

# Research Note: Effect of chicken genotype and white striping–wooden breast condition on breast meat proximate composition and amino acid profile

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**ABSTRACT** The present experiment compared the proximate composition, the amino acid content, and profile of the breast meat of a commercial broiler hybrid (**Hybrid-Normal**) vs. a broiler hybrid affected by the simultaneous presence of white striping (**WS**) and wooden breast (**WB**) myopathies (**Hybrid-WSWB**) vs. the Italian purebred Polverara chicken (Polverara). To this purpose, a total of  $n = 30$  breast meat cuts from male chickens/group were subjected to meat quality evaluations. Chickens were slaughtered at their commercial age. The meat of the Polverara breed showed the highest protein ( $P < 0.0001$ ) and the lowest lipids ( $P < 0.0001$ ) contents, whereas that of the Hybrid-WSWB broiler chickens had the lowest protein and ash ( $P < 0.0001$ ) contents and the highest ( $P < 0.0001$ ) amount of fat. Meat of Hybrid-Normal chickens displayed intermediate values. Polverara meat was the richest in most amino acids (g/100 g meat), whereas Hybrid-WSWB one had

the lowest content ( $P < 0.0001$ ). Taurine was not detected in the meat of the Polverara chicken. The meat of Hybrid-Normal chickens was the richest in valine and taurine amino acids ( $P < 0.0001$ ). Results on the amino acids proportions (% of total amino acids) highlighted that lysine, arginine, leucine, glutamic acid, aspartic acid, alanine, and serine were the most representative essential and nonessential amino acids, respectively, in all 3 meat-types chickens. The study confirmed that WS and WB myopathies negatively affect the meat proximate composition and the amino acid content. The meat of the Polverara breed displayed a remarkable meat quality including a high protein content of very good quality. This may represent a tool to promote its meat among consumers and help the survival of this endangered breed. Furthermore, research efforts should be conducted to understand why taurine was absent in the breast meat of Polverara chicken.

**Key words:** polverara chicken, broiler chicken, myopathies, meat quality, chemical composition

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## INTRODUCTION

Chicken is one of the most consumed meat species in the World, thanks to a series of positive features such as farming easiness, absence of religious restraints, low cost, sensory properties, and healthy nutritional profile (Magdelaine et al., 2008). The chicken breast is the prime meat cut of the carcass which has gained increasing interest by consumers and the poultry industry. In fact, in addition to the general abovementioned aspects, the chicken breast is quick and easy to cook,

which is a fundamental aspect considered by modern consumers when purchasing meat (Cullere and Dalle Zotte, 2018). Moreover, consuming meat with less fat and high protein is of utmost importance in nutritionally aware societies, and chicken breast meat perfectly fits within these requirements (Kim et al., 2013). For these reasons, the poultry industry has progressively increased the efforts toward the genetic selection to reduce the growing time to obtain a market weight bird and to improve breast yield which has increased by 5% in the last decade. As a result, the actual breast meat cut contributes to more than one-fifth of the weight of the chicken which is industrially interesting in the perspective of further processing (Petracci et al., 2015).

As an aside effect, this intense selection has also led to a growing incidence of breast meat abnormalities including white striping (**WS**) and wooden breast (**WB**) myopathies. In fact, the intense exploitation of chicken's growth potential, including the breast muscle

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development, was possible, thanks to the selection mainly for hypertrophy of muscle fibers, leading to birds with high density of fast-twitch fibers with a high diameter and a reduced rate of protein degradation (Petracci et al., 2015). Unfortunately, such muscles are also characterized by lower capillarization and a consequent lower oxygen supply to the muscles, which is considered a predisposing factor for the development of the above-mentioned myopathies (Soglia et al., 2019). WS is visually described as white striations of intramuscular deposits parallel to muscle fibers on the surface of broiler breast fillets (Kuttappan et al., 2016). Breasts affected by WB myopathy are characterized by remarkable hardness at palpation, pale color, and a slimy surface because of exudate covering the hardened areas, presence of bulges, and small hemorrhages (Sihvo et al., 2014; Dalle Zotte et al., 2017). These 2 myopathies have been associated with various meat quality alterations such as higher ultimate pH because of a lower glycolytic potential, altered energy status, and metabolic pathways, increased moisture and fat to the detriment of both protein and ash contents because of the profound alterations in muscle structure (Beauclercq et al., 2017; Petracci et al., 2019). Notwithstanding this, it is not known if the quality of the meat protein, specified by the amino acid profile (proportion) and content, is affected by such alterations. Amino acids are mainly considered as building blocks for protein synthesis, but they have also been reported to exert several other metabolic functions such as gene expression, synthesis, secretion of hormones, nutrient metabolism, oxidative defense, intracellular protein turnover, immune function, reproduction, and lipid metabolism (Wu, 2009). More specifically, the so-called functional amino acids (arginine, cysteine, glutamic acid, leucine, proline, and tryptophan) have a key role in ensuring optimal growth, reproductive function, and immunity. Tyrosine or phenylalanine are precursors to synthesize epinephrine, norepinephrine, dopamine, and thyroid hormones (Suenaga et al., 2008). Arginine and glutamic acid contribute to an effective ammonia detoxification because they maintain the hepatic urea cycle in an active state. Alanine regulates gluconeogenesis and glycolysis to ensure glucose production by hepatocytes during feed shortage (Meijer, 2003). Glutamate and aspartate regulate glycolysis and redox state of cells (Brosnan, 2001). Mainly arginine and phenylalanine, but also taurine, lysine, glutamic acid, and homocysteine, contribute to the synthesis and the hydroxylation of aromatic amino acids (Wu and Meininger, 2002). Owing to their key metabolic and nutritional importance and to the limited existing research dealing with their content in meat and meat products, further research in this sense is desirable.

On the another hand, the intense selection for highly productive hybrids led to a declining diffusion of local slow-growing chicken breeds and a consequent progressive loss of biodiversity. Despite this, modern consumers exhibit an increasing interest for poultry products from

free-range or organic systems because they are perceived as more environmentally friendly, healthier, and with superior sensory attributes compared with chicken meat from conventional systems (Fanatico et al., 2007). However, few objective measurements have been identified and are available to consumers to identify such meat (Smith et al., 2012). Polverara chicken is a rustic medium-size slow-growing Italian purebred of the Veneto region which is currently of interest for scientists, local institutions, and farmers, because of its productive potentiality in alternative production systems and its strong link to regional traditions. Recent research dealt with some meat quality aspects of this breed (Tasoniero et al., 2018; Dalle Zotte et al., 2019), but information about its meat quality features is still scarce, nonetheless required as tool to characterize this breed and promote its consumption among consumers. The latter would be an indirect tool for a successful conservation program.

Based on the abovementioned premises, the aim of the present research was to compare the proximate composition and the amino acid profile (relative percentage of single amino acids) and content (amount of single amino acids) of the breast meat of a commercial broiler hybrid with that of the same hybrids affected by the simultaneous presence of severe WS and WB myopathies and that of the purebred Polverara chicken.

## MATERIAL AND METHODS

### *Experimental Groups and Sampling Procedure*

The present trial was conducted at the Department of Animal Medicine, Production and Health (MAPS) of the University of Padova (Italy). For the experiment, a total of  $n = 90$  chicken breasts (*Pectoralis major* muscles) were sampled from a commercial slaughterhouse;  $n = 30$  were obtained from high-breast-yield hybrid chickens (Hybrid-Normal);  $n = 30$  were selected from the same hybrid having, simultaneously, severe WS and WB myopathies (**Hybrid-WSWB**), whereas  $n = 30$  breasts were obtained from a local slow-growing chicken breed (Polverara) of the Veneto Region, Italy. All breasts were obtained from male chickens at their commercial slaughter age which was 40 D for groups Hybrid-Normal and Hybrid-WSWB and 180 D for the group Polverara. Chicken breasts from Hybrid-Normal and Hybrid-WSWB groups derived from the same poultry farm and received the same diet. Polverara chickens were farmed at the Agricultural Professional High School "Duca degli Abruzzi" (Padova). The chemical composition of the diets offered to Hybrid and Polverara chickens is given in Table 1. Farming specifications are reported in the work by Tasoniero et al. (2018). Chickens were processed in an authorized commercial slaughterhouse by electrical stunning (120 V, 200 Hz). Subsequently, after eviscerations, they were soft-scalded (53°C for 2 min) and air-chilled (precooling at 5°C for 60 min, followed by chilling at 0°C for 90 min). Breasts

**Table 1.** Chemical composition (g/kg as fed) and energy content (MJ/kg as fed) of the diets fed to broiler hybrid and to Polverara breed chickens (average of 4 and 3 periods for hybrid and Polverara chickens, respectively).

Nutrients composition	Diets	
	Hybrid	Polverara
Dry matter	895	895
Crude protein	197	168
Ether extract	71.5	40.7
Crude fiber	36.8	39.4
Nitrogen-free extracts (NFE) <sup>1</sup>	546	579
Ash	44.5	68.2
Gross energy <sup>2</sup>	17.6	16.3
Ca	6.30	14.4
P	5.65	7.33
L-Lysine	11.9	8.63
DL-Methionine	4.10	4.17
Taurine	0.20	0.22

<sup>1</sup>100-(water + CP + crude fat + crude fiber + ash).

<sup>2</sup>(NFE\*4.11) + (CP\*5.64) + (EE\*9.44) + (CF\*4.78)\*10.

were then dissected, sorted, and then collected by the working team. Sorting procedure consisted in a visual and palpatory inspection to detect the simultaneous presence on breasts (pectoralis major muscle) of lesions attributable to WS (Kuttappan et al., 2013) and WB (Sihvo et al., 2014). Severe WB detection considered the presence of hard areas at palpation of both the left and right breast muscles and the detection of bulges, exudate, hemorrhages, and concomitant presence of WS, consisting in the presence of visible white striations on the breasts surface. Once sampled, chicken breasts were packaged in food-grade plastic bags and transported in refrigerated conditions ( $4 \pm 1^\circ\text{C}$ ) to the MAPS Department.

### Samples Preparation, Diets, and Meat Chemical Analysis

Chicken breasts were individually ground with a GRINDOMIX GM 200 grinder (Retsch, Haan, Germany) at 7,000 g for 10 s, frozen at  $-40^\circ\text{C}$ , freeze-dried, and ground again (7,000 g for 5 s) to obtain a fine powder which was used to determine proximate composition and amino acid content and profile. The proximate composition of meat samples was analyzed in quadruplicate using the AOAC (2012) methods including dry matter (procedure 934.01), crude protein (procedure 2001.11), and ash (procedure 967.05). Ether extract was determined after acid hydrolysis (EC, 1998). The same abovementioned procedures were adopted to analyze diet samples (in duplicate); moreover, also crude fiber (procedure 978.10) was determined. The dietary contents of Ca, P, lysine, and methionine were provided by the feed companies Agricola Italiana Alimentare S.p.A and PROGEO Società Cooperativa Agricola for Hybrid and Polverara chickens, respectively.

The amino acid profile of the chicken breasts was analyzed according to the methods described in the European Pharmacopoeia 5.0 (Council of Europe, 2005) by using an HPLC Agilent 1260 Infinity equipped

with diode array and fluorescence detectors and an Agilent ZORBAX Eclipse AAA column (4.6 mm  $\times$  75 mm, 3.5  $\mu\text{m}$ ). A precolumn derivatization using o-phthalaldehyde (OPA) for primary amino acids and 9-fluorenylmethyl-chloroformate for secondary amino acids was performed. Precolumn derivatization of amino acids with OPA is followed by a reversed-phase HPLC separation. Because of the instability of the OPA-amino acid derivative, HPLC separation and analysis are performed immediately following derivatization. Fluorescence intensity of OPA-derivatized amino acids is monitored with an excitation wavelength of 348 nm and an emission wavelength of 450 nm. Precolumn derivatization of amino acids with 9-fluorenylmethyl chloroformate followed by reversed-phase HPLC separation with fluorometric detection is used. Each derivative eluted from the column is monitored by a fluorometric detector set at an excitation wavelength of 260 nm and an emission wavelength of 313 nm.

Calibration of amino acid analysis instrumentation involved the analysis of the amino acid standard (Amino Acid Standard 0.1 nmol/ $\mu\text{l}$  10/pk; Agilent Technologies, Santa Clara, CA), which consists of a mixture of amino acids at a number of concentrations, to determine the response factor and range of analysis for each amino acid (the concentration of each amino acid in the standard is known). Peak areas obtained for each amino acid are plotted vs. the known concentration for each of the amino acids in the standard dilution. These results will allow to determine the range of amino acid concentrations where the peak area of a given amino acid is an approximately linear function of the amino acid concentration. The response factor is calculated as the average peak area or peak height per nanomole of amino acid present in the standard. A calibration file consisting of the response factor for each amino acid is prepared and used to calculate the concentration of each amino acid present in the test sample. This calculation involves dividing the peak area corresponding to a given amino acid by the response factor for that amino acid to give the nanomoles of the amino acid. The calibration file is updated frequently and tested by the analysis of analytical controls to ensure its integrity.

### Statistical Analysis

Data were analyzed using the SAS 9.1.3 statistical software package for Windows (SAS, 2008). The effect of the experimental group was tested on chicken breast proximate composition and amino acid content and profile through a one-way ANOVA, using the PROC GLM model. Post-hoc pairwise contrasts were evaluated by Bonferroni adjustments, and  $P < 0.05$ ,  $P < 0.01$ ,  $P < 0.001$ , and  $P < 0.0001$  were considered as significance levels.

## RESULTS

Results presented in Table 2 show that the proximate composition of the 3 chicken meat types markedly

**Table 2.** Proximate composition (g/100 g meat) of chicken breast meat coming from normal commercial hybrid, commercial hybrid affected by white striping and wooden breasts (WBWS) myopathies, and slow-growing breed Polverara.

Variables	Chickens			P-value	RSD
	Hybrid, normal	Hybrid, WSWB	Polverara		
No.	30	30	30		
Water	75.9 ± 0.74 <sup>B</sup>	77.0 ± 1.18 <sup>A</sup>	74.5 ± 0.46 <sup>C</sup>	<0.0001	0.15
Protein	21.3 ± 0.87 <sup>B</sup>	19.8 ± 1.12 <sup>C</sup>	23.6 ± 0.44 <sup>A</sup>	<0.0001	0.16
Lipids	1.21 ± 0.54 <sup>B</sup>	1.59 ± 0.61 <sup>A</sup>	0.45 ± 0.17 <sup>C</sup>	<0.0001	0.09
Ash	1.19 ± 0.06 <sup>A</sup>	1.08 ± 0.04 <sup>C</sup>	1.15 ± 0.07 <sup>B</sup>	<0.0001	0.01

A, B, C Means in the same row with unlike superscripts significantly differ ( $P < 0.01$ ).

Abbreviation: RSD, residual standard deviation.

differed: breast meat from Polverara breed had the highest protein ( $P < 0.0001$ ) and the lowest lipids ( $P < 0.0001$ ) contents, whereas the breast meat from Hybrid-WSWB broiler chickens had the lowest protein and ash ( $P < 0.0001$ ) contents and the highest ( $P < 0.0001$ ) amount of fat. Meat of Hybrid-Normal chickens presented intermediate values for protein and lipids and the highest ash content ( $P < 0.0001$ ).

Breast meat from Polverara chickens showed also the highest amino acid content (Table 3), whereas Hybrid-WSWB had the lowest ( $P < 0.0001$ ). Considering the content of single amino acids, Polverara meat was

**Table 3.** Total amino acids and amino acid content (g/100 g meat) of chicken breast meat derived from normal commercial hybrid, commercial hybrid affected by white striping and wooden breasts (WBWS) myopathies, and slow-growing breed Polverara.

Amino acids	Genotype			P-value	RSD <sup>1</sup>
	Hybrid, normal	Hybrid, WSWB	Polverara		
No.	30	30	30		
Total amino acids	21.5 <sup>B</sup>	17.6 <sup>C</sup>	23.4 <sup>A</sup>	<0.0001	1.96
Essential amino acids:					
Arginine	1.88 <sup>A</sup>	1.11 <sup>B</sup>	1.92 <sup>A</sup>	<0.0001	0.33
Histidine	0.74 <sup>B</sup>	0.67 <sup>B</sup>	0.94 <sup>A</sup>	<0.0001	0.12
Isoleucine	0.83 <sup>A,b</sup>	0.70 <sup>B</sup>	0.94 <sup>A,a</sup>	<0.0001	0.16
Leucine	1.51 <sup>B</sup>	1.31 <sup>C</sup>	1.66 <sup>A</sup>	<0.0001	0.15
Lysine	2.12 <sup>A</sup>	1.62 <sup>B</sup>	2.44 <sup>A</sup>	<0.0001	0.61
Methionine	1.06 <sup>B</sup>	0.96 <sup>C</sup>	1.29 <sup>A</sup>	<0.0001	0.09
Phenylalanine	0.79 <sup>B</sup>	0.67 <sup>C</sup>	0.90 <sup>A</sup>	<0.0001	0.10
Threonine	1.05 <sup>A</sup>	0.93 <sup>B</sup>	1.10 <sup>A</sup>	<0.0001	0.11
Tryptophan	0.44	0.44	0.41	0.3363	0.10
Valine	1.02 <sup>A</sup>	0.71 <sup>B</sup>	0.72 <sup>B</sup>	<0.0001	0.22
Nonessential amino acids:					
Alanine	1.07 <sup>B</sup>	0.98 <sup>C</sup>	1.25 <sup>A</sup>	<0.0001	0.10
Aspartic acid	1.92 <sup>B</sup>	1.65 <sup>C</sup>	2.12 <sup>A</sup>	<0.0001	0.18
Cysteine	0.22	0.23	0.22	0.9543	0.03
Glutamic acid	3.71 <sup>A</sup>	2.91 <sup>B</sup>	3.94 <sup>A</sup>	<0.0001	0.38
Glycine	0.87 <sup>B</sup>	0.70 <sup>C</sup>	0.94 <sup>A</sup>	<0.0001	0.09
Proline	0.56 <sup>B</sup>	0.58 <sup>B</sup>	0.75 <sup>A</sup>	<0.0001	0.08
Serine	0.99 <sup>B</sup>	0.75 <sup>C</sup>	1.14 <sup>A</sup>	<0.0001	0.19
Tyrosine	0.66 <sup>B,a</sup>	0.60 <sup>B,b</sup>	0.74 <sup>A</sup>	<0.0001	0.09
Taurine	0.15 <sup>A</sup>	0.05 <sup>B</sup>	0.00 <sup>C</sup>	<0.0001	0.02

A, B, C Means in the same row with unlike superscripts significantly differ ( $P < 0.01$ ).

a, b, c Means in the same row with unlike superscripts significantly differ ( $P < 0.05$ ).

<sup>1</sup>Residual standard deviation.

superior for most of all single amino acids, except tryptophan and valine among the essential ones and cysteine and taurine among the nonessential ones. Specifically, tryptophan and cysteine contents were not affected by the breast meat origin, whereas taurine was not detected in the meat of the Polverara chicken. The Hybrid-WSWB showed the lowest values for most of the amino acids. The meat of Hybrid-Normal chickens presented an intermediate situation, whereas it showed the greatest contents of valine and taurine ( $P < 0.0001$ ). Looking at the proportions among single amino acids (% of total amino acids; Table 4), it was highlighted that lysine, arginine, leucine, glutamic acid, aspartic acid, and alanine were the most representative amino acids among the essential and nonessential ones, respectively, in all 3 breast meat-type chickens. As a result of the single amino acid contents, also the relative amino acid proportions were affected by the experimental treatment in a similar manner.

## DISCUSSION

Even if previous research found that WSWB-affected breasts show a profound modification of the proximate composition only within the surface of the breast muscle because of the higher presence of abnormalities (Baldi et al. 2019), results of the present research highlighted once more the negative impact of the WS and WB conditions on the overall meat quality of the breast. Meat quality, intended as nutritional characteristics of the food product “meat”, is impaired because of the intense alterations that occur in muscle structure. Breasts with severe WB and WS myopathies are affected by inflammatory processes which lead to fluid accumulation (edema), explaining their increased water content compared with normal breasts (Sihvo et al., 2014). Furthermore, the concomitant presence of these 2 myopathies is the result of myodegeneration and necrosis, lymphocyte and macrophage infiltration, fibrosis, lipodosis, and regenerative changes (Sihvo et al., 2014; Kuttappan et al., 2016). Severe fibrosis leads to the replacement of muscle fibers with connective tissue, which becomes the main constituent of primary myofiber fascicles. Lipodosis implies the replacement of degenerated muscle fibers by adipose tissue (Soglia et al., 2016). These conditions are responsible for a reduction of the protein and an increase in the lipid contents, respectively, of the chicken breast affected by WS (Baldi et al., 2018) and WB (Soglia et al., 2016) myopathies. The sole (Soglia et al., 2016) or concomitant (Mazzoni et al., 2015; Tasoniero et al., 2016) presence of WS and WB conditions were reported to alter the mineral content of the meat which is likely to be the reason behind the lower ash content of the Hybrid-WSWB chicken breast meat compared with that of the Hybrid-Normal group observed in the present study. Regarding specific minerals, the simultaneous occurrence of WS and WB conditions was reported to increase Fe and Na and to reduce K and P contents (Tasoniero et al., 2016). Another research study observed also an

**Table 4.** Amino acid profile (% of total amino acids) of chicken breast meat derived from normal commercial hybrid, commercial hybrid affected by white striping and wooden breasts (WBWS) myopathies, and slow-growing breed Polverara.

Amino acids	Genotype			P-value	RSD <sup>1</sup>
	Hybrid, normal	Hybrid, WSWB	Polverara		
No.	30	30	30		
Essential amino acids:					
Arginine	8.70 <sup>A</sup>	6.31 <sup>B</sup>	8.16 <sup>A</sup>	<0.0001	1.15
Histidine	3.39 <sup>B</sup>	3.85 <sup>A</sup>	4.01 <sup>A</sup>	<0.0001	0.45
Isoleucine	3.79	3.99	3.99	0.2305	0.54
Leucine	6.99 <sup>B</sup>	7.48 <sup>A</sup>	7.11 <sup>B</sup>	<0.0001	0.24
Lysine	9.74	9.11	10.4	0.1473	2.48
Methionine	4.98 <sup>B</sup>	5.49 <sup>A</sup>	5.57 <sup>A</sup>	0.0001	0.56
Phenylalanine	3.64 <sup>B</sup>	3.83 <sup>A</sup>	3.82 <sup>A</sup>	0.0020	0.24
Threonine	4.86 <sup>B</sup>	5.29 <sup>A</sup>	4.72 <sup>B</sup>	<0.0001	0.24
Tryptophan	2.08 <sup>B,a</sup>	2.50 <sup>A</sup>	1.76 <sup>B,b</sup>	<0.0001	0.45
Valine	4.69 <sup>A,a</sup>	4.04 <sup>A,b</sup>	3.09 <sup>B</sup>	<0.0001	0.89
Nonessential amino acids:					
Alanine	4.99 <sup>C</sup>	5.59 <sup>A</sup>	5.33 <sup>B</sup>	<0.0001	0.26
Aspartic acid	8.91 <sup>B</sup>	9.40 <sup>A</sup>	9.03 <sup>B</sup>	<0.0001	0.43
Cysteine	1.05 <sup>B</sup>	1.29 <sup>A</sup>	0.96 <sup>B</sup>	<0.0001	0.15
Glutamic acid	17.2 <sup>a</sup>	16.6 <sup>b</sup>	16.8 <sup>a,b</sup>	0.0306	0.96
Glycine	4.03	4.00	4.01	0.9130	0.29
Proline	2.59 <sup>B</sup>	3.31 <sup>A</sup>	3.21 <sup>A</sup>	<0.0001	0.32
Serine	4.62 <sup>a,b</sup>	4.29 <sup>b</sup>	4.90 <sup>a</sup>	0.0182	0.81
Tyrosine	3.05 <sup>B</sup>	3.39 <sup>A,a</sup>	3.15 <sup>A,B,b</sup>	0.0007	0.34
Taurine	0.70 <sup>A</sup>	0.28 <sup>B</sup>	0.00 <sup>C</sup>	<0.0001	0.14

A, B, C Means in the same row with unlike superscripts significantly differ ( $P < 0.01$ ).

a, b, c Means in the same row with unlike superscripts significantly differ ( $P < 0.05$ ).

<sup>1</sup>Residual standard deviation.

augmented Ca content, together with that of Na, in WB-affected chicken breasts (Soglia et al., 2016). The augmented contents of Na and Ca, in particular, were reported to possibly lead to multifocal degeneration and necrosis of myofibers through the involvement of the  $\text{Na}^+/\text{Ca}^{2+}$  exchanger (Sandercock and Mitchell, 2004); an augmented Na level can lead to higher intracellular Ca level which triggers myofibers necrosis, as a result of the concomitant extracellular Ca influx and the release of the intracellular stores of Ca from the damaged sarcolemma structure and sarcoplasmic reticulum of myofibers (Sandercock and Mitchell, 2003, 2004). It was also observed that increased Ca and Na levels might activate specific enzymes, such as phospholipase A2, that are involved in membrane damage (Tasoniero et al., 2016).

The overall superior meat quality of the Polverara breast meat compared with that of Hybrid-Normal observed in the present research was consistent with literature results comparing slow-growing indigenous chicken breeds with broiler hybrids (Wattanachant et al., 2004; Rikimaru and Takahashi, 2010). Typically, as an animal ages, the composition of body and muscle changes, protein and fat contents increase, and moisture content decreases (Fanatico et al., 2007). This was in agreement with the results of the present research, except for the lipid content. The lower lipid content of Polverara meat compared with Hybrid chickens can be attributable to the intrinsically higher locomotor activity of this breed which was further stimulated by the presence of an outdoor paddock (Tasoniero et al., 2018; Dalle Zotte et al., 2019). A higher locomotor activity is known to favor myogenesis instead of lipogenesis (Fanatico et al., 2007).

Despite its nutritional importance for humans, the amino acid content and profile of chicken meat has been scarcely investigated in literature. Findings of the present study confirmed that arginine, leucine, and lysine are the most abundant essential amino acids in the chicken breast; whereas, glutamic acid, aspartic acid, and alanine are the most abundant nonessential ones (Straková et al., 2002, 2006). Not only the quantity of protein differed among the 3 treatments but also its quality as highlighted by the different results on the single amino acid contents in the 3 experimental groups.

According to the World Health Organization (2007), there are 9 essential amino acids in human nutrition, namely histidine (10 mg/kg body weight per day), isoleucine (20 mg/kg body weight per day), leucine (39 mg/kg body weight per day), lysine (30 mg/kg body weight per day), methionine (+Cysteine: 15 mg/kg body weight per day), phenylalanine (+Tyrosine: 25 mg/kg body weight per day), threonine (15 mg/kg body weight per day), valine (26 mg/kg body weight per day), and tryptophan (4 mg/kg body weight per day). For this purpose, breast meat of the Polverara breed was the best source among the 3 considered chicken meat-types, as it contained the highest amount of all the essential amino acids for humans. Specifically, for a human of 70 kg body weight, 100 g of Polverara breast meat (vs. 100 g of Hybrid-Normal breast meat) cover the daily requirements of histidine by 134% (vs. 106%), isoleucine by 67% (vs. 59%), leucine by 61% (vs. 55%), lysine by 116% (vs. 101%), methionine + cysteine by 144% (vs. 122%), phenylalanine + tyrosine by 94% (vs. 83%), threonine by 105% (vs. 100%), valine by 40% (vs. 56%), and tryptophan by 146% (vs. 157%).

This could be a very important aspect for marketing purposes to start exploiting the potential of this rustic slow-growing chicken breed in alternative production systems, which are niche meat products nowadays more and more requested by modern consumers (Tasoniero et al., 2018). The reason of the richest amino acids content of Polverara meat could lie in the older age of these chickens at slaughter (180 D; compared with the 42 D for hybrids). In previous research, it was demonstrated that the amino acid content of the breast meat cut of different hybrid broilers increased when the feeding period was prolonged (Straková et al., 2002). This hypothesis further corroborated in a subsequent study showing that the digestibility of dietary amino acids overall increases with age of chickens, as a result of the increase in the intestinal mass, even if variations considering specific amino acids and feed ingredients have been reported (Huang et al., 2005). Independently to the experimental group, however, chicken meat of the present research confirmed to be an excellent source of high-quality protein as 100 g of their breast meat satisfied most of the abovementioned amino acid requirements. However, it was also highlighted that WB and WS myopathies determined a relevant decrease in the amino acid content, thus in the biological value of the protein, and consequently, the meat of the Hybrid-WSWB group did not meet the human nutrient requirements of lysine, threonine, and sulfur amino acids. The lower biological value of the Hybrid-WSWB meat protein compared with that of the other 2 groups could be evidenced also by the comparison of the protein content obtained from the analysis of the meat proximate composition with the sum of the total amino acids. In the meat of Hybrid-Normal and Polverara groups, the 2 values almost coincide, whereas in the meat of the Hybrid-WSWB group, the total amino acids correspond to the 89.9% of the analytically determined protein. This could be because of a higher content of nonprotein nitrogen in the WSWB meat as a result of a most intense proteolysis associated to the myodegeneration of the breast muscle (Daszkiewicz et al., 2012).

Taurine is a sulfur-containing  $\beta$ -amino acid that is generally present in relevant concentrations in all animal tissues, especially muscle, viscera, and brain and which plays several biological roles such as antioxidant, bile acids conjugation, calcium homeostasis maintenance, osmoregulation, and membrane stabilization (Lu et al., 2019). Previous studies detected a great variability in the taurine content of chicken meat ranging from 0.01 to 0.33 g/100 g meat in raw, boneless, skinless chicken breast meat (Spitze et al., 2003), being the causes of such variation not well defined. Results of the present study indicated that they were coherent with the abovementioned range. However, a very peculiar finding of the present study was that the taurine was absent in the breast meat of the Polverara chicken breed. As for the other amino acids, the dietary inclusion of taurine is positively correlated to the meat content, as it was observed in the study by Huang et al. (2014b), where Cobb chicks were fed with diets supplemented with 0,

0.125, 0.50, 2.00, or 8.00 g/kg taurine. However, in our study, all diets contained taurine, and the diet provided to Polverara chickens was the richest in taurine. Taurine can also be synthesized in the liver from methionine via cysteine by several enzymatic reactions, with the enzyme cysteine sulfonate decarboxylase being the rate-limiting step in taurine biosynthesis in chickens (Wang et al., 2009). In fact, a low activity of the latter enzyme was reported to generate a poor efficiency in the hepatic synthesis of taurine in chickens, but this was only observed during the first week after hatch (Huang et al., 2014a). Previous studies also hypothesized that taurine content in the muscle can be affected by husbandry practice, breeds, and environment (Spitze et al., 2003), but no in-deep genetic or physiological explanations are available, thus highlighting that further research to this regard would be recommended. Adequately managing the amino acid content of chicken meat would be a key tool to provide meat of satisfactory nutritional quality to better satisfy human's dietary requirements.

## CONCLUSIONS

The choice of the present research to focus on the amino acid profile of the breast meat of different meat-type chickens allowed an in deep evaluation of the protein quality of this meat cut, which has paradoxically been poorly investigated up to now. It was highlighted once more that the WS and WB myopathies have a deleterious effect on chicken meat quality, which involves also the amino acid content and profile. Also, it was found that the meat of the Polverara breed, a slow-growing chicken well-adapted to extensive production systems, has a remarkable meat quality including a high protein content of very good biological value. This finding could represent a tool to promote the meat of this poorly known rustic breed among consumers, which would help the survival of this endangered breed in the perspective of biodiversity conservation. Furthermore, it would be appropriate to investigate why taurine was absent in the breast meat of Polverara chicken, possibly studying its content in the whole carcass, considering both sex and different growth ages. An evaluation of the role of the dietary level of taurine in influencing its meat content, together with measuring the activity of the enzyme cysteine sulfonate decarboxylase, would also be recommended.

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