Effect of different arginine-to-lysine ratios in broiler chicken diets on the occurrence of breast myopathies and meat quality attributes

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ABSTRACT This study was carried out to evaluate the effect of different digestible arginine-to-lysine (dig Arg:Lys) ratio in broiler diets on the occurrence of breast myopathies, productivity, and meat quality traits. A total of 1,755 1-day-old Ross 308 male chicks was randomly divided in 3 experimental groups (9 replications/group): CON, fed a 4 feeding-phases commercial diet (dig Arg:Lys ratio = 1.05, 1.05, 1.06, 1.07, respectively in starter, grower I, grower II and finisher phase), and ARG2 and ARG3 groups fed CON diet supplemented respectively with 20 and 30% higher levels of crystalline L-arginine (dig Arg:Lys ratio = 1.25, 1.25, 1.26, 1.27 and 1.35, 1.35, 1.36, 1.37, respectively). Productive performance was recorded throughout the rearing cycle. At processing (43 d), breasts (n = 150/group) were randomly collected to evaluate the incidence and severity of white striping (WS), wooden breast (WB), and spaghetti meat (SM) defects (3-points scale). Meat quality traits, such as color, pH, drip and cook losses, marinade performances, and proximate composition were determined on 12 fillets/group. Although productive performance and meat quality traits resulted not significantly affected, the occurrence of some breast myopathies was modified by the dietary treatments. ARG2 and ARG3 exhibited a significantly higher percentage of breast without WS compared to CON (28 and 41 vs. 17%, respectively; $P < 0.001$). ARG3 reported the lowest percentage of breasts with severe WS (11 vs. 27 and 31%, respectively for ARG3, ARG2, and CON; $P < 0.001$) and the highest of those showing no SM abnormality (81 vs. 69 and 65%, respectively for ARG3, ARG2, and CON; $P < 0.01$). Furthermore, a numerical reduction of breasts with severe WB was observed in ARG3 (12 vs. 25 and 19%, respectively for ARG3, ARG2, and CON; $P = 0.12$). In conclusion, the dietary supplementation of arginine to increase the dig Arg:Lys ratio by about 30% in respect to the current recommendations for broiler chickens has positive implications on the occurrence of some breast meat abnormalities.

Key words: broiler chicken, arginine, breast myopathy, meat quality, productivity

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INTRODUCTION

The poultry industry is currently dealing with a tremendous increase in the occurrence of myopathies that affect the Pectoralis major of fast-growing broiler chickens. These muscle abnormalities, mainly white striping (**WS**), wooden breast (**WB**), and spaghetti meat (**SM**), are associated with a marked reduction of acceptability, nutritional, technological and sensory properties of breast meat determining negative outcomes on the economical sustainability of the poultry industry (Petracci et al., 2015; Kuttappan et al., 2016). The etiology of these myopathies has not been completely understood yet, even though both genetic (Alnahhas et al., 2016) and environmental factors (Bailey et al., 2015) are thought to be involved in the onset of this condition. Recent findings highlighted that breasts affected by WB or WS myopathies are characterized by a severe hypoxic status (Mutryn et al., 2015; Boerboom et al., 2018). This condition is likely determined by the massive hypertrofic-based growth of muscle fibers in high breast-yield broiler lines, which can reduce the space usually occupied by the endomysial and perimysial connective tissue layers and blood vessels contained in them, resulting in a limited blood supply to the breast muscle and then to hypoxia and cellular damages (Velleman, 2015). Very recently, Boerboom et al. (2018) pointed out that hypoxia could be considered as the triggering event of WS alterations in broiler chickens. Furthermore, it has been reported that arginine conversion into citrulline (i.e., arginine-nitric oxide pathway) was one of the most impaired metabolic pathways in breasts showing severe WS (Boerboom et al., 2018). L-arginine can be converted stoichiometrically into citrulline and nitric oxide by means of the enzyme nitric oxide synthase (Fernandes and Murakami,

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2010; Khajali and Wideman, 2010). Nitric oxide is a potent vasodilator compound (Khajali and Wideman, 2010) that could enhance blood flow to the muscle improving oxygen supply as well as the removal of harmful catabolites. Therefore, these metabolic aspects of arginine have boosted the interest toward its dietary supplementation at higher levels than those currently recommended as a potential strategy to mitigate the occurrence of breast myopathies in broilers. Recently, Bodle et al. (2018) reported that the dietary supplementation of arginine to increase the arginine-to-lysine ratio from 1.12 to 1.20 in starter, 1.14 to 1.26 in grower, 1.15 to 1.26 in finisher, and 1.14 to 1.26 in withdraw phase was able to reduce the average WB score in broilers processed at 45 d of age. However, the authors observed no significant effect of the dietary treatment on the occurrence of WS, while SM defect was not considered in their study. Similarly, the administration of dietary arginine-to-lysine ratio ranging from 1.15 to 1.17 did not exert significant effect on meat quality attributes and breast myopaties occurrence (Zampiga et al., 2018). Therefore, the effect of the dietary supplementation of high dosages of L-arginine on the occurrence of breast muscle myopathies is still poorly investigated and not completely defined.

Furthermore, quality traits and technological attributes of poultry meat can be strongly influenced by modification of the dietary concentrations of specific amino acids (**AA**), such as lysine (Corzo et al., 2002; Berri et al., 2008), methionine (Albrecht et al., 2017; Wen et al., 2017), or arginine (Corzo et al., 2003; Jiao et al., 2010; Ebrahimi et al., 2014). However, only limited information regarding the effect of increased dietary arginine-to-lysine ratio on breast meat quality traits is available. To address these concerns, this study was carried out to evaluate the effect of different digestible arginine-to-lysine (**dig Arg:Lys**) ratios in broiler chicken diets on productive performance, occurrence of breast myopathies, and meat quality attributes.

MATERIALS AND METHODS

Animals and Diet

A total of 1,755 1-day-old Ross 308 male chicks was obtained from a commercial hatchery. Chicks were vaccinated against coccidiosis, infectious bronchitis, and Marek, Newcastle and Gumboro disease at hatch. Chicks were transferred to an environmental controlled facility with 27 pens of 6 m^2 each, all equipped with 2 circular pan feeders and 10 nipples, while the floor was covered with chopped straw (2 kg/m^2). At placement, chicks were weighed and randomly assigned to 3 experimental groups (9 replications/group, 65 birds/replication, 11 birds/m^2): **CON**, fed a 4-phases commercial diet formulated according to the current recommendations for fast-growing broilers (Aviagen, 2014) and widely used in commercial practices (Table 1; dig Arg:Lys ratio = 1.05, 1.05, 1.06, 1.07, respectively in starter, grower I, grower II, and finisher phase); **ARG2**, fed the CON diet supplemented on-top with 2.46, 2.34, 2.16, and 1.90 g/kg of crystalline L-arginine in starter, grower I, grower II, and finisher feed, respectively (dig Arg:Lys ratio = 1.25, 1.25, 1.26, 1.27, respectively); and **ARG3**, receiving CON diet supplemented on-top with 3.73, 3.51, 3.20, and 2.85 g/kg of crystalline L-arginine (purity 99%, Barentz, Hoofddorp, The Netherlands) respectively in starter, grower I, grower II, and finisher feed (dig Arg:Lys ratio = 1.35, 1.35, 1.36, 1.37, respectively). The AA concentration of the experimental diets was analyzed by AMINOLab (Evonik Industries, Hanau, Germany). Digestible AA values were calculated by multiplying digestibility coefficients (Ajinomoto, 2015) to the analyzed total AA content of each ingredient. According to the analysis, the dig Arg:Lys ratio resulted 1.25, 1.25, 1.26, 1.27 in ARG2 group and 1.35, 1.35, 1.36, 1.37 in ARG3 group. The values regarding CON diet are shown in Table 1. In addition, moisture and ash content were determined in duplicate according to the Association of Official Analytical Chemists (AOAC, 1990) procedure. Crude protein and crude fat content were assessed by the standard Kjeldahl copper catalyst method and the Soxhlet method as reported in AOAC (1990), respectively. All the diets were administered in a mash form and obtained from the same batch of feed. Water and feed were administered for ad libitum consumption. According to the European legislation (European Commission, 2007), the photoperiod was 23L:1D from 0 to 7 d and in the last 3 d of the study, while 18 h of light was used in the remaining period. All the aspects related to handling, processing, and raising of the birds strictly accomplished with the European legislation (European Commission, 2007, 2009, 2010). The Ethical Committee of the University of Bologna approved the experimental protocol and procedures (ID: 928/2018).

Productive Performance

Birds were weighed and feed consumption recorded on a pen basis at the end of each feeding phase (12, 22, 33, and 43 d), and body weight (**BW**), daily weight gain, daily feed intake, and feed conversion rate were calculated. Dead or culled birds were recorded and weighed daily to determine the mortality percentage and to correct the productive performance data. At the end of the trial (43 d), all the birds were slaughtered in a commercial processing plant according to the current legislation (European Commission, 2009) using a water-bath electrical stunning (200 to 220 mA, 1,500 Hz). After air-chilling, eviscerated carcass yield, as well as breast, leg, and wing yields, was evaluated on all the processed birds and the results reported on a group basis.

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Table 1. Ingredients and chemical composition of the basal diet in each feeding phase.

	Starter (0 to 12 d)	Grower I (13 to 22 d)	Grower II (23 to 33 d)	Finisher (34 to 43 d)
Ingredients, g/100 g				
Corn	33.4	36.7	19.2	15.0
White corn	0.00	0.00	15.0	18.1
Wheat	20.0	20.0	25.0	30.0
Vegetable oil	2.45	2.68	3.61	3.97
Soybean meal 48%	18.2	20.2	14.2	9.33
Full-fat soybean	10.0	10.0	15.0	15.0
Concentrated SBM	5.00	0.00	0.00	0.00
Corn gluten	2.00	2.00	0.00	0.00
Pea	3.00	3.00	3.00	3.00
Sunflower	2.00	2.00	2.00	3.00
Lysine sulfate	0.54	0.53	0.46	0.43
DL-Methionine	0.29	0.00	0.00	0.00
Methionine h.a. 85%	0.00	0.32	0.33	0.26
L-Threonine	0.12	0.11	0.10	0.08
Choline chloride	0.10	0.10	0.05	0.00
Calcium carbonate	0.53	0.52	0.60	0.69
Dicalcium phosphate	1.29	0.80	0.47	0.21
Sodium chloride	0.29	0.30	0.23	0.21
Sodium bicarbonate	0.05	0.05	0.15	0.25
Vit.-min. premix[1]	0.54	0.46	0.38	0.30
Phytase	0.05	0.05	0.05	0.05
Xylanase	0.05	0.05	0.05	0.05
Emulsifier	0.08	0.08	0.08	0.08
Proximate composition				
AME, kcal/kg	3100	3150	3275	3325
Dry matter,* %	88.8	88.2	88.5	88.5
Crude protein,* %	23.2	22.8	19.8	18.2
Total lipid,* %	6.25	6.51	8.29	8.64
Crude fiber, %	2.96	2.92	2.99	3.08
Ash,* %	5.24	4.60	4.29	4.03
Ca (total), %	0.77	0.62	0.55	0.50
P (total), %	0.61	0.51	0.44	0.38
Dig Lysine,* %	1.25	1.15	1.05	0.94
Dig Arginine,* %	1.32	1.21	1.11	1.00
Dig Met+dCys,* %	0.93	0.85	0.79	0.70
Dig Threonine,* %	0.81	0.75	0.68	0.61
Dig Arg:dLys	1.06	1.05	1.06	1.07

[1]Provided the following per kg of diet: vitamin A (retinyl acetate), 13,000 IU; vitamin D3 (cholecalciferol), 4,000 IU; vitamin E (DL-α_tocopheryl acetate), 80 IU; vitamin K (menadione sodium bisulfite), 3 mg; riboflavin, 6.0 mg; pantothenic acid, 6.0 mg; niacin, 20 mg; pyridoxine, 2 mg; folic acid, 0.5 mg; biotin, 0.10 mg; thiamine, 2.5 mg; vitamin B12 20 μg; Mn, 100 mg; Zn, 85 mg; Fe, 30 mg; Cu, 10 mg; I, 1.5 mg; Se, 0.2 mg; ethoxyquin, 100 mg.

*Analyzed values. Amino acid concentration of the experimental diets was analyzed by AMINOLab (Evonik Industries, Hanau, Germany). Digestible amino acid (dig.) values were calculated by multiplying digestibility coefficients (Ajinomoto®, 2015) to the analyzed total amino acid content of each ingredient.

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Occurrence of Breast Myopathies

The incidence and severity of WS, WB, and SM defects were evaluated on 150 randomly collected breasts/experimental group approximately 24 h after processing. For each defect, a 3 point-scale evaluation system (**NOR**: no lesions; **MOD**: moderate lesions; **SEV**: severe lesions) was used to classify the magnitude of the defect. The dimension of white striations (Kuttappan et al., 2012), the hardness at palpation (Sihvo et al., 2014), and the proneness to show muscle destructuration in response to finger pinching (Sirri et al., 2016) were used as classification criteria for WS, WB, and SM defect, respectively. All the breasts were scored by the same well-trained operator in analogous environmental conditions.

Meat Quality Evaluations

Breast meat quality traits were assessed on 12 fresh P. major muscles per dietary treatment obtained from carcasses with BW similar to the average BW of each group. In order to avoid any interference of main breast abnormalities, P. major muscles having visual signs of pale, soft, and exudative-like, WS, WB, or SM condition were excluded. Breasts were selected at the processing plant and then transported under refrigerate conditions to the laboratories. Technological traits were determined on fresh samples while proximate composition was carried out on frozen ones. Following the removal of superficial fat and connective tissue, each fillet was used to determine technological traits as previously described by Sirri et al. (2017). In detail, a modification

Table 2. Productive performance of broilers chickens fed diets with different dig Arg:Lys ratios in the overall period of trial (0 to 43 d).

	CON[1]	ARG2[2]	ARG3[3]	SEM	*P* value
n.	9	9	9		
Body weight (g/bird)	2,864	2,834	2,821	21.7	0.72
Daily weight gain (g/bird/d)	65.7	65.0	64.7	0.50	0.72
Daily feed intake (g/bird/d)*	109.1	108.0	107.1	0.51	0.29
Feed conversion rate*	1.675	1.675	1.677	0.01	0.99
Mortality (%)	1.88	2.22	2.91	0.02	0.50

*Corrected for mortality.
[1]CON: dig Arg:Lys = 1.05, 1.05, 1.06, 1.07, respectively, in starter, grower I, grower II, and finisher phase.
[2]ARG2: dig Arg:Lys = 1.25, 1.25, 1.26, 1.27, respectively.
[3]ARG3: dig Arg:Lys = 1.35, 1.35, 1.36, 1.37, respectively.

of the iodoacetate method (Jeacocke, 1977) was used to the assess breast muscle pH at 48 h postmortem. The CIE L*a*b system color profile [lightness (L*), redness (a*), and yellowness (b*)] (CIE, 1976) of breast meat was determined on the medial surface of the fillet (bone side) in an area showing no macroscopic defects by a reflectance colorimeter (Minolta Chroma Meter CR-300, Minolta Italia S.p.A., Milan, Italy) using illuminant source C. A parallelepiped meat cut (8 × 4 × 3 cm), weighing about 80 g, and obtained from the cranial part of each fillet, was used to determine drip and cooking losses as previously described (Sirri et al., 2017). For the drip loss determination, samples were kept suspended in a sealed glass box for 48 h at 2 to 4°C, and loss was calculated as percentage of weight loss during storage. Cook loss was determined on the same fillet by cooking the samples on aluminum trays in a water bath at 80°C for 45 min. Samples were then allowed to equilibrate to room temperature, weighed again, and cook loss was determined as percentage of weight loss (Sirri et al., 2017). In addition, a second parallelepiped meat cut (8 × 4 × 2 cm) weighing approximately 60 g was excised from the middle part of each fillet and was individually labeled and tumbled with a 20% (wt/wt) brine solution containing sodium tripolyphosphate (2.3%) and sodium chloride (7.6%) and then cooked in a water bath at 80°C for 25 min according the procedures described by Mazzoni et al. (2015). Meat samples were weighed again immediately after tumbling to measure marinade uptake and placed in covered plastic boxes on sieved plastic racks in a 2 to 4°C cooler. After 48 h, samples were again weighed to determine purge loss.

Finally, proximate composition analysis was performed on the same 12 P. major muscles/dietary treatment to evaluate moisture and ash content in duplicate (AOAC, 1990), as well as crude protein (AOAC, 1990) and total fat (Folch et al., 1957).

Statistical Analysis

As for productive performance data, the experimental unit was the pen. Individual bird was considered as the experimental unit for the occurrence of breast muscle myopathies, meat quality traits, and proximate composition. Productive performance, breast meat quality traits and proximate composition data were analyzed through 1-way ANOVA considering the dietary arginine-to-lysine ratio as independent variable (SAS, 1988). Mortality percentages were submitted to arcsine transformation prior to statistical analysis. Chi-square test was applied for the statistical analysis of data regarding the occurrence of breast myopathies. Differences were considered statistically significant when P value was lower than 0.05.

RESULTS AND DISCUSSION

The dietary supplementation of L-arginine at the levels tested herein did not significantly affect the productive performance of the birds in the whole period of trial (Table 2), as well as in each feeding phase (data not shown). At slaughter, carcass and cut-up yields resulted similar among the experimental groups (data not shown).

Considering the occurrence of breast myopathies (Figure 1), both ARG2 and ARG3 groups showed a significantly higher percentage of breast without WS compared to CON (28 and 41 vs. 17%, respectively; $P < 0.001$; Figure 1: WS). Furthermore, ARG3 group showed the lowest percentage of breast with severe WS (11 vs. 27 and 31%, respectively for ARG3, ARG2, and CON; $P < 0.001$).

Even though the occurrence of WB defect was not significantly changed by the dietary treatments ($P = 0.13$), a numerical reduction of breasts showing severe WB was observed in ARG3 group (12 vs. 25 and 19%, respectively for ARG3, ARG2, and CON; Figure 1: WB). In addition, ARG3 group also reported the greatest numerical percentage of breasts without WB signs (54 vs. 42 and 43%, respectively for ARG3, ARG2, and CON; $P = 0.13$; Figure 1: WB).

The highest incidence of breast exempt from SM defect was observed in ARG3 group (81 vs. 69 and 65%, respectively for ARG3, ARG2, and CON; $P < 0.01$;

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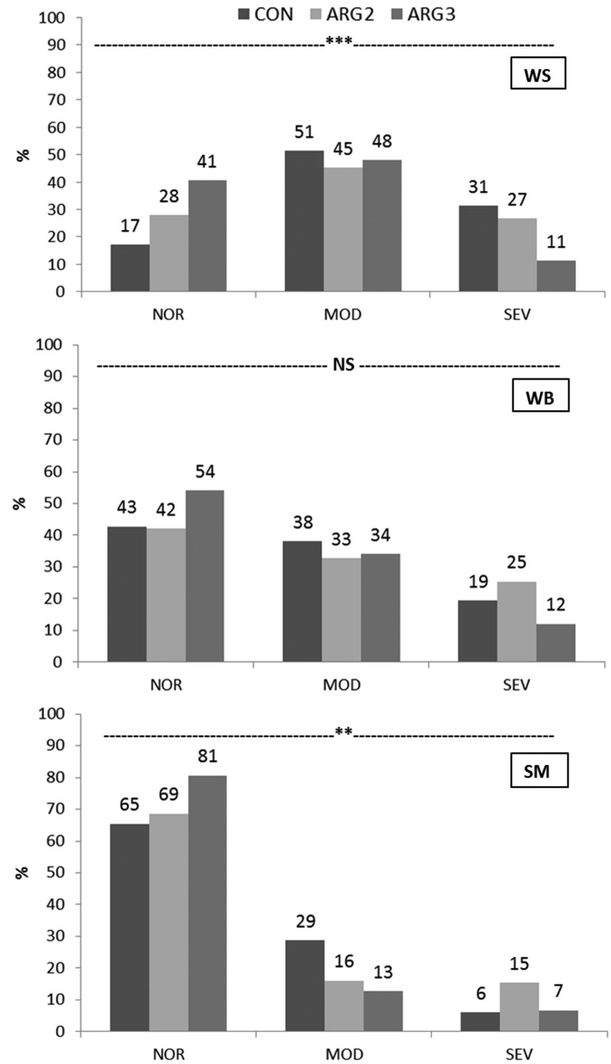

Figure 1. Occurrence (%) and severity (NOR: no lesions, MOD: mild lesions, SEV: severe lesions) of white striping (WS), wooden breast (WB), and spaghetti meat (SM) abnormality in Pectoralis major of broiler chickens fed diets with different dig Arg:Lys ratio (n = 150/group) (dig Arg:Lys ratio: CON = 1.05, 1.05, 1.06, 1.07, respectively in starter, grower I, grower II, and finisher phase; ARG2 = 1.25, 1.25, 1.26, 1.27, respectively; ARG3 = 1.35, 1.35, 1.36, 1.37, respectively). Frequencies distribution analyzed by Chi-square test ($^{**}P < 0.01$; $^{***}P < 0.001$).

Figure 1: SM). Both ARG2 and ARG3 groups exhibited a lower incidence of breasts with moderate SM defect compared to CON group (16 and 13 vs. 29%, respectively for ARG2, ARG3, and CON; $P < 0.01$). Intriguingly, ARG2 showed a higher percentage of breasts with severe SM defect compared to the other groups (15 vs. 7 and 6%, respectively for ARG2, ARG3, and CON; $P < 0.01$; Figure 1: SM).

Taken together, the dietary supplementation of the highest dosages of L-arginine, approximately 30% higher than those currently recommended for fast-growing broilers (Aviagen, 2014), was able to attenuate the incidence and severity of WS and SM abnormalities while it had no significant effect on WB. It could be hypothesized that this improvement is associated with an increased production of nitric oxide via the arginine-nitric oxide pathway. Nitric oxide can enhance vasodilation and hence promote a better blood flow to the breast muscle, limiting muscle damages likely through a greater oxygen supply to muscle fibers (Khajali and Wideman, 2010). However, since nitric oxide concentration was not determined in this study, this hypothesis cannot be confirmed. Recently, Bodle et al. (2018) observed a significant reduction of the average WB score in birds receiving an arginine-supplemented diet (dig Arg:Lys ratio = 1.20, 1.26, 1.26, 1.26 in starter, grower, finisher, and withdraw phase) in comparison to those fed a control diet (dig Arg:Lys ratio = 1.12, 1.14, 1.15, 1.14, respectively). On the other hand, the same dietary dosages did not exert any significant change in the average WS score. In a previous study, Christensen et al. (2015) observed no significant effect of diets with different dig Arg:Lys ratio (0.95 or 1.25 on a digestible AA basis) on the mean score of WB or WS in fast-growing, high-yielding male broilers at 53 d of age.

On the other hand, the dietary supplementation of arginine indirectly reduced the relative concentration of the other AA, including lysine, in the ideal protein. It has been reported that modifying the dietary lysine concentration during critical periods of growth could be considered a nutritional strategy to limit the incidence and severity of WS and WB (Meloche et al., 2018). Furthermore, Cruz et al. (2016) observed a higher occurrence of WS and WB lesions, as well as improved growth performance and carcass traits, when diets were fortified with increased levels of digestible lysine. The reduction of the dietary lysine density could be considered an effective strategy to mitigate the incidence of muscle abnormalities as long as productive performance and processing yields are not negatively affected by this dietary manipulation. Meloche et al. (2018) showed that short-term reduction of digestible lysine levels from 100% to 75% of primary breeder recommendations during grower I (12 to 18 d) and II (19 to 26 d) phase reduced the incidence and severity of WS and WB myopathies but compromised breast weight and yield in Yield Plus x Ross 708 broilers at 48 d of age. In their second trial, the authors observed a significant reduction in the occurrence of the abovementioned myopathies and no detrimental effects on slaughtering performance of 62-day-old broilers fed diets with lysine levels equal to 85% of primary breeder recommendations during grower (12 to 28 d) and finisher 1 (29 to 42 d of age) phase (Meloche et al., 2018).

The data for the breast meat quality determinations are summarized by dietary treatment in Table 3. There were no treatment effects on ultimate pH, color ($L^*a^*b^*$), water holding capacity assessed by drip and cooking losses, and marination performances. No significant differences were also found for the proximate composition of breast meat. However, yellowness (b^*) tended to be higher ($P = 0.06$) in ARG3 group, followed by CON and ARG2 ones (6.18 vs. 5.85 vs. 5.22, respectively). On the contrary, previous studies reported some effects of changing dietary level of arginine in broilers,

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Table 3. Meat quality attributes and proximate composition of Pectoralis major muscle showing no macroscopic defects obtained from broiler chickens fed diets with different dig Arg:Lys ratios.

	CON[1]	ARG2[2]	ARG3[3]	SEM	*P* value
n.	12	12	12		
Meat quality attributes					
pHu	5.81	5.80	5.78	0.02	0.91
Lightness (L*)	59.5	59.8	60.1	0.35	0.79
Redness (a*)	2.07	1.99	1.79	0.11	0.57
Yellowness (b*)	5.85	5.22	6.18	0.17	0.06
Drip loss (%)	1.97	2.33	1.84	0.10	0.14
Cooking loss (%)	15.4	16.4	15.2	0.39	0.39
Marinade uptake (%)	10.6	11.8	10.8	0.71	0.76
Purge loss (%)	12.5	12.5	13.7	0.34	0.22
Proximate composition					
Moisture (%)	76.4	77.1	77.2	0.17	0.11
Crude protein (%)	21.7	20.8	20.7	0.23	0.13
Total fat (%)	1.71	1.56	1.89	0.09	0.74
Ash (%)	1.40	1.53	1.30	0.07	0.40

[1]CON: dig Arg:Lys = 1.05, 1.05, 1.06, 1.07, respectively, in starter, grower I, grower II, and finisher phase.
[2]ARG2: dig Arg:Lys = 1.25, 1.25, 1.26, 1.27, respectively.
[3]ARG3: dig Arg:Lys = 1.35, 1.35, 1.36, 1.37, respectively.

but these effects were not always consistent or necessarily dramatic. Indeed, Corzo et al. (2003) observed a linear increase in fillet lightness (L*) and yellowness (b*), but no effect on redness (a*), increasing the dig Arg:Lys ratio from 0.91 to 1.45 between 42 and 56 d of bird age. Jiao et al. (2010) pointed out that increasing the dietary level of arginine from 80 to 140% of NRC recommendation significantly affected L* value, cooking loss and ultimate pH of breast meat. However, no significant alterations were observed for a* and b* values as well as for drip loss and pH measured after 45 min. Crude protein and dry matter content breast meat resulted significantly increased in response to the dietary supplementation of 153% of digestible arginine (dig Arg:Lys ratio = 1.57, 1.68, 1.79 from 0 to 10 d, 11 to 24 d, and 25 to 46 d, respectively) in a control diet (100% Ross recommendations) (Ebrahimi et al., 2014). However, higher levels of digestible arginine (183% and 168%) were necessary to induce significant changes in ash and fat content, respectively (Ebrahimi et al., 2014). On the other hand, intramuscular fat content resulted not significantly affected by the dietary supplementation of graded levels of arginine (0.25%, 0.50%, and 1.00%) to a control diet from 21 to 42 d of bird age (Arg:Lys = 1.17) (Fouad et al., 2013). Because of the differences found in the breast muscle abnormality occurrence, in any case an effect on the overall breast meat quality could be expected. In fact, even if P. major muscle showing visible abnormal conditions were intentionally excluded during sample collection, previous reports showed that almost all breast fillets of heavy broiler chickens produced in traditional commercial practices had histological lesions, which reflected on the chemical composition and impaired water holding/binding capacities of the meat (Mazzoni et al., 2015). Therefore, although higher dig Arg:Lys ratio reduced the occurrence of breast abnormalities in the present study, our findings revealed that no positive implications on meat quality properties arise at least in the macroscopically normal samples. On the other hand, the supplementation of incremental dosages of arginine (to increase the Arg:Lys ratio) did not affect meat quality traits as evidenced with other essential AA such as lysine (Corzo et al., 2002; Berri et al., 2008) or methionine (Albrecht et al., 2017; Wen et al., 2017).

In conclusion, these results indicate that the dietary supplementation of arginine to increase the dig Arg:Lys ratio by about 30% in respect to the current recommendations has positive implications on the occurrence of breast meat abnormalities (mainly WS and SM) without affecting live performance, processing yields, and breast meat quality traits.

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