ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)
Food Science and Technology

(cc) BY

DOI: https://doi.org/10.1590/fst.16320

The use of white striped chicken breasts on the quality of nuggets and hamburgers

Sinara BORDIGNON[1], Lenita Moura STEFANI[2], Marcel Manente BOIAGO[3*]

Abstract

The objective of this study was to evaluate physically and chemically chicken breasts with different degrees of white striping (WS), as well as its effect on the process and quality of nuggets and hamburgers. Chicken breasts fillets were obtained from male chicken broilers weighing approximately 3 kg at the slaughterhouse and classified based on the WS degree as normal, moderate or severe. Chemical composition was evaluated (moisture, crude protein, fat, mineral matter and total collagen), as well as pH, color (CIELab), thiobarbituric acid reactive substances, water holding capacity, cooking loss, shear force, dough stability, cooking yield and size reduction of nuggets and hamburgers. The presence of severe WS in chicken breasts changed its chemical composition leading to increased content of fat and collagen, higher lipid oxidation (TBARS), as well as lower crude protein. In addition, breasts with severe WS showed greater cooking loss and lower water holding capacity, besides increased yellow intensity. The presence of WS did not affect significantly the production and quality of chicken nuggets and hamburgers, causing only few changes in hamburger´s cooking loss, and therefore, it is a good destination for this kind of meat.

Keywords: breast muscle myopathies; collagen; poultry meat; thiobarbituric acid reactive substances.

Practical Application: Chicken breast meat with white striping myopathy do not affect the quality of nuggets and hamburgers.

1 Introduction

The white striping (WS) anomaly is an emerging problem in the poultry industry worldwide and it is directly related to the appearance of chicken meat, specifically the breast (*Pectoralis major*). This myopathy is characterized by the appearance of whitish streaks in the same direction of the muscle fiber with different degrees of intensities, which may impact meat quality, consumer´s acceptance (Kuttappan et al., 2012a), causing condemnantion by the industry (Galiropoulou, 2013) and considerable economic losses (Kuttappan et al., 2012b).

The etiology this type of myopathy is not well understood, and there is no scientific evidence that it could be a public health issue (Ferreira et al., 2014), but the fact is that it can altere raw and cooked meat quality, especially with regard to physical and chemical parameters. Due to its high incidence, the industry was forced to establish internal controls during the slaughter process in order to minimize possible losses. Thus, chicken breasts classified as severely affected by WS are currently used in industrialized products, such as sausages and hamburgers, among others. Breasts with moderate degree of WS are commercialized in the domestic market, since their visual aspects do not meet the quality standards for exportation. These extra procedures cause economic losses in the overall process (Kuttappan et al., 2012a).

In the group of emulsified meat derivatives, there is the chicken nugget, which is defined as an industrialized meat product obtained from meats of different animal species, and other ingredients, breaded or not, and coated with appropriate cover (Brasil, 2000). The chicken burger is characterized as a restructured formed industrialized meat product obtained from grounded meat, with or without adipose tissue and ingredients, such as flavorings and spices (Brasil, 2001). The hamburger is a product that can be marketed raw, semi-cooked, cooked, fried, frozen or cooled.

There is a lack of studies regarding the use of white striped chicken breasts as the main ingredient for chicken meat derivatives, since it is a complex process that requires meat of good quality in order to ensure the standardization of the process, as well as the quality and safety of the final product. Many problems faced in the everyday process require quick and precise decisions. Thus, there is a need to clarify whether chicken meat with different degrees of WS myopathy can cause changes in the quality of processed foods such as chicken nuggets and hamburgers. In this context, the present study aimed to characterize physically and chemically broiler breast meat with different levels of WS and to evaluate their use to produce nuggets and hamburgers .

2 Material and methods

Fillets of chicken breasts (*Pectoralis major*) were collected in a processing plant located in Xaxim city, Southern Brazil from the same chicken broiler flock (45 day-old, 3 kg of body weight on average, males, same genetic background).

Received 06 May, 2020
Accepted 15 Sept., 2020
[1]*Programa de Pós-Graduação em Ciência e Tecnloliga de Alimentos, Universidade do Estado de Santa Catarina – UDESC, Pinhalzinho, SC, Brasil*
[2]*Departamento de Ciência e Tecnologia, Florianópolis, Departamento de Zootecnia, Universidade do Estado de Santa Catarina – UDESC, Chapecó, SC, Brasil*
[3]*Departamento de Zootecnia, Universidade do Estado de Santa Catarina – UDESC, Chapecó, SC, Brasil*
*Corresponding author: mmboiago@gmail.com

These samples were collected and evaluated after cooling, at the end of the deboning line, and were visually classified by well trained employees according to three categories (normal, moderate and severe) as described by Kuttappan et al. (2013). Normal fillets showed distinct lines and those classified as moderate showed fine striae with thicknesses smaller than 1 mm; and the last category (severe) showed thick striae with thicknesses greater than 1 mm. Chicken breast fillets (n=24 per treatment) were separated in the cold area of the processing plant for pH measurement, packed in plastic bags, placed in thermal boxes with ice, and sent to the laboratories. Ten units of each treatment were sent to the Laboratory of Food Technology of the Department of Animal Science at the Universidade do Estado de Santa Catarina (UDESC), where physical and chemical analyzis were carried out. The remaining 14 units of each treatment were sent to the Meat Processing Laboratory of the National Service for Industrial Training (SENAI-SC), Chapecó unit, for the preparation of nuggets and hamburgers.

2.1 Chemical and physical analyses

The chemical composition (moisture, crude protein, lipids and mineral matter) of the samples were carried out following the official AOAC methodology (Association of Official Analytical Chemists, 1995). Total collagen concentration was determined according to methodologies described by Cross et al. (1973).

To determine the pH in chicken breasts, dough and raw hamburgers, a digital pHmeter model Testo 205 (Testo SE & Co., acquired in 2012) was used. Color evaluation of fresh meat (skinned chicken breast without fat, connective tissue and blood vessels) and products was performed by using the Minolta Chrome Meter model CR-400 (Konica Minolta, acquired in 2014), which provided the variables: L*(luminosity), a* (intensity of red) and b (intensity of yellow). In order to determine the color of the ground chicken meat and raw products, the samples were adjusted in a plate under a white surface in order to standardize the thickness, avoiding exposure of parts with irregularities that could change the original color of the final product (Ramos & Gomide, 2007).

The lipid oxidation of fresh meat, nuggets and hamburger was determined by the test of thiobarbituric acid reactive substances (TBARs), according to the methodology described by Vyncke (1970). To determine the water holding capacity (%) in fresh chicken breasts, the pressure method (10 kg) using the Filter Paper Method (FPPM) developed by Hamm (1960) was followed.

Cooking losses were determined in deboned chicken breast using the methodology described by Honikel (1987). The shear force of steaks and cooked steak dough was measured using a texture analyzer (TA-XT2i coupled to the Warner-Bratzler device), following the methodology of Lyon et al. (1998). The samples were subjected to shear with the fibers oriented in the perpendicular direction to the texturometer blade. The result was expressed in kgf/cm^2.

The steak dough stability was determined in triplicate following the procedure of Parks & Carpenter (1987). To determine the cooking yield, nuggets and hamburgers were weighed, frozen and heated in a convection oven (Parks & Carpenter, 1987). Yield was determined by the following equation: % yield = (cooked sample weight/raw sample weight) * 100.

Size reduction of nuggets and hamburgers were measured before and after heat treatment, following the methodology described by Berry (1992). The percentage of shrinkage was determined by the following equation: shrinkage = (raw sample diameter – cooked sample diameter) * 100.

2.2 Nuggets

Chicken nuggets were prepared using fillets of chicken breasts previously classified as normal, moderate or severe for white stripping under the same dough formulation (Table 1) and processing method. For that, the following steps were used as described by Dill et al. (2009): (1) weighing frozen raw materials and other ingredients; (2) grinding the meat; (3) mixing and homogenization; (4) freezing; (5) modeling; (6) dough addition; (7) adding the coating flour; (8) pre-frying; (9) cooking; (10) freezing.

Fat emulsion was prepared with soybean oil (50%), soy protein (10%) and ice (40%). The dough was obtained with 30% of a binder for patties (Romariz®) and 70% of water. A commercial flour was used for cover (Kraker Mill®). Each treatment was submitted to the process of size reduction (grinding) using a meat grinder with a disc of 8 mm. Chicken ground meat was initially placed inside refrigeration chambers, aiming to reach the temperatures between 0 and 1 °C.

2.3 Hamburgers

For the hamburger preparation, the formulation was used in order to meet the standards of the Brasil Ministry of Agriculture, Livestock, and Supply normative instruction (Brasil, 2000), as follows: chicken breast meat (100%), salt (22 g/kg), soy protein isolate (50 g/kg), emulsifying agent (230 g/kg), minced white pepper (1 g/kg), monosodium glutamate (1 g/kg), cold water (620 g/kg), chopped anion (1.5 g/kg), garlic powder (1 g/kg), egg whites (170 g/kg), sugar (30 g/kg), powdered milk (80 g/kg).

The process of hamburger manufacturing is similar to the process of breaded products, however with a very relevant differential since it contains a meaty emulsion. Thus, burgers were made in the following order: (1) selection of raw materials; (2) weighing raw materials and ingredients; (3) grinding the meat;

Table 1. Formulation used for nuggets.

Ingredients	Composition (%)
Chicken breast	78
Fat emulsion	16
Ice	3
Egg whites	3
Total	100

Condiment composition: salt (18 g/kg), sugar (1 g/kg), curry (0.3 g/kg), white pepper (0.3 g/kg), powdered milk (10 g/kg), chopped anion (1.5 g/kg), garlic powder (1 g/kg).

(4) modeling; (5) freezing; (6) modeling; (7) primary packaging (packed separately in plastic film, sealed under vacuum and kept under freezing temperatures).

2.4 Experimental design and statistical analysis

The experimental design was completely randomized with three treatments and five replicates each. The means were submitted to the normality test to verify data distribution, followed by analysis of variance. In cases of significant differences, the means were compared by the Tukey test (P <0.05).

3 Results and discussion

Chicken breasts classified with severe WS showed significant increased (P<0.05) moisture and lipids and decreased protein compared to those classified as normal or moderate (Table 2). These results corroborate with Mudalal et al. (2014).

High fat levels found in chicken breasts with severe WS are related to lipidiosis, which causes an increase in intramuscular fat content. According to Kuttappan et al. (2013), the protein reduction observed in breasts with WS correlates with the degeneration and atrophy of the muscles and this fact may also be related to decreased myofibril and sarcoplasmic proteins in the breasts of broiler chickens. The decrease in gross protein percentage indirectly explains the increase in lipids, as well as the higher collagen content of the fillets affected by severe degrees of WS (Petracci et al., 2014).

For mineral matter (%), no significant differences (P> 0.05) were observed between which corroborates with Tasoneiro et al. (2016) and Zambonelli et al. (2016). It is known that there is a relationship between mineral levels, especially calcium, and the occurrence of WS myopathy due to a higher mobilization of calcium from the sarcoplasmic reticulum, and consequently, degeneration of muscle tissue (Sandercock & Mitchell, 2003). However, this theory does not apply to the present study since mineral levels were similar between treatments.

Meat pH is an important post-slaughter parameter directly related to post-mortem and meat quality modifications. For chicken meat the ideal initial pH should be around 7.0 to 7.2 and 5.5 to 5.8 four hours after slaughter. The pH may interfere with the meat emulsion process due to its effect on proteins that can reach their maximum emulsion capacity when the pH is close to neutrality. Meat products with pH above 5.7 need higher salt content, separated or in combination, in order to improve the efficacy of myofibrillar proteins (Puolanne et al., 2001). In the present study, pH values were above the range considered normal (Table 3). It is believed that even after four hours, *rigor mortis* was not yet established.

Chicken breasts affected by severe WS showed higher luminosity when compared to the other groups, that is, this meat showed higher brightness, possibly due to a greater release of exudate, a fact evidenced by a lower water holding capacity (WHC) and higher cooking losses (CL) (P <0.05). These findings are in accordance with Petracci et al. (2014), that states that the higher the value of L*, the lower the WHC.

Color analysis helps the meat industry to determine the best use of each meat in order to obtain products of high quality. There was significant difference in the intensity of yellow in chicken breasts with severe degree of WS compared with normal ones. This finding can be justified by a higher fat content leading to a different shade of muscle color, tending to be yellowish. The WHC was gradually reduced in normal to moderate and severe breast meat. This result is in agreement with those obtained for CL, where there was a gradual increase of CL from normal to severe meat, that is, severe meat has lower

Table 2. Averages for the percentages of moisture (M), crude protein (CP), lipids (L), mineral matter (MM) and total collagen (TC) of chicken breast affected by different levels of white striping myopathy.

Treatments	M	CP	L	MM	TC
Normal	73.75 ^{B}	22.97 ^{A}	2.21 ^{B}	1.44	0.250 ^{B}
Moderate	74.11 ^{B}	22.75 ^{A}	2.24 ^{B}	1.40	0.249 ^{B}
Severe	75.13 ^{A}	21.54 ^{B}	2.75 ^{A}	1.28	0.352 ^{A}
P	0.002	<0.001	0.0052	0.091	<0.001
CV (%)	1.39	3.02	19.76	15.27	24.65

A, B - Different letters in the columns differ statistically by the Tukey test (P <0.05); CV = coefficient of variation.

Table 3. Averages for pH, luminosity (L*), red intensity (a*), yellow intensity (b*), water holding capacity (WHC, %), cooking losses (CL, %) and shear force (kgf/cm2) of chicken breasts affected by different levels of white striping myopathy.

	pH	L	a*	b*	WHC	CL	SF
Normal	6.02	54.31 ^{B}	1.00	5.89 ^{B}	75.67 ^{A}	17.20 ^{C}	1.85 ^{B}
Moderate	6.00	54.33 ^{B}	0.99	6.16 ^{AB}	74.10 ^{AB}	18.21 ^{B}	2.15 ^{A}
Severe	6.02	56.20 ^{A}	0.82	7.10 ^{A}	73.32 ^{B}	20.35 ^{A}	1.82 ^{B}
P	0.443	0.002	0.634	0.007	0.008	0.011	<0.001
CV (%)	1.27	4.25	33.12	23.53	3.79	18.42	19.41

A, B - Different letters in the columns differ statistically by the Tukey test (P <0.05); CV = coefficient of variation.

Table 4. Averages for luminosity (L*), red intensity (a*), yellow intensity (b*), diameter reduction (DR, %) and cooking loss (CL, %) of hamburgers prepared with chicken breasts affected by different levels of white striping.

	L*	a*	b*	DR	CL
Normal	66.17	5.04	20.95	5.30	20.52 B
Moderate	65.61	4.61	19.71	5.94	23.24 A
Severe	65.96	4.44	16.55	5.41	21.99 AB
P value	0.861	0.534	0.429	0.832	0.050
CV (%)	2.46	17.79	27.38	31.74	6.58

A, B - Different letters in the columns differ statistically by the Tukey test (P <0.05); CV = coefficient of variation.

WHC, as well as greater loss of water during cooking. This fact must be investigated to find in what extent it may compromise the process of industrialization of meat products that use this meat as the main ingredient.

The ability of the muscle tissue to retain water is a very important characteristic in order to maintain its functional properties. When moisture is lost, many features such as yield, softness, texture, taste and nutritional value are negatively affected (Byron et al., 2020). WHC is one of the most important functional properties in the manufacture of emulsified and breaded meat products. Its ability to bind and form the emulsion promotes a homogeneous texture similar to an intact muscle. The WHC is considered an indicator of yield, economic result and quality of the final product (Apple & Yancey, 2013).

It can be observed that samples with moderate degree of WS showed higher texture when compared with the other groups, reflected by a greater shear force (P<0.001). These results are contrary to those found by Kuttappan et al. (2013), who reported that breasts classified as severe showed lower shear strength due to lower integrity of muscle fibers.

Our results show that there is a significant influence of different degrees of WS on the physical and chemical characteristics of chicken breast meat, which are corroborated by the literature (Ferreira et al., 2014; Mudalal et al., 2014; Tasoneiro et al., 2016; Alnahhas et al., 2016).

Table 4 shows that after grinding the meat and preparing the hamburgers, there were no significant differences for the variables luminosity and intensities of red and yellow, that is, meat processing eliminated differences found previously in raw meat regarding luminosity and intensity of yellow, as shown in Table 3.

Yield analyses demonstrated that hamburgers made of meats with different degrees of WS did not show significantly differences, i.e, WS did not reduce the diameter of these hamburgers. For the determination of CL, it was observed that hamburgers made of meats with moderate WS showed higher losses than those made with normal meat (P=0.05). However, hamburgers produced with meats classified as severe did not differ from the others.

The dough used for nuggets showed no significant difference regarding shear force and emulsion stability (Table 5). These results are quite positives to the industry, since it shows that of WS does not interfere with texture and stability of chicken nuggets. According to Nunes (2003), chicken breasts

Table 5. Averages of shear force (SF, kgf/cm^2) and dough emulsion stability (DES, %) for nuggets using chicken breasts affected by different levels of white striping myopathy.

	SF (kgf/cm^2)	DES (%)
Normal	0.460	14.16
Moderate	0.437	14.24
Severe	0.411	15.70
P value	0.246	0.717
CV (%)	9.71	22.31

A, B - Different letters in the columns differ statistically by the Tukey test (P <0.05); CV = coefficient of variation.

have important properties such as excellent water retention, fat content and other nutrients which remains stable even after cooking. The results obtained in our study corroborate with this previous statement.

The parameters of color, area reduction and CL were also evaluated for chicken nuggets (Table 6). All parameters did not show significant differences (P >0.05). The processing of these products followed the same conditions and formulations. The meat dough used for nuggets is usually subjected to an aggressive physical process of grinding and homogenization, so the WS anomaly did not interfere in the studied aspects, which is a good result for the industry, enabling the use of meats with different degrees of WS without compromising any technological aspect and the quality of the final product.

TBARS results of chicken breasts meat affected by severe WS myopathy showed higher values for lipid oxidation (Figure 1). Higher lipid content in chicken breasts with severe WS might be related to higher TBARS indices, since higher fat content leaves the meat more susceptible to lipid oxidation, and consequently, greater values for TBARS.

Nuggets made of chicken meat with severe WS also showed higher oxidation compared to those produced with normal chicken meat. This result shows that the nuggets manufacturing process does not neutralize the effect of the initial oxidation of the raw meat. On the other hand, the values obtained for TBARS did not differ significantly for hamburgers produced with chicken breast meat affected by the different degrees of the WS. The susceptibility for oxidation of one product can be modified by the formulation and the processing conditions. Certain processes may result in profound alterations of its structure, causing the rupture of fat globules, favoring the action of lipolytic enzymes (Lawire, 2005).

Table 6. Mean values obtained for luminosity (L*), red intensity (a*), yellow intensity (b*), area reduction (AR, %) and cooking losses (CL, %) of nuggets prepared with chicken breasts affected by different levels of white striping myopathy.

	L*	a*	b*	AR	CL
Normal	79.69 [B]	3.27	18.43	16.60	17.65
Moderate	81.31 [A]	3.15	17.59	17.41	17.73
Severe	80.13 [AB]	2.88	17.35	16.98	21.24
P value	0.018	0.509	0.374	0.771	0.068
CV (%)	0.89	17.01	6.70	10.36	12.43

CV = coefficient of variation.

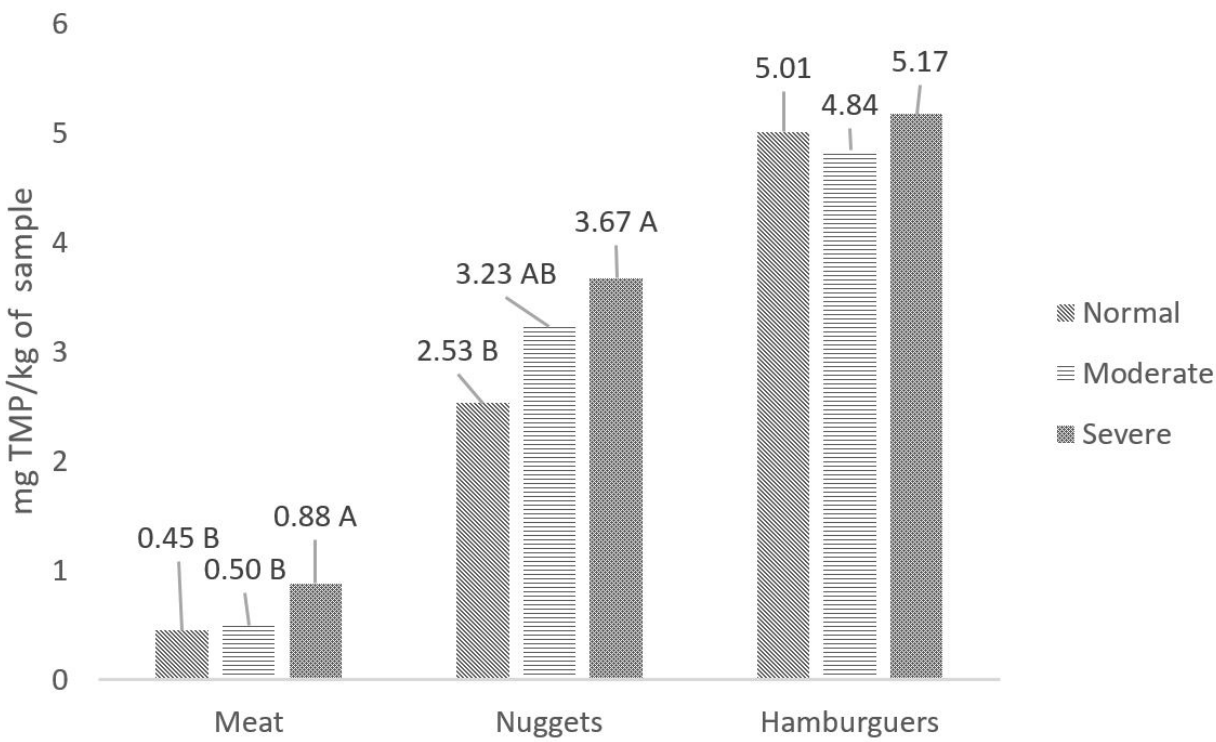

Figure 1. Mean values obtained for thiobarbituric acid reactive substances (TBARS, mg of TMP/kg of sample) of the chicken breast meat, nuggets and hamburgers prepared with chicken breasts affected by different levels of white striping. Statistical parameters: meat ($P<0.001$; CV=25.25), nuggets ($P<0,01$; CV=12.43), hamburgers ($P=0.266$, CV=5.80).

4 Conclusion

According to our results it can be concluded that the white stripping myopathy affects the physicochemical parameters of chicken breast meat. Meat severely affected by WS showed increased lipid oxidation (TBARS), fat and collagen contents and reduced crude protein, as well as lower and higher values for water holding capacity and cooking losses, respectively.

With the exception of the higher values of thiobarbituric acid reactive substances found in nuggets produced with WS meat, the other physicochemical alterations verified in the meat were not observed in the products. So, that chicken breasts with WS can be used to produce chicken nuggets and hamburgers without affecting the process and quality of these products, and therefore, it is a good destination for this kind of meat by the poultry industry worlwide.

5 Funding

The research was funded by National Council for Scientific and Technological Development (CNPq) and the Foundation of Support for Research of Santa Catarina (FAPESC). The authors also thanks the Cooperativa Central Aurora Alimentos for supplying the meat used in the experiment.

References

Alnahhas, N., Berri, C., Chabault, M., Chartrin, P., Boulay, M., Bourin, M. C., & Le Bihan-Duval, E. (2016). Genetic parameters of white striping in relation to body weight, carcass composition, and meat quality traits in two broiler lines divergently selected for the ultimate pH of the pectoralis major muscle. *BMC Genetics*, 17(1), 61. http://dx.doi.org/10.1186/s12863-016-0369-2. PMid:27094623.

Apple, J. K. & Yancey, J. W. S. (2013). Water holding capacity of the meat. In C.R. Kerth (Ed.), *The science of meat quality* (pp. 119-145). Ames, Iowa: Wiley-Blackwell.

Association of Official Analytical Chemists – AOAC. (1995). *Official methods of analysis* (pp. 1094-1995). Arlington: AOAC.

Berry, B. W. (1992). Low fat level effects on sensory, shear, cooking, and chemical properties of ground beef patties. *Journal of Food Science*, 57(3), 537-540. http://dx.doi.org/10.1111/j.1365-2621.1992.tb08037.x.

Byron, M. D., Zhang, X., Staden, M. E. V., Jarvis, T. R., Crist, C. A., Zhai, W., & Schilling, M. W. (2020). Impact of refrigerated storage time on woody broiler breast severity and instrumental quality. *Meat and Muscle Biology*, 4(1), 1-12.

Brasil, Ministério da Agricultura, Pecuária e Abastecimento. (2000). *Technical regulations for meat products*. Retrieved from http://extranet.agricultura.gov.br/sislegis-consulta/consultarLegislacao.do?operacao=visualizar&id=1681

Brasil, Ministério da Agricultura, Pecuária e Abastecimento (2001) *Technical regulations for salted meat products*. Retrieved from http://extranet.agricultura.gov.br/sislegis-consulta/consultarLegislacao.do?operacao=visualizar&id=2198

Cross, H. R., Carpenter, Z. L., & Smith, G. C. (1973). Effects of intramuscular collagen and elastin on bovine muscle tenderness. *Journal of Food Science*, 38(6), 998-1003. http://dx.doi.org/10.1111/j.1365-2621.1973.tb02133.x.

Dill, D. D., Silva, A. P., & Luvielmo, M. M. (2009). Breaded processing: covering system. *Technological Studies*, 5(1), 33-49.

Ferreira, T. Z., Casagrande, R. A., Vieira, S. L., Driemeier, D., & Kindlein, L. (2014). An investigation of a reported case of white striping in broilers. *Journal of Applied Poultry Research*, 23(4), 1-6. http://dx.doi.org/10.3382/japr.2013-00847.

Galiropoulou, S. (2013). *Effect of wooden breast disorder on protein oxidation in Pectoralis major muscle* (Dissertation). University of Helsinki, Helsinki.

Hamm, R. (1960). Biochemistry of meat hydratation. *Advances in Food Research*, 10(2), 335-443. PMid:13711042.

Honikel, K. O. (1987). Influence of chilling on meat quality attributes of fast glycolysing pork muscles. In: P. V. Tarrant, G. Eikelenboom & G. Monin (Eds.). *Evaluation and control of meat quality in pigs* (p. 273-283). Dordrecht: Martinus Nijhoff.

Kuttappan, V. A., Brewer, V., Apple, J., Waldroup, P., & Owens, C. M. (2012a). Influence of growth rate on the occurrence of white striping in broiler breast fillets. *Poultry Science*, 91(10), 2677-2685. http://dx.doi.org/10.3382/ps.2012-02259. PMid:22991557.

Kuttappan, V. A., Goodgame, S. D., Bradley, C. D., Mauromoustakos, A., Hargis, B. M., Waldroup, P. W., & Owens, C. M. (2012b). Effect of different levels of dietary vitamin E (dl-α-tocopherol acetate) on the occurrence of various degrees of white striping on broiler breast fillets. *Poultry Science*, 91(12), 3230-3235. http://dx.doi.org/10.3382/ps.2012-02397. PMid:23155035.

Kuttappan, V. A., Huff, G. R., Huff, W. E., Hargis, B. M., Apple, J. K., Coon, C., & Owens, C. M. (2013). Comparison of hematologic and serologic profiles of broiler birds with normal and severe degrees of white striping in breast fillets. *Poultry Science*, 92(2), 339-345. http://dx.doi.org/10.3382/ps.2012-02647. PMid:23300298.

Lawire, R. A. (2005). Ciência da carne. *The Art of Medication*

Lyon, C. E., Lyon, B. G., & Dickens, J. A. (1998). Effects of carcass stimulation, deboning time, and marination on color and texture of broiler breast meat. *Journal of Applied Poultry Research*, 7(1), 53-60. http://dx.doi.org/10.1093/japr/7.1.53.

Mudalal, S., Babini, E., Cavani, C., & Petracci, M. (2014). Quantity and functionality of protein fractions in chicken breast fillets affected by white striping. *Poultry Science*, 93(8), 2108-2116.

Nunes, T. P. (2003). *Efeito da pré-cura na estabilidade microbiológica da carne mecanicamente separada e elaboração de um produto reestruturado com filés de peito de galinhas de descarte* (Dissertação de Mestrado em Ciências). Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba, 101 p.

Parks, L. L., & Carpenter, J. A. (1987). Functionality of six nonmear proteins in meat emulsion systems. *Journal of Food Science*, 52(2), 271-274. http://dx.doi.org/10.1111/j.1365-2621.1987.tb06590.x.

Petracci, M., Samer, M., Banbini, E., & Cavani, C. (2014). Effect of white striping on chemical composition and nutritional value of chicken breast meat. *Italian Journal of Animal Science*, 13(1), 3138. http://dx.doi.org/10.4081/ijas.2014.3138.

Puolanne, E., Ruusunen, M., & Vainionpaa, J. (2001). Combined effects of NaCl and raw meat pH on water-holding in cooked sausag with and without added phosphate. *Meat Science*, 58(1), 1-7. http://dx.doi.org/10.1016/S0309-1740(00)00123-6. PMid:22061912.

Ramos, E. M., & Gomide, L. A. M. (2007). *Avaliação da qualidade de carnes: fundamentos e metodologias*. Viçosa: UFV.

Sandercock, D. A., & Mitchell, M. A. (2003). Myopathy in Broiler Chickens: A role for Ca(2+) - activated phospholipase. *Poultry Science*, 82(8), 1307-1312. http://dx.doi.org/10.1093/ps/82.8.1307. PMid:12943302.

Tasoneiro, G., Cullere, M., Cecchinato, M., Puolanne, E., & Dalle Zotte, A. (2016). Technological quality, mineral profile, and sensory attributes of broiler chicken breasts affected by White Striping and Wooden Breast myopathies. *Poultry Science*, 95(11), 2707-2714. http://dx.doi.org/10.3382/ps/pew215. PMid:27486252.

Vyncke, B. W. (1970) Direct determination of the thiobarbituric acid value in trichloracetic acid extracts of fish as a measure of oxidative rancidity. *Fette Seifen Anstrichm*, 72(12), 1084-1087.

Zambonelli, P., Zappaterra, M., Soglia, F., Petracci, M., Sirri, F., Cavani, C., & Davoli, R. (2016). Detection of differentially expressed genes in broiler pectoralis major muscle affected by White Striping – Wooden Breast myopathies. *Poultry Science*, 95(12), 2771-2785. http://dx.doi.org/10.3382/ps/pew268. PMid:27591279.