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Evaluation of physicochemical and functional properties of broiler breast with White Striping

Avaliação das propriedades físico-químicas e funcionais de peitos de frango com White Striping

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Highlights

There is a high incidence of WS in fillets from slaughterhouses.
The WS myopathy causes macroscopic alterations on the surface of chicken meat.
WS influences the chemical composition of chicken meat.
WS compromises meat quality.

Abstract

Intense genetic selection due to the economic need for faster weight gain in poultry and shorter slaughter times has altered animal physiological behavior and caused muscle tissue damage. WS in broiler chickens is characterized by the appearance of white striations on breast and thigh meat parallel to the direction of muscle fibers and can be categorized as normal (NORM), moderate (MOD) or severe (SEV). This study aimed to determine the incidence of WS and characterize breast meat according to pH, color, size, chemical composition, total (TC) and soluble collagen (SC), water holding capacity (WHC), cooking loss (CL), shear force (SF), emulsifying capacity (EC) and fatty acid profile. The WS incidence (n = 660) was 51.67 and 31.36% for MOD and SEV samples, respectively. The highest L* values were observed in meat classified as MOD and SEV. Cranial thickness values were higher in SEV meat, with 29% of these samples also exhibiting more TC, 26% greater CL, and 27% higher lipid levels and SF when compared to the NORM group. No significant differences were observed for the remaining determinations.
Key words: Color. Collagen. Myopathy. pH. White striping.

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Resumo

A intensa seleção genética devido à necessidade econômica de maior ganho de peso em menor tempo de abate tem alterado o comportamento fisiológico dos animais e ocasionando danos ao tecido muscular. O *White Striping* (WS) em frangos é caracterizado pelo aparecimento de estrias brancas na carne do peito e da coxa paralelas a direção das fibras musculares e pode ser categorizada como normal (NORM), moderada (MOD) ou severa (SEV). As estrias do WS são facilmente identificadas na superfície da carne de frango e podem afetar diretamente a aceitação e intenção de compra dos consumidores. Este estudo teve como objetivo determinar a incidência do WS e caracterizar a carne do peito de frango quanto ao pH, cor, tamanho, composição química, colágeno total (CT) e colágeno solúvel (CS), capacidade de retenção de água (CRA), perda por cocção (PC), força de cisalhamento (FC), capacidade emulsificante (CE) e perfil de ácidos graxos. A incidência do WS (n= 660) foi de 51.67% e 31.36% para MOD e SEV, respectivamente. Os maiores valores de L* foram observados nas carnes classificadas como MOD e SEV. Os valores de espessura cranial foram maiores nas carnes SEV, com 29% mais CT, 26% mais PC, 27% mais lipídeos e FC quando comparado ao grupo NORM. Não foram observadas diferenças significativas para as demais determinações.
Palavras-chave: Cor. Colágeno. Miopatia. pH. Estrias brancas.

Introduction

Intense genetic selection due to the economic need for rapid weight gain in poultry and shorter slaughter times has altered animal physiological behavior and caused muscle tissue alterations (Pedrão et al., 2021). Abnormalities such as PSE (pale, soft, exudative) meat (Dong et al., 2020), wooden breast (Madruga et al., 2019), spaghetti meat (Baldi et al., 2021) and white striping (WS) (Pedrão, et al., 2021; J. Lee et al., 2023) compromise meat quality, posing a problem for the industry (Petracci et al., 2019).

WS is an abnormality characterized by white striations on the surface of chicken breasts and the thighs in the direction of muscle fibers, it is a result of muscle fiber infiltration with fat and connective tissue (Barbut, 2019). The presence of WS is easily recognized in poultry breast. Given its negative effect on the appearance of the final product, several studies have been conducted to characterize this phenomenon. L. T. Carvalho et al. (2021a) showed that WS samples presented lower acceptability and purchase intention when compared to Normal samples.

Researchers characterized this phenomenon over the years in order to elucidate WS in many countries,: evaluation of growth production factor as predictor of the incidence and severity of WS in United States (Aguirre et al., 2020), pathologic characterization of WS in broiler chickens in Italy (Prisco et al., 2021), textural and physical properties of breast fillets in Canadian broiler chickens (C. Wang et al., 2023), incidence of WS and its effect on the quality traits of raw and processed turkey breast meat of Palestinian slaughterhouse (Mudalal, 2019) and restriction of dietary digestible lysine allowance in grower phase to reduce the occurrence of WS in broiler chicken in Turkey (Ahsan & Cengiz, 2020).

The severity of this condition can be classified based on its visual aspect, as: Normal (NORM), Moderate (MOD) or Severe (SEV) (Kuttappan et al., 2012). Considering this studies, the present study focused on evaluating the characteristics of the breast meat of broiler under Brazilian conditions (in the South region) in different degrees of WS: determine whether visual changes in chicken fillets influence characteristics such as size and color, and characterize WS severity in the *Pectoralis major* muscle for the following physical and chemical parameters: chemical composition, total (TC) and soluble collagen (SC), water holding capacity (WHC), cooking loss (CL), shear force (SF), pH, emulsifying capacity (EC), fatty acid profile and to examine its impact on meat quality.

Material and Methods

Sample classification

The experiment was conducted in a plant in southern Brazil, using 47-day-old male and female broilers. The animals were slaughtered in line with standard industrial practice, via hanging, electrical stunning and bleeding, followed by scalding, defeathering, evisceration, cooling in a chiller, deboning and refrigeration. The breast fillets (n=660) were collected and visually classified according to Kuttappan et al. (2012) as NORM (no white striations on the surface of chicken breast); MOD (white striations < 1 mm thick on the surface, parallel to the muscle fibers); and SEV (white striations >1 mm thick covering a large part of the surface). After classification, the chicken breasts were stored at 4 °C for 24 hours inside the commercial plant for subsequent color and size analysis. Next, 10 samples of each grade were transported to the laboratory and analyzed for WHC, CL, SF, chemical composition, TC and SC, and another 20 samples per grade (n = 60) were assessed for pH, EC and fatty acid profile.

Size and color measurement of fillets

The size (mm) of the chicken fillets was measured in duplicate using a digital caliper (Digimess 300 mm) with 0.01 mm resolution (Mehaffey et al., 2006), as follows: length (L) (the longest point), width (W) (at the widest point), and thickness of the cranial (T1) and caudal regions (T2). Color analyses were performed in sextuplicate, 24 hours *post-mortem,* using a Minolta® CR-400 colorimeter with illuminant D65 and 10° angle of view. Six different points (3 points per side) of the breast were read (ventral cranial side) to determine the color parameters (L*, a*, b*) according to the CIELab system.

Biochemical and physicochemical parameters and statistical analyses

Chemical composition was analyzed in triplicate (Association of Official Analytical Chemists [AOAC], 2012) and TC content extracted in duplicate (Woessner, 1961). Collagen content was calculated based on hydroxyproline content using a factor of 8.0 (Kolar, 1990). SC was extracted in duplicate (Oliveira et al., 1998) and WHC was determined in duplicate 24 h post-mortem (Hamm, 1960). CL was determined in duplicate (Honikel, 1998). Shear strength was measured in five replications in the same samples used for CL analysis (Bratzler, 1949). The pH was determined in triplicate 24 h post-mortem (Boulianne & King, 1995). Emulsifying capacity was analyzed in triplicate and expressed in mL of added oil (until emulsion breaking) per 100 mg of protein (Swift et al., 1961).

Lipid extraction followed the methodology of Bligh & Dyer (1959) with some modifications. Hydrolysis and transesterification of fatty acids was in accordance with ISO 5509:1978 (International Organization for Standardization, 1978). Fatty acid methyl esters were analyzed in a Shimadzu chromatograph (17A gas chromatograph) with a flame ionization detector and CP SII 88 capillary column (100 m x 0.25 mm x 0.25 µm). The ramp rate was programmed as follows: 65 °C for 15 min; 10 °C.min^{-1} until 165 °C, maintained for 2 min; 4 °C.min^{-1} until 185 °C, maintained for 8 min; and 4 °C.min^{-1} until 235 °C, maintained for 5 min. The detector and injector were set at 260 °C, with a 1/100 split ratio. Flow rates were 1.2 mL.min^{-1} for the carrier gas (H_2), 30 mL.min^{-1} for the auxiliary gas (N_2), and 30 and 300 mL.min^{-1} for the flame gases H_2 and synthetic air, respectively. Fatty acids were identified based on fatty acid methyl esters (Sigma). Peak areas were determined via an integrator coupled to the gas chromatograph. The results were expressed as relative percentages of the fatty acids identified.

Statistical analyses were performed using Statistica software, version 7.0. The results were submitted to analysis of variance (ANOVA) followed by Tukey's test at 5% probability to compare the findings for the three meat quality groups (NORM, MOD and SEV).

Results and Discussion

Occurrence of WS

The incidence of WS in breast meat was highest (51.67%) in the MOD group and 31.36% for the SEV group, totalizing 83.03% of samples. Mudalal (2019), showed lower incidence: 49,4% in the MOD group and 11,9% for the SEV group in Palestinian slaughterhouse. Valenta et al. (2023) showed higher incidence: 58,7% in American processing plant.

Color, pH analysis and WS dimensions

There was no significant difference between the three meat groups for pH, a* and b*, whereas L* values were significantly higher for the groups with striations (MOD and SEV) when compared to the NORM group (Table 1). Similarly, L. T. Carvalho et al. (2021a), reported no differences for pH values and higher L* values for the groups with striations (MOD and SEV). Several studies have reported an association between breast meat color and pH. According to Hou et al. (2020), a decline in pH increases light reflectance because of the amount of water on the surface of meat.

Table 1
Dimensions, pH and color values (L*, a*, b*) of chicken breasts classified according to WS severity

Dimension (mm)	NORM (n=112)	MOD (n=341)	SEV (n=207)
Cranial thickness (T1)[1]	28.91 ± 5.72[c]	29.10 ± 5.85[b]	30.69 ± 5.24[a]
Caudal thickness (T2)[2]	8.51 ± 3.01[a]	8.86 ± 2.88[a]	9.47 ± 5.73[a]
Length (L)	145.52 ± 11.30[a]	145.24 ± 11.92[a]	147.71 ± 12.89[a]
Width (W)	161.35 ± 13.25[a]	162.42 ± 13.15[a]	161.48 ± 11.91[a]
pH	5.99 ± 0.15[a]	6.00 ± 0.14[a]	5.99 ± 0.13[a]
L*	56.91 ± 2.68[b]	57.32 ± 2.71[ab]	57.83 ± 2.77[a]
a*	1.83 ± 1.04[a]	1.85 ± 1.10[a]	1.62 ± 0.96[a]
b*	8.37 ± 2.01[a]	7.94 ± 1.77[a]	8.29 ± 1.75[a]

[1] Values are presented as mean ± standard deviation. [a-b] Means followed by different lowercase letters in the same row differ significantly (Tukey's test, $p \leq 0.05$).
[1]T1 = Cranial thickness; [2]T2 = Caudal thickness.

Cranial thickness (T1) values were high in the SEV group, low in meat classified as NORM and intermediate in MOD meat (Table 1). There were no intergroup differences for the other dimensions measured (Table 1). These results were similar by Pekel et al. (2020), with cranial thickness of broilers with SEV WS were higher than those broilers with NORM or MOD meat. Aguirre et al. (2020) also found that WS have other growth parameters reported as potential predictors include breast fillet weight and yield, demonstrating the relationship between increased growth rate and muscle size with a significantly influence the severity of WS myopathy scores.

Biochemical and physicochemical parameters

Moisture analysis, protein, ash and SC showed no significant differences between the different degrees of WS (Table 2); however, lipids and TC were higher ($p < 0.05$) in the SEV group (Table 2). Recent studies have reported differences in histological samples of chicken fillets with surface striations. Despite this study did not find significant difference in protein content, other researchers affirmed that protein content decrease can be explained by the degeneration or atrophy of muscle fibers, while the increase of fat and collagen contents are related to the injured area replacement with lipidosis and fibrosis (Salles et al., 2019; L. T. Carvalho et al., 2021a).

In the present study, the total collagen/protein ratio was higher for SEV meat when compared to other samples. This increase was similar to that found by other researchers, who reported that low collagen digestibility and essential amino acid deficiency may explain the poor nutritional quality of protein in chicken fillets with WS (L. T. Carvalho et al., 2021a).

Table 2
Proximate chemical composition, total and soluble collagen, collagen/protein ratio and biochemical parameters in chicken fillets visually classified as NORM or WS (MOD/SEV)

Parameter	NORM (n=10)	MOD (n=10)	SEV (n=10)
Moisture (%)	76.31 ± 1.77[a]	75.60 ± 1.88[a]	75.66 ± 1.63[a]
Protein (%)	21.45 ± 1.50[a]	21.92 ± 1.82[a]	21.80 ± 1.55[a]
Ash (%)	0.94 ± 0.10[a]	0.96 ± 0.12[a]	0.98 ± 0.10[a]
Lipids (%)	1.00 ± 0.07[b]	1.03 ± 0.14[b]	1.27 ± 0.16[a]
TC (g 100^{-1})[1]	0.82 ± 0.16[b]	0.89 ± 0.31[b]	1.16 ± 0.27[a]
SC (g 100^{-1})[2]	0.36 ± 0.19[a]	0.34 ± 0.09[a]	0.29 ± 0.14[a]
Collagen: protein ratio	3.86 ± 0.81[b]	4.04 ± 1.32[ab]	5.40 ± 1.51[a]
CL (%)[3]	22.67 ± 4.90[b]	22.69 ± 5.14[b]	30.55 ± 7.00[a]
WHC (%)[4]	67.63 ± 1.68[a]	66.85 ± 3.01[a]	65.98 ± 1.90[a]
SF (N)[5]	23.57 ± 3.65[b]	25.36 ± 6.09[b]	32.17 ± 6.82[a]

[1] Values are presented as mean ± standard deviation. [a-b] Means followed by different lowercase letters in the same row differ significantly (Tukey's test, $p \leq 0.05$). [1]TC = total collagen, [2]SC = soluble collagen, [3]CL = cooking loss, [4]WHC = water holding capacity, 5SF = shear force.

Higher CL values were recorded for the SEV group when compared to its MOD and NORM counterparts (Table 2). However, no differences in CL values were observed between NORM and WS turkey samples for L. T. Carvalho et al. (2021a). Our results for CL indicates that more fluid is lost in samples affected with WS when compared to meat classified as NORM, and consequently reduces the yield (Petracci et al., 2019).

In relation to WHC, WS did not influence this parameter (Table 2). WS did not cause substantial metabolic abnormalities in muscle, which affected WHC, as also observed by L. T. Carvalho et al. (2021a), who found no significant differences in pH. This differs from other phenomena such as PSE (Pale, Soft and Exudative), in which fillets are paler as a result of lower pH (Y. Lee & Choi, 2021), compromising the functional quality of raw materials due to myofibrillar protein denaturation and hampering industrial productivity.

The SEV samples exhibited greater SF than other degrees of WS (Table 2). Similar results were obtained by L. Carvalho et al. (2021b), who reported higher values for hardness, gumminess and chewiness in MOD and SEV samples when compared to NORM samples, and associated the results with the increased fibrosis and greater collagen content in WS chicken breast. There were no significant differences ($p < 0.05$) between WS classifications for CL or SF (Table 3).

Table 3
pH and emulsification capacity (EC) of chicken fillets visually classified as NORM or WS (MOD/SEV)

Samples (n=60)	NORM	MOD	SEV
pH	5.87 ± 0.10[a]	5.91 ± 0.12[a]	5.92 ± 0.09[a]
EC (mL.100 mg^{-1})	29.80 ± 2.38[a]	29.24 ± 1.72[a]	29.43 ± 2.69[a]

[1] Values are presented as mean ± standard deviation. [a-b] Means followed by different lowercase letters in the same row differ significantly (Tukey's test, $p \leq 0.05$).

Initial pH analysis of the samples showed no significant differences for the groups tested, with no effect on EC. Bordignon et al. (2021), evaluated the quality of nuggets with WS chicken breasts. These studies revealed no significant difference regarding emulsion stability. Low protein and high lipid levels in the muscle tissue of samples classified as SEV were insufficient to influence EC. Samples with visible WS are often used to manufacture processed products to prevent consumer rejection at purchase. According to the present study, using meats with WS does not modify the structure of these products.

The highest fatty acid contents in the samples analyzed were for 16:1*n−9* acid; 16:0; 18:3*n−6* and 18:2*n−6* (linoleic acid), albeit with no significant differences between the degrees studied (Table 4). Among these acids, the most abundant was linoleic acid, an essential fatty acid in humans that plays an important role in reducing the risk of coronary heart disease and must be obtained through diet (Shadyeva et al., 2019; S. Wang et al., 2022). Levels of 17:1n−*9* (8-heptadecenoic acid) and 20:4n−*6* fatty acids were significantly higher in SEV samples when compared to the other groups (Table 4). The opposite was observed for 18:1n−*7* (cis-vaccinic acid), with the lowest concentrations recorded in SEV samples, and 20:3n−*6* (8,11,14-eicosatrienoic acid) and 22:5n−*6*, whose levels were significantly higher in NORM samples (Table 4). There were no significant differences between saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) (Table 4). Adabi and Soncu (2019), showed lower SFA and higher PUFA percentages were measured in WS samples.

Table 4
Fatty acid profile of chicken fillets visually classified as NORM or WS (MOD/SEV)

Fatty acid	NORM	MOD	SEV
14:1	0.609 ± 0.137[a]	0.586 ± 0.108[a]	0.656 ± 0.060[a]
15:0	4.387 ± 0.855[a]	4.272 ± 1.047[a]	4.317 ± 1022[a]
15:1	0.092± 0.029[a]	0.093 ± 0.024[a]	0.111 ± 0,022[a]
16:0	17.129 ± 2.617[a]	17.145 ± 2.336[a]	16.282 ± 1,665[a]
16:1*n*−9	12.570 ± 6.043[a]	11.294 ± 6.358[a]	12.772 ± 6,004[a]
17:0	0.121 ± 0.021[a]	0.128 ± 0.024[a]	0.123 ± 0,034[a]
17:1*n*−9	4.441 ± 0.783[b]	4.633 ± 1.386[b]	5.265 ± 0.887[a]
18:0	3.314 ± 0.909[a]	3.475 ± 0.725[a]	3.404 ± 0.727[a]
18:1*n*−7	6.751 ± 1.087[a]	6.765 ± 1.034[a]	3.856 ± 1.108[b]
18:1*n*−9	0.156 ± 0.043[a]	0.161 ± 0.035[a]	0.144 ± 0.016[a]
18:2*n*−6	20.547 ± 0.961[a]	21.482 ± 2.818[a]	23.289 ± 1.529[a]
18:3*n*−3	0.192 ± 0.072[a]	0.197 ± 0.069[a]	0.229 ± 0.052[a]
18:3*n*−6	18.655 ± 2.138[a]	19.440 ± 1.273[a]	19.222 ± 1.290[a]
20:3*n*−6	0.359 ± 0.204[a]	0.299 ± 0.121[b]	0.265 ± 0.058[b]
20:4*n*−6	0.315 ± 0.241[b]	0.327 ± 0.106[b]	0.460 ± 0.159[a]
20:5*n*−3	0.150 ± 0.020[a]	0.150 ± 0.036[a]	0.167 ± 0.012[a]
21:0	1.448 ± 0.899[a]	1.814 ± 0.244[a]	1.836 ± 0.157[a]
22:4*n*−6	0.434 ± 0.317[a]	0.404 ± 0.151[a]	0.01 ± 0.220[a]
22:5*n*−3	0.937 ± 0.862[a]	0.697 ± 0.397[a]	0.517 ± 0.233[a]
22:6*n*−3	0.535 ± 0.243[a]	0.514 ± 0.249[a]	0.516 ± 0.191[a]
22:5*n*−6	0.991 ± 0.661[a]	0.571 ± 0.228[b]	0.490 ± 0.180[b]
23:0	1.868 ± 0.686[a]	1.439 ± 0.922[a]	1.661 ± 0.238[a]
SFA[1]	28.265 ± 6.262[a]	28.272 ± 6.268[a]	27.622 ± 5.904[a]
MUFA[2]	24.610 ± 4.955[a]	23.531 ± 4.536[a]	22.803 ± 4.889[a]
PUFA[3]	43.060 ± 8.078[a]	44.177 ± 8.471[a]	45.565 ± 8.854[a]
PUFA/MUFA	1.750[a]	1.877[a]	1.998[a]
PUFA/SFA	1.523[a]	1.563[a]	1.650[a]
n−6/*n*−3	25.354[a]	32.779[a]	39.910[a]

[1] Values are presented as mean ± standard deviation. [a-b] Means followed by different lowercase letters in the same row differ significantly (Tukey's test, $p \leq 0.05$). [1]SFA - Saturated Fatty Acid; [2]MUFA - Monounsaturated Fatty Acid; [3]PUFA - Polyunsaturated Fatty Acid.

SEV fillets contained higher levels of oleic and elaidic acids. Finally, the PUFA/SFA ratio indicates lipid quality, whereby the higher the ratio, the better the lipid quality due to the greater PUFA content. The United Nations Food and Agriculture Organization [FAO] (2010) recommends a ratio of 0.4, since high SFA intake can lead to cardiovascular diseases. All the groups analyzed in the present study obtained values above 0.4.

Conclusion

The incidence of WS at the slaughterhouse studied was greater than 50% in SEV samples. WS affects chicken breasts macroscopically in the form of striations, in addition to changing the luminosity parameter and cranial thickness. The presence of WS modifies broiler breast quality by influencing lipid and collagen content in particular, thereby affecting the juiciness of the cooked product. As such, further research is needed to investigate the use of chicken fillets with WS in meat products and identify its causes in order to adopt pre

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Conflicts of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manu¬script.

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