nutritional composition of the experimental diets of laying hens at different development phases.

Ingredients (%)	Pre-laying	Laying I	Laying II	Laying III
Maize grain	55.00	60.00	60.00	60.00
Soybean Meal	28.62	16.08	23.76	17.75
Calcitic limestone	8.70	9.37	9.19	9.53
Wheat bran	5.55	13.26	5.35	10.71
Soybean oil	1.21	0.33	0.56	1.03
Vitamin/mineral Premix[1]	0.40	0.40	0.40	0.40
Salt	0.38	0.43	0.35	0.35
Dicalcium Phosphate	0.00	0.00	0.14	0.00
DL-Methionine	0.00	0.05	0.10	0.05
Mycotoxin binder[2]	0.10	0.10	0.10	0.10
L-Lysine	0.00	0.05	0.00	0.04
L-Threonine	0.00	0.0002	0.03	0.03
L-Tryptophan	0.00	0.0052	0.00	0.00
BHT	0.01	0.01	0.01	0.01
Phytase[3]	0.01	0.01	0.005	0.005
TOTAL	100	100	100	100
Calculated nutritional composition				
Metabolizable energy (kcal/kg)	2,800	2,750	2,750	2,750
Crude Protein (%)	18.00	13.96	16.00	14.12
Crude Fibre (%)	2.99	3.15	2.81	3.00
Calcium (%)	3.70	3.90	3.74	3.83
Fat (%)	3.89	3.25	3.34	3.88
Sodium (%)	0.16	0.18	0.15	0.15
Linoleic acid (%)	2.06	1.74	1.77	2.07
Available Phosphorous (%)	0.51	0.50	0.33	0.31
Digestible methionine (%)	0.33	0.33	0.41	0.33
Digestible MethionineCystine (%)	0.61	0.57	0.67	0.57
Digestible Lysine (%)	0.84	0.62	0.72	0.63
Digestible Threonine (%)	0.60	0.45	0.55	0.48
Digestible Tryptophan (%)	0.20	0.15	0.17	0.15
Digestible Arginine (%)	0.80	0.80	0.95	0.82
Digestible Isoleucine (%)	0.68	0.49	0.59	0.50
Digestible Valine (%)	0.78	0.59	0.68	0.60

[1]Composition of the product (guaranteed levels per kg of product): Vit A = 2250000 IU; Vit D3 = 750000 IU; Vit E = 3750 IU; Vit K3 = 625 mg; Vit B1 = 375 mg; Vit B2 = 1250 mg; Vit B6 = 750 mg; Vit B12 = 3750 mcg; Pantothenic acid = 2000 mg; Niacin = 6250 mg; Folic acid 250 mg; Choline = 75 g; Biotin = 25 mg; Copper = 2500 mg; Iron = 12,5 g; Manganese = 20 g; Iodine = 250 mg; Zinc = 15 g; Selenium = 75 mg; Methionine = 245 g; Halquinol = 7500 mg. [2]Zeotek® (organo-aluminosilicate sequestrant). [3]Phyzyme® 10,000 FTU.

strategy resulted in four treatments that were tested, which differed in the quantity of daily feed supplied to the birds (different volumes): T1 - *Lohmann Brown* – control diet (LB 100 %); T2 - Embrapa 051 fed 93 % of the control diet (E051 93 %); T3 - Embrapa 051 fed 100 % of the control diet (E051 100 %) and T4 - Embrapa 051 fed 107 % of the control diet (E051 107 %). The food was ground and weighed in accordance with each treatment and the number of birds in each pen, and supplied once a day, in the morning. Water supply was done throughout nipple drinkers, ad libitum. In the afternoon period, all the birds were offered grinded grasses (30g/bird/day), varying between Dwarf Elephant Grass *(Pennisetum purpureum Schum. Cv. Mott)* and Westerwolds Ryegrass (*Lolium multiflorum)* according to availability along the period. The purpose of supplying grasses to the birds was to promote an alternative system of production. Grass chemical composition is presented in Table II.

Carcass yield and physicochemical quality of the breast muscle (*Pectoralis major*)

At 73 weeks of age, the carcass and cut yields were determined, followed by breast meat physicochemical quality evaluation. Three birds were selected per replicate (15 birds per treatment). Birds were selected based on body weight, choosing weights within the average body weight of replicate ± 2.5 %. The overall average body weight of the hens before slaughter was 2,073.6 g ± 203.3 (CV=9,8 % n=60). Birds were identified, fasted for an 8-hour period, and slaughtered in the experimental processing plant at Embrapa - Concórdia/SC, following the commercial slaughter standards according to ministerial directive 210 (Brazil 1998). Immediately after stunting, the birds were scalded at a temperature between 60 - 62°C, the feathers removed mechanically using a plucking machine, eviscerated and hot carcass weight was recorded, followed by cooling of the carcass in an immersion chiller.

The chilled carcass weight was determined after 24 hours of cooling in a cooling chamber (0 - 5 °C). Then carcasses were submitted to cutting, and breast, legs and thighs, back and neck, wings, and abdominal fat weight were recorded individually. The cut yield was calculated according to the formula: yield = [(piece weight / refrigerated carcass weight) * 100]. The physicochemical and quality characteristics of the breast meat were determinedfor the following parameters: pH of the breast muscle (*Pectoralis major*) with a portable pH/temperature gauge (Hanna, Modelo Hi 99163), and color at 24 hours post-mortem. Color analysis was conducted on the fresh sample, wich was exposed to light for 20 minutes prior to taking readings at three different points of the piece (digital chroma meter, Konica Minolta CR-400), using the CIE Lab system, measuring the parameters L* (luminosity), a* (tendency to red) and b* (tendency to yellow) (Van Laack et al. 2000).

Table II. Nutritional composition of the Westerwolds Ryegrass and Dwarf Elephant Grass.

Composition[1]	Westerwolds Ryegrass	Dwarf Elephant Grass
Dry Matter (%)	14.89	13.87
Raw energy (kcal/kg)	628.33	550.33
Crude Fibre (%)	3.59	3.30
Ash (%)	1.92	2.32
Phosphorus (mg/kg)	834.00	725.00
Calcium (mg/kg)	938.00	758.00
Nitrogen (mg/kg)	4,062.00	3,794.00
Sodium (mg/kg)	34.00	19.66

[1]**Physicochemical Laboratory, Embrapa Swine and Poultry, Concórdia, SC.**

The water holding capacity (WHC) was determined according to the method described by Hamm (1960) and adapted by Wilhelm et. al. (2010), based on the measurement of water loss when applying pressure (10 kg / 5 min) over approximately 2.0 g of deboned breast sample. The breast sample was weighed after applying pressure, and the amount of water lost was determined by the difference in weight. The result was expressed as a percentage of exudated water in relation to the initial sample weight. For the cooking loss (CL) the *in natura* breast meat samples were weighed (100 g ± 5 g), packaged, and cooked until the internal temperature reached 82 °C. The cooked samples were exposed under filter paper until completely cooled at room temperature and then weighed again to calculate the corresponding water loss (Honikel 1987).

To attain the objective measurement of tenderness, texture analyzer equipment was used (Stable Micro Systems, Texture Analyzer TA-XTPlus). The cooked breast meat samples were cut into strips (at least in triplicate) of approximately 1.0 cm x 1.0 cm x 2.0 x 2.0 cm, with the fibers placed perpendicularly to the texture analyzer blades. The test speed is set at 0.33 cm/sec and 5.0 g trigger force, thus ascertaining the maximum shear force (kgf/cm²) (Honikel 1998).

Statistical analysis

The data were submitted to analysis of variance (ANOVA) and subsequently, the treatment means were compared by the *Tukey* test at a level of significance of 5%, using the statistical software R (R CORE TEAM 2017).

RESULTS

No significant differences were found between the treatments for the leg/thigh and back/neck cut yields (P = 0.393 and P = 0.051, respectively) (Table III). For all carcass and cut yields no significant difference between birds of the E051 lineage fed with an extra 7% (E051 107 %) in relation to the E051 lineage fed a control diet (E051 100%), but there was a greater body weight (P<0.001) in relation to the E051 93%. The LB hens presented the lowest body weight but did not differ significantly from treatments E051 93% and E051 100%. The E051 100% was on average 124 grams heavier than the LB, but this difference was not statistically significant. Both lineages are classified as semi-heavy laying

Table III. Body and carcass weight, cut yield percentage, and abdominal fat (mean ± standard deviation) of laying hens of 73 weeks submitted to different feeding volumes for 55 weeks and housed in an alternative rearing system.

Parameters	Treatments				P value	CV (%)
	LB 100%	E051 93%	E051 100%	E051 107%		
Body weight (g)	1973.33 ±116.00 b	1980.00 ±132.32 b	2097.73 ±277.25 ab	2243.66 ±120.73 a	<0.001	7.47
Cold carcass (g)	1376.00 ±106.74 c	1467.51 ±103.79 b	1628.80 ±58.30 a	1623.47 ±107.20 a	<0.001	5.26
Breast (%)	22.36±0.91 b	23.56±1.73 a	23.69±0.88 a	23.55±1.10 a	0.017	5.31
Leg/thigh (%)	28.69±1.06	28.45±0.89	29.06±0.92	28.77±1.62	0.393	3.44
Back and neck (%)	28.55±1.33	28.42±2.05	26.98±1.76	28.40±1.92	0.051	6.09
Wings (%)	9.91±0.27 ab	10.05±0.22 a	9.71±0.40 b	9.68±0.47 b	0.024	3.73
Abdominal Fat (%)	2.19±0.75 ab	1.50±0.63 b	2.61±0.79 a	2.50±0.68 a	0.003	32.41

LB 100% - lineage *Lohmann Brown* control feed 100% of the diet, E051 93% - lineage Embrapa 051 + 93% feed of control diet, E051 100% - lineage Embrapa 051 + 100% feed of control diet, and E051 107% - lineage Embrapa 051 + 107% feed of control diet. Different letters on the same line differ by the Tukey test (P≤0.05)

hens. Hence, the E051 100% and 107% treatments presented a cold carcass weight that was on average 250 grams greater than the treatment with the lightest cold carcass weight, LB, and approximately 150 grams heavier in relation to the E051 93% treatment (P<0.05).

The different diet volumes did not influence the breast cut yield, however, the E051 lineage was superior in this variable (P = 0.017) in comparison with the LB lineage. The E051 93% treatment presented greater wing cut yield, differing from the E051 107% and from the E051 100% (P<0.05). However, the E051 100% and 107% treatments presented a greater percentage of abdominal fat, 2.61%, and 2.50%, respectively, in comparison with the E051 93% treatment, which was a diet with 7% less volume than the control (P=0.003). The results of the different diet volumes on the breast meat quality variables are presented in Table 4. No significant differences were found for the variable pH, cooking loss of water, water retention capacity (WRC), color-luminosity (L*), color-red content (A*) and, shear force. However, the E051 lineage did present a yellower breast meat color (b*) than the *Lohmann Brown* 100% (P=0.004), regardless of the feeding volume offered (Table IV).

DISCUSSION

The E051 laying hen is a slightly larger bird than the LB, according to the lineage manuals, and therefore, the body weight and cold carcass weight (P<0.001) of the laying hens followed the natural tendency of each lineage. The E051 birds that were fed a 7% greater diet than the control group presented a heavier body weight and carcass weight. The results are justified, for the birds that receive more energy gain more weight than those that receive a less energetic diet (Harms et al. 2000). Murugesan & Persia (2013) suggest that the calculation of the required dietary energy follows the production and maintenance standard prior to energy storage demands (fat), with this being the most sensitive indicator of the short-term energy state of the diet in laying hens.

On the other hand, the results show that the different diet volumes do not interfere so effectively with the cut yield at the end of the laying cycle. This occurs by reason of the cut yield being a measurement that is proportional to the initial carcass weight. Also, as laying birds, even those of dual purpose, do not display a great aptitude for muscular gain, the cut yield is not significantly distinct. However, aspects of

Table IV. Quality of breast meat (*Pectoralis major)* (mean ± standard deviation) of laying hens of 73 weeks submitted to different feeding volumes for 55 weeks and housed in an alternative rearing system.

Parameters	Treatments				P value	CV (%)
	LB 100%	E051 93%	E051 100%	E051 107%		
pH	5.94±0.10	5.90±0.12	5.95±0.15	5.93±0.07	0.690	2.00
WRC (%)	14.74±4.20	17.89±4.47	17.40±3.95	17.51±5.24	0.083	21.66
Cooking loss (%)	33.55±2.80	34.37±2.06	33.30±2.55	32.64±2.32	0.121	5.81
Luminosity (L*)	48.18±1.99	49.37±2.21	49.26±2.32	48.00±2.31	0.219	4.58
Red content (a*)	-1.90±0.64	-2.01±0.64	-1.81±0.53	-1.55±0.68	0.223	34.24
Yellow content (b*)	1.20±0.77 b	2.29±1.11 a	2.18±0.89 a	2.54±1.32 a	0.004	49.36
Shear force (kgf/cm²)	2.05±0.35	2.11±0.30	2.04±0.23	1.94±0.23	0.417	14.02

LB 100% - lineage *Lohmann Brown* control feed 100% of the diet, E051 93% - lineage Embrapa 051 + 93% feed of control diet, E051 100% - lineage Embrapa 051 + 100% feed of control diet, and E051 107% - lineage Embrapa 051 + 107% feed of control diet. Different letters on the same line differ by the Tukey test (P≤0.05)

animal production such as genetic heritage, pre-slaughter handling (transport, rest, stunning, and bleeding), and nutrition can also influence muscular properties (Mendes & Komiyama 2011).

At the time of slaughter of the bird, the physiological pH begins to fall as a result of the onset of rigor mortis, with the production of lactic acid due to anaerobic glycolysis (Lawrie 1998). This process of muscle conversion into meat is slow, and if it continued indefinitely it would lead to the complete degradation of the tissues and their constituents (Hedrick et al. 1994). The onset of rigor mortis in chickens takes approximately 30 minutes or less (Olivo 2006, Komiyama et al. 2010). However, the speed of the fall in pH varies according to the muscle type, available glucose, and temperature, and can also vary between lineages and individual birds.

According to Olivo (2001), the color observed on the surface of meat is the result of the selective absorption of light by the myoglobin and other important components, such as the muscle fibers and their proteins, and is also influenced by the quantity of free liquid present in the meat. According to Qiao et al. (2001), the parameter L* is used to classify chicken meat as pale ($L^* > 53$), normal ($48 \leq L^* \leq 53$), and dark ($L^* < 46$). The results obtained were $48 \leq L^* \leq 49.37$, therefore, for the parameter in question, we can consider the samples to fall within the range of normal meat. Olivo et al. (2006) describe that a post-mortem muscle pH in the range of 5.70 to 5.85 and L* values higher than 53 results in the development of PSE (Pale, Soft, Exudative) chicken meat. On the other hand, Soares et al. (2002) report that pH levels higher than 6.05 and L* below 44 lead to the chicken meat being characterized as DFD (Dark, Firm, Dry).

The difference between PSE and DFD is that the former is associated with quick stress, which occurs immediately before slaughter, whereas DFD is associated with a long period of pre-slaughter stress, where both (PSE and DFD) result from alterations to the post-mortem metabolism. It should be highlighted that the pre-slaughter conditions directly influence the meat pH, and therefore it can be concluded that regardless of the treatment, the birds in this study were not subjected to prolonged and/or momentary stress, given the pH and luminosity (L*) values presented. Komiyama et al. (2010) evaluated the meat quality of heavy hens and found L* values similar to those of this study, yet the a* and b* values were different. Faria et al. (2009) asserted that the ingestion of a greater quantity of carotenoid-rich fodder by slow-growth birds determines a more intense yellow carcass color (flesh and skin), resulting in a higher b* value. Despite the quantity of fodder supplied being the same for all the birds, the E051 hens obtained a higher b* value compared to the LB lineage, thus indicating a genetic effect in pigment deposition in these birds, adding value to the product, free-range chicken.

Water retention capacity (WRC) is a bio physiochemical parameter that can be defined by a greater or lesser capacity to secure water in the actin-myosin chains that form the muscle (Osório et al. 2009). The water retention capacity is influenced by the development of *rigor mortis*, as well as other parameters, such as succulence, softness, species, breed, age, muscle type, temperature, and *ante*- and *post-mortem* treatments (James and James 2002), resulting in the sensation of greater or lesser succulence upon chewing. This parameter is relevant to meat quality, whether for direct consumption or industrialization, as the greater the water retention capacity, the lower the loss will be during storage, commercialization, and processing (Gomide et al. 2013). Natural moistness of the flesh is essential for attaining good yield and final quality of the products, contributing toward the texture, succulence, flavor, and palatability of the meat as food.

According to Lawrie (2005), water retention capacity is related to the speed at which the pH falls during *rigor mortis* and its final value. The higher the pH, the greater the water retention capacity will be. Despite these variables not diverging between treatments (P>0.05), the water retention capacity and cooking loss of water were low, possibly due to the advanced age of the birds. Bridi & Constantino (2009) report that as the animal's age advances, there is greater cross-linking within and between the tropocollagen and collagen molecules. These pyridinoline cross-links afford greater stability to the molecule, but on the other hand, increase the insolubility of the collagen. Consequently, with the advance of the animal's age, the meat becomes stiffer. Meat texture, the most important factor in determining the quality of meat from a consumer point of view, (Nishimura 2015, Dransfield et al. 1984) is closely related to the quantity of water retained in the muscle/myofibrillar structure and, therefore, the water retention capacity of the meat, in such a way that the higher the water content in the muscle generally a product with a higher sensory tenderness and juiciness is obtained (Hughes et al. 2014). Warner (2023) reports that reducing water losses is important to maintain the flavor, texture, and succulence of the product, which are important sensory characteristics for the consumer.

The mean shear force of the breast meat (*Pectoralis major*) was 2.0 kg f. This average is similar to results obtained by Loetscher et al. (2014) in the breast meat of 78-week-old birds in all treatments. Pinto et al. (2010) report that the Warner-Bratzler shear force is currently the most commonly employed method to evaluate the resistance (tension) of the cut; the greater the shear force, the lesser the meat's softness. Mueller et al. (2018) found values of around 1.2 kg f for the shear force of the dual-purpose lineage *Lohmann* Dual, of two traditional dual-purpose lineages (*Belgian Malines* and *Schweizerhuhn*) and one laying hen lineage *(Lohmann Brown Plus*). The effects of age on the shear force often result from alterations in the collagen characteristics, such as increased collagen cross-linking in the muscle (Chueachuaychoo et al. 2011). According to Sterten et al. (2009), variations in the meat pH can also influence the shear force and cooking loss of water, which are important parameters for consumer acceptance of the meat and satisfaction with its preparation and consumption. However, causes of variation in water-holding, color, and tenderness of raw meat do not generally correspond to variations in the properties of cooked meat (Hughes et al. 2014). The consumption and acceptability of the final product obtained from laying hens meat are always made in the cooked form. For this reason, further studies evaluating the effects of cooking meat on the characteristics and acceptability of meat by consumers from discarded E051 laying hens are needed.

CONCLUSIONS

The alteration to the diet of 7% more or less volume than the standard did not affect the physicochemical quality of the meat and the cut yield of Embrapa 051 laying hens. However, the 7% reduction did cause lighter body weight and cold carcass weight.

At the end of its production cycle, the Embrapa 051 lineage presents technological quality characteristics compatible with its use as raw material for the development of industrialized products and domestic consumption.

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