Breast meat quality of turkey breeder hens at disposal age affected by deep pectoral myopathy

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ABSTRACT Deep pectoral myopathy (**DPM**) considerably affects the meat quality of commercial poultry, thus representing a challenge to the poultry industry. In this study, we examined the breast meat quality of turkey breeder hens at disposal age affected by different degrees of DPM. Samples were collected from Nicholas turkeys at disposal age (385 d), at an average weight of 12.5 kg, which were reared and slaughtered in the south region of Brazil. The breast was first classified according to the degree of DPM and then samples of the *Pectoralis major* were collected from birds affected (DPM degrees 2 and 3; n = 20 of each) and nonaffected (normal, absence of lesions; n = 20) by the myopathy. After the affected *Pectoralis minor* muscle was discarded, the carcasses were released for human consumption by the Federal Inspection Service. The meat affected by the myopathy exhibited color changes (L*, a* and b*) ($P < 0.05$), especially in the inner surface. Higher ($P < 0.05$) water-holding capacity, pH, sarcomere length and fat concentration and lower ($P < 0.05$) shear force and moisture percentage were observed when compared to the normal samples. From this study, can be concluded that the severe condition of deep pectoral myopathy which affects the *Pectoralis minor* muscle, causes variations in the quality of *Pectoralis major* muscle of turkey on disposal age. As a raw material, this type of meat has a higher fat content and greater capacity for retaining intracellular water, important attributes to the manufacture of processed products. In this way, the processing is an economically viable alternative to the commercialization of breast meat from birds affected by myopathy.

Key words: green muscle, Oregon disease, *Pectoralis minor* muscle, deep pectoral myopathy

2021 Poultry Science 100:101259
https://doi.org/10.1016/j.psj.2021.101259

INTRODUCTION

The poultry meat industry enjoys an outstanding position in the production and sale of animal protein worldwide. The success of this sector is linked to the progress achieved in poultry breeding as well as use of technologies and improvements in animal management and nutrition. One of the segments of the poultry sector is the production of turkey meat and industrialized products, which have increasingly gained more acceptance in the consumer market due to their protein value and low fat and cholesterol concentrations. The growing interest in healthy eating habits has propelled not only the diversification of turkey meat products in the market, but also the expansion of its consumption across the globe.

However, the excessive muscle growth resulting from advances in poultry breeding led to alterations in muscle fibers and in the vascular structure of birds, which started to be reported as breast muscle myopathies (Hoving-Bolink et al., 2000). Among them is deep pectoral myopathy (**DPM**), the most critical of all, described in chickens and turkeys in several countries (Kijowski and Kupińska, 2013). Deep pectoral myopathy is characterized by muscle degeneration, which causes necrosis and atrophy, especially in the *Pectoralis minor* muscle. Its lesions can affect both portions of the pectoral muscles and vary in color, evolving from a pinkish, bloody-like appearance to a grayish-green discoloration (Bilgili and Hess, 2008).

The occurrence of this myopathy may be related to factors such as genetics, sex, slaughter weight, bird mobility, rearing conditions and age (Kijowski and Kupińska, 2013). Though not associated with infectious

Received June 17, 2020.
Accepted May 10, 2021.

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agents, DPM considerably affects the appearance (Bilgilie and Hess, 2008) and quality of meat, as it affects both the *Pectoralis minor* and *Pectoralis major* (at a lower frequency and in a lesser degree) muscles. Besides possible quality losses, alterations in valued parts of the carcass may directly influence its sale, since changes in the visual aspect of the product can negatively impact consumer acceptance. The greatest damage to the turkey meat market resulting from DPM is due to partial condemnation of the breast muscle by virtue of lesions caused by the myopathy.

Considering that DPM affects the poultry industry globally, research should be done to elucidate the dynamics of this disorder as well as determine its effects on poultry meat quality. Therefore, the present study proposes to examine the quality of breast meat from turkey breeder hens at disposal age affected by different degrees of DPM.

MATERIAL AND METHODS

Location, Period and Sample Collection

This study was developed in the Laboratory of Animal-Derived Foods (**LaOra**) at the Department of Technology of the Faculty of Agricultural and Veterinary Science (**FCAV**), São Paulo State University (**Unesp**), Jaboticabal Campus, SP, Brazil (21°08'S, 48° 11'W, 583 m altitude).

Breast meat samples were harvested from turkey breeder hens of the Nicholas line at disposal age (385 d), at an average weight of 12.5 kg. The birds were reared and slaughtered in the south region of Brazil following the procedures adopted by the packing plant. In broilers, the degeneration process of deep pectoral myopathy hardly reaches the breast fillet (*Pectoralis major*), but as the disease progresses with age it is possible that in matrices this region is affected (Paschoal and Santos, 2013). Therefore, we used matrices at disposal age due to the greater occurrence of deep pectoral myopathy in these animals compared to those at the marketing age.

The carcasses were classified as to the degree of severity of DPM affecting the *Pectoralis minor* muscle, at the time of deboning, following the criterion of condemnation for special diseases, according to which only the affected part of the carcass should be discarded (Brasil, 1997).

For the classification, breast samples (*Pectoralis major* + *Pectoralis minor* muscle pairs) were selected at random on the slaughter line according to the occurrence of the myopathy. Pairs exhibiting well-defined lesions on the *Pectoralis minor* muscle, some of them surrounded by a clear hemorrhagic halo, were classified as "Degree 2" (n = 20). Those which showed progressive degeneration of the *Pectoralis minor* muscle, with the damaged muscle tissue having a greenish appearance, were classified as "Degree 3" (n = 20), in accordance with the methodology adopted by Bilgili and Hess (2008) (Figure 1). After the classification step, the *Pectoralis minor* muscle of each pair was discarded and samples of the reminiscent *Pectoralis major* muscle (which were released for human consumption by the Federal Inspection Service) were sent for quality analysis. Along with the samples affected by DPM, 20 samples of *Pectoralis major* muscle classified as normal (absence of myopathy; control group) were also examined. The proposed physical analyses were performed immediately after collection, and the samples to be later used for the chemical analysis were frozen in a freezer (−20°C; for a period no longer than 30 d).

Laboratory Analyses

The pH was determined in duplicate, in the cranial part of the *Pectoralis major* muscle, using a digital pH meter (Testo 205, Testo Inc., Sparta, NJ), equipped with a penetration electrode, which was inserted directly into the muscle.

Water-holding capacity (**WHC**) was determined on a 2-g sample of the *Pectoralis major* muscle. For this evaluation, the sample was placed between 2 filter papers and acrylic plates and a 10-kg weight was placed on top of the plate for 5 min. Subsequently, the sample was weighed again to measure the amount of water lost, using the following formula: (Final weight × 100)/Initial weight (Hamm, 1961).

To evaluate cooking losses, samples of the *Pectoralis major* muscle of similar weights and sizes were weighed individually, vacuum-packed and cooked in a water bath (85°C) for 30 min. Next, the samples were cooled at room temperature and weighed again to determine cooking loss, by the following formula: (Initial weight − Final weight) × 100/Initial weight (Honikel, 1987).

Sarcomere length was determined by phase contrast microscopy. A 0.5-g sample was homogenized in a Turrax homogenizer (MA 102, Marconi Equipamentos para Laboratório Ltd., Piracicaba/SP, Brazil) with 30 mL of a KCl (008 mol/L) and KI (0.08 mol/L) mixed solution (50:50) at a speed higher than 15000 rpm, for 30 s, to rupture the cells and facilitate the removal of myofibrils for suspension. A drop of the homogenate was deposited on a microscope slide, which was then covered with a coverslip. Subsequently, the material was read in a phase contrast microscope (Novel BM2100) under 1000× magnification (100× objective, ocular 10× ocular).

Shear force was analyzed in samples of the *Pectoralis major* muscle that had been used for the analysis of cooking loss, using the Warner-Bratzler device (Lyon et al., 1998). The instrument was coupled to a texture analyzer (TA-XT2i, Stable Micro Systems, Godalming, UK). Samples were cut into strips (1 cm^2 section area and 3 cm in length) that were positioned with the fibers perpendicular to the Warner-Bratzler device, and sheared. The force required to shear the samples, was expressed in kilograms (kg).

Color was determined using a Minolta Chrome Meter colorimeter (CR-400, Konica Minolta Sensing, Inc., Osaka, Japan), which employs the CIELAB system (L, a* and b*). Lightness (L*), redness (a*) and yellowness (b*) were evaluated in the *Pectoralis major* muscle.

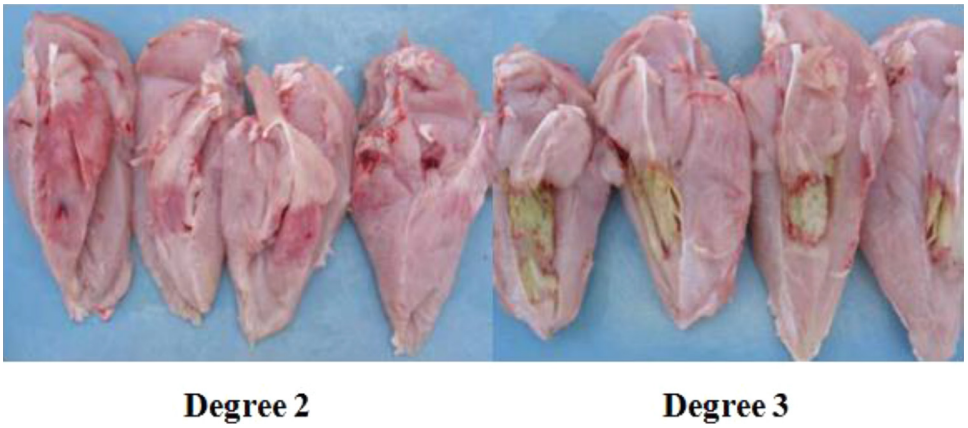

Figure 1. Degree 2 (Development and well-defined lesions on the *Pectoralis minor* muscle) and Degree 3 (progressive degeneration of the *Pectoralis minor* muscle) of deep pectoral myopathy. Source: Adapted from Bilgili and Hess (2008).

Color was determined in the outer (which was previously in contact with the skin) and inner (which was in contact with the *Pectoralis minor* muscle and the sternum bone) surfaces of the *Pectoralis major* muscle, in a way that the slaughter process would not interfere with this variable. The evaluation was performed at 3 different points on each surface.

To determine the chemical composition of the *Pectoralis major* muscle, the moisture (method no. 950.46), protein (method no. 977.14), and mineral matter (method no. 920.153) contents were measured by procedures recommended by the Association of Official Analytical Chemists (AOAC, 2005). Fat was determined by the methodology described by Bligh and Dyer (1959).

Cholesterol was analyzed by an adaptation of the methodology described by Saldanha et al. (2004), using a 0.5-g sample of lyophilized *Pectoralis major* muscle instead of fresh sample (the standard curve was adapted as a function of the sample dry matter). The cholesterol concentration was measured using an enzymatic kit for blood cholesterol analysis (adaptation of LaOra) (Labtest: COLESTEROL Liquiform, Ref.: 76 MS: 10009010068). Readings were obtained by a spectrophotometer (Shimadzu UV-1800, Kyoto, Japan), with λ defined as indicated by the manufacturer of the enzymatic kit (500 nm).

The concentrations of total, soluble and insoluble collagen were quantified by measuring the amino acid hydroxyproline (Woessner Junior (1961) and Cross et al. (1973), adapted by Hadlich et al. (2006) and by the Laboratory of Animal-Derived Foods (**LaOra**) at the Faculty of Agrarian and Veterinary Sciences at Unesp, Jaboticabal Campus, São Paulo, Brazil). Five grams of raw *Pectoralis major* muscle were weighed and frozen in 50-mL Falcon tubes to which 20 mL distilled water was added. Subsequently, the tubes were placed in a water bath (80°C) for 2 h. Next, the samples were homogenized in an Ultra-turrax homogenizer (MA 102, Marconi Equipamentos para Laboratório Ltd.) (22,000 rpm) for 1 min and centrifuged (HITACHI CR22N, Made in Japan) (4,000 rpm) for 15 min. The samples were transferred to autoclavable tubes and separated into sediment and supernatant. Thirty millimeters of 6N HCl were added to the supernatant and 50 mL 6N HCl was added to the sediment (Woessner Junior, 1961). The samples were hydrolyzed in an autoclave (Phoenix AV-75Plus, Araraquara/SP, Brazil) for 4 h (120°C, 1 atm) (Cross et al., 1973). The pH was adjusted to 6.0 using 2N NaOH. Thereafter, the samples were filtered in volumetric flasks (250 and 100 mL for sediment and supernatant, respectively), which were completed with distilled water. A 10-mL aliquot was transferred to new volumetric flasks (100 and 50 mL for sediment and supernatant, respectively), which were also completed with distilled water. Next, 2-mL aliquots were pipetted into test tubes, to which 1 mL of an oxidation reagent (Chloramine-T 1.41%) and 1 mL of a color reagent (10 g p-Dimethylaminobenzaldehyde in 35 mL 60% perchloric acid and 65 mL isopropanol) (adaptation by LaOra) were added. The tubes containing the samples were kept in a water bath (60°C) for 15 min and the solution was read in a spectrophotometer (Shimadzu UV-1800, Kyoto, Japan) under $\lambda = 560$ nm. The collagen concentration was estimated as 7.14 times the hydroxyproline concentration (Hadlich et al., 2006). Total, insoluble and soluble collagen values were calculated by the following equations:

$$\%\text{Total collagen} = \%\text{Insoluble collagen} + \%\text{Soluble collagen}$$

$$\%\text{ Insoluble collagen} = \frac{\text{absorbance} \times F^{*} \times 250 \times 100 \times 7.14^{**} \times 10 - 6 \times 100}{10 \times 2 \times \text{meat sample weight (g)}}$$

$$\%\text{ Soluble collagen} = \frac{\text{absorbance} \times F^{*} \times 100 \times 50 \times 7.14^{**} \times 10 - 6 \times 100}{10 \times 2 \times \text{meat sample weight (g)}}$$

Where:

*F assumes the value of 8.33, corresponding to the average of absorbance values equivalent to 1 mg of hydroxyproline obtained from the standard curve, which was constructed following the same procedure performed on the samples.

Table 1. Values of pH, water retention capacity (WRC), weight of cooking losses (WCL), sarcomere length and shear force (SF) of pectoral major muscle of turkey breeder hens at disposal age affected by the deep pectoral myopathy.

	pH	WRC, %	WCL, %	Sarcomere, μm	SF, kg
Normal	5.82 ± 0.06^{c}	73.00 ± 4.27^{b}	23.59 ± 1.31	2.07 ± 0.03^{b}	1.38 ± 1.39^{a}
Category 2	5.88 ± 0.09^{b}	73.75 ± 4.14^{b}	22.50 ± 1.30	2.15 ± 0.06^{a}	1.32 ± 1.44^{ab}
Category 3	5.95 ± 0.08^{a}	77.99 ± 3.88^{a}	23.76 ± 2.49	2.16 ± 0.02^{a}	1.23 ± 1.67^{b}
P-value	<0.0001	<0.0001	0.2711	<0.0001	<0.0001

[a-c]Means followed by different letters (in the columns) differ from each other by the Tukey test ($P < 0.05$).

**Hydroxyproline-to-collagen conversion factor, considering that the content of this amino acid in collagen is 14%.

The fatty acids were isolated by removing the liquid phase from the sample (Bligh and Dyer, 1959). The fatty acids were esterified (Maia and Rodrigues-Amaya, 1993) and then analyzed in a Shimadzu 14B gas chromatograph (Shimadzu Corporation, Kyoto, Japan) equipped with a flame ionization detector and a fused silica capillary. The peaks were identified by comparing the retention times with fatty acid metal ester standards of known composition.

Statistical Analysis

The experiment was set up as a completely randomized design with 3 treatments (degrees of severity 2 and 3 and a control group) with 20 replicates each. Data were analyzed using the One-Way ANOVA procedure of SAS software (Statistical Analysis System; SAS Institute Inc, Cary, NC). Results were subjected to analysis of variance, and in case of significance, means were compared by Tukey's test with significance defined as $P < 0.05$.

RESULTS

The meat pH increased with the DPM severity degree, samples classified as degree 2 and degree 3 presented higher pH values (5.88 and 5.95, respectively) than the normal samples (5.82). Samples classified as degree 2 and degree 3 also showed higher water-holding capacity (73.75% and 77.82%, respectively) in comparison with the normal samples (73%). The affected samples of degree 2 and degree 3 resulted in longer sarcomeres (2.15 μm and 2.16 μm, respectively) by comparing to normal samples (2.07μm) and lower shear force values (1.32 kg and 1.23 kg, respectively) than the normal samples (1.38 kg) (Table 1).

Variations in lightness (L*) were detected in the outer and inner surfaces of the *Pectoralis major* muscle. The meat from birds affected by the myopathy and classified as degree 3 showed a higher L* values in the outer and inner surfaces of the *Pectoralis major* muscle (59.93 and 60.31, respectively) by comparing to the samples classified as degree 2 (57.62 and 56.27, respectively) and normal (59.28 and 57.44, respectively), meaning that the degree 3 had a brighter appearance (Table 2). The meat classified as degree 2 presented higher red intensity (a*) value in the inner surface of the *Pectoralis major* muscle (5.94) when compared to normal samples and the classified as degree 3 (5.16 and 5.27, respectively), which indicate it had a darker appearance.

The fat concentration increased whereas moisture decreased in samples from birds affected by degree 3 of myopathy (3.52% and 70.29%, respectively), compared to the samples classified as degree 2 and normal (2.85% and 71.37% × 3.08% and 71.13%, respectively) (Table 3). The protein, mineral matter and cholesterol

Table 2. Lightness (L*), redness (a*) and yellowness (b*) of the outer and inner surfaces of pectoral major muscle of turkey breeder hens at disposal age affected by the deep pectoral myopathy.

Degree	Outer surface coloring			Inner surface coloring		
	L*	a*	b*	L*	a*	b*
Normal	59.28 ± 2.35^{a}	3.74 ± 1.14	1.87 ± 1.53	57.44 ± 2.58^{b}	5.16 ± 0.70^{b}	2.76 ± 1.33
Category 2	57.62 ± 2.40^{b}	4.19 ± 1.21	1.99 ± 1.48	56.27 ± 2.03^{b}	5.94 ± 1.14^{a}	2.62 ± 1.31
Category 3	59.93 ± 3.71^{a}	3.62 ± 1.16	1.30 ± 2.43	60.31 ± 3.40^{a}	5.27 ± 1.37^{b}	2.98 ± 1.49
P-value	0.0357	0.1725	0.2573	<0.0001	0.0059	0.5543

[a,b]Means followed by different letters (in the columns) differ from each other by the Tukey test ($P < 0.05$).

Table 3. Chemical composition and cholesterol concentration of pectoral major muscle of turkey breeder hens at disposal age affected by the deep pectoral myopathy.

Degree	Protein, %	Fat, %	Moisture, %	Mineral matter, %	Cholesterol, mg/100g
Normal	23.46 ± 0.18	3.08 ± 0.69^{B}	71.13 ± 0.70^{A}	2.02 ± 0.50	68.00 ± 0.74
Category 2	23.50 ± 0.18	2.85 ± 0.45^{B}	71.37 ± 1.87^{A}	1.72 ± 0.35	67.99 ± 7.04
Category 3	23.91 ± 0.18	3.52 ± 1.00^{A}	70.29 ± 0.88^{B}	1.89 ± 0.47	69.05 ± 2.62
P-value	0.1617	0.0003	<0. 0001	0.0507	0.4272

[A,B]Means followed by different letters (in the columns) differ from each other by the Tukey test ($P < 0.05$).

Table 4. Collagen concentration of pectoral major muscle of turkey breeder hens at disposal age affected by the deep pectoral myopathy.

Degree	Total collagen, %	Soluble collagen, %	Insoluble collagen, %
Normal	0.29 ± 0.05	0.03 ± 0.02	0.26 ± 0.05
Category 2	0.25 ± 0.07	0.02 ± 0.01	0.25 ± 0.08
Category 3	0.23 ± 0.09	0.02 ± 0.01	0.23 ± 0.09
P-value	0.1597	0.9784	0.2967

contents (Table 3) and the collagen concentration (Table 4) were not affected ($P > 0.05$) by the occurrence of DPM.

There was a statistical difference in the composition of fatty acids present in the fat of breast meat from turkey breeder hens affected by DPM (Table 5). The affected samples classified as degrees 2 and 3 exhibited higher ($P < 0.05$) concentrations of C17:0 (0.17 and 0.18%, respectively), C20:0 (0.09 and 0.09%, respectively), and C20:3n6 (0.35 and 0.37, respectively); and lower concentrations of C14:1 (0.06 and 0.07%, respectively), C16:1 (2.20 and 2.63%, respectively), C17:1 (0.04 and 0.05%, respectively), C18:1n9c (26.98 and 27.86%, respectively) and C18:2c9,t11 (0.02 and 0.02%, respectively) fatty acids when compared to the normal samples.

Table 5. Fatty acid composition (%) of pectoral major muscle of turkey breeder hens at disposal age affected by the deep pectoral myopathy.

	Degree of myopathy severity			
Acids, %	Normal	Category 2	Category 3	*P*-value
Capric (C10:0)	0.02	0.02	0.02	0.2770
Lauric (C12:0)	0.03	0.03	0.03	0.6163
Miristic (C14:0)	0.51	0.51	0.52	0.9589
Pentadecanoic (C15:0)	0.10	0.10	0.11	0.2781
Palmitic (C16:0)	23.81	23.62	23.52	0.7926
Heptadecanoic (C16:0)	0.14[b]	0.17[a]	0.18[a]	0.0031
Estearic (C18:0)	7.36[c]	9.64[a]	8.69[b]	<0.0001
Arachidic (C20:0)	0.08[b]	0.09[a]	0.09[a]	<0.0001
Myristoleic (C14:1)	0.12[a]	0.06[b]	0.07[b]	<0.0001
Palmitoleic (C16:1)	4.36[a]	2.20[b]	2.63[b]	<0.0001
Heptadecenoic (C17:1)	0.07[a]	0.04[b]	0.05[b]	0.0007
Oleic (C18:1n9c)	30.59[a]	26.98[b]	27.86[b]	<0.0001
Cis-vaccenic (C18:1n7)	1.61	1.70	1.68	0.5151
Eicosenoic (C20:1n9)	0.19[b]	0.17[a]	0.19[b]	<0.0001
Conjugated linoleic acid (CLA) (C18:2 c9,t11)	0.04[a]	0.02[b]	0.02[b]	0.0128
Eicosadienoic (C20:2)	0.23[c]	0.31[a]	0.27[b]	0.0219
Linoleic (C18:2n6c)	25.15	26.23	26.58	0.1876
γ linolenic (C18:3n6)	0.15	0.16	0.17	0.1240
α linolenic (C18:3n3)	1.15	1.04	1.19	0.0897
Eicosatrienoic (cis - 8, 11, 14) (C20:3n6)	0.31[c]	0.35[b]	0.37[a]	<0.0001
Arachidonic (C20:4n6)	2.59	4.36	3.94	0.5045
Docosatetraenoic (DTA) (C22:4n6)	0.85	1.22	1.02	0.1068
Eicosapentaenoic (EPA) (C20:5n3)	0.08	0.08	0.08	0.9498
Docosapentaenoic (DPA) (C22:5n3)	0.30	0.57	0.48	0.0700
Docosahexaenoic (DHA) (C22:6n3)	0.14[c]	0.31[a]	0.26[b]	0.0055
Total	100.00	100.00	100.00	

[a-c]Means followed by different letters (in the columns) differ from each other by the Tukey test ($P < 0.05$).

Among the palmitic (**C16:0**), oleic (**C18:1n9c**), and linoleic (**C18:2n6c**) fatty acids, which are found in larger concentrations in the fat of breast meat from turkey breeder hens, a statistical difference was only found between the studied samples for oleic acid, as described previously. Samples from the birds affected by DPM showed higher percentages of n-3 (2.00%, on average) and n-6 (32.20%, on average) fatty acids compared to those which were not affected by the disease (1.67 and 29.05%, respectively).

DISCUSSION

In turkey meat, pH values lower than 5.8 are considered low, whereas values greater than 6.2 are considered high (Pastuszczak-Frąk and Uradziński 2009). Thus, despite the observed statistical differences between the evaluated samples, the pH values of the breast meat from turkey breeder hens affected by different degrees of DPM can be considered normal ($5.8 \leq$ pH ≤ 6.2) for human consumption. A previous study reported that the interruption of oxygen supply caused by the development of the disease may lead to an increase in the pH of the *Pectoralis minor* muscle, while the pH of the reminiscent *Pectoralis major* muscle is maintained at normal values (Pastuszczak-Frąk and Uradziński, 2009).

Initially, during the *rigor mortis* process, all the oxygen stored in the myoglobin is used. After its depletion, the muscle starts to utilize glycolytic mechanisms (anaerobiosis) to obtain energy, promoting lactate accumulation and pH decline. In the case of animals affected by DPM, while still living, the *Pectoralis minor* muscle depletes its entire oxygen reserve during the development of the disease. Without oxygen, muscle activity is maintained anaerobically, which possibly results in a reduction of glycogen reserves (Berri et al., 2007). In this situation, in the first hours postslaughter, the lack of muscle glycogen lowers the rate of pH decline, resulting in a significantly higher final value (Debut et al., 2005). Thus, it can be stated that meat pH increases with disease severity and, as occurs in the *Pectoralis minor*, the lack of glycogen reserves also affects the *Pectoralis major*, though at a lower intensity.

Higher water-holding capacity (WHC) values were found in the samples affected by the myopathy in degree 3, which may be related to their higher pH value (5.95). The pH of meat is one of the main factors influencing its WHC (Barbut et al., 2008), as it affects protein solubility. The pH value alters the distribution of charges in a protein, interfering with the protein-protein and protein-water interactions and, consequently, influencing WHC. The lowest WHC in breast meat was found at the isoelectric point (IP ~ 5.0−5.4), where the net charge in a protein solvent is zero and its positive and negative charges are essentially equal, resulting in a maximum number of bonds between peptide chains (Knipe, 2003). This ultimately leads to a reduction in the number of water molecules attracted to and kept by the proteins.

On the other hand, pH values below or above the protein isoelectric point induce increased solubility due to the change in the number of negative or positive molecular charges (Knipe, 2003). Excessive positive or negative charges produce a repulsion between the protein molecules, resulting in greater interaction between the water and protein molecules and, consequently, a higher WHC value. Therefore, the higher established pH value (5.95), which was above the isoelectric point (IP ~ 5.0−5.4), observed in the meat affected by the myopathy in degree 3 likely increased the solubility of myofibril proteins in the meat, resulting in higher WHC.

The results demonstrate that sarcomeres are greater as the degree of severity of DPM increases. The meat texture is greatly influenced by the integrity of myofibrillar structures. Thus, possibly, there was damage to the myofibrillary structure of the *Pectoralis major* muscle remaining from the *Pectoralis minor* muscle affected by category 3 of myopathy, which is characterized by the degeneration of muscle tissue, resulting in an increase of the sarcomere length. The presence of muscle injuries in both muscles (*Pectoralis major* and *Pectoralis minor*) has already been reported in a study on the anatomopathological aspects of DPM in broilers (Vieira et al., 2006). Similar results were found by Tijare et al. (2016) in a study with broiler breast meat with muscle myopathies (white striping (WS) and woody breast (WB)), the authors suggested that the increase in sarcomeres in samples affected by myopathies compared to normal samples be the result of increased collagen and/or loss of myofibrillar structure (due to fiber degeneration). This finding may explain the lower shear force seen in the meat affected by the myopathy in degree 3, considering that increases in sarcomere length lead to decreased shear force (Zhou et al., 2018) and improved meat tenderness (Smulders et al., 1990).

The myopathy can also affect the color of the *Pectoralis major* muscle since the *Pectoralis minor* muscle is located immediately beneath the inner surface. In previous studies, Pastuszczak-Frąk and Uradziński (2009) and Kijowski and Kupińska (2013) attributed changes in the L* and a* values to the results obtained for the colors green and yellow, considering that the necrosis process characteristic of degree 3 of this myopathy results in a predominating greenish color in the affected region.The degree 2 of DPM is considered the stage of lesion development, wherein the lesion in the *Pectoralis minor* muscle is well-defined and often surrounded by a clear hemorrhagic halo (Bilgili and Hess, 2008). Accordingly, the development of hemorrhagic lesions might explain the higher a* values observed in the inner surface of samples classified as degree-2, as described by Kijowski and Konstanczak (2009).

Higher fat and lower moisture values in turkey breast meat affected by DPM were also reported in the study of Pastuszczak-Frąk and Uradziński (2009), indicating an inverse relationship between water content and fat concentration in this meat. Thus, the higher the fat content, the lower the moisture, since water is more attracted to protein than to fat. The higher fat percentages found in the samples classified as degree 3 may be the result of muscle tissue regeneration in response to the development of lesions in the region. The muscle tissue has the ability to regenerate through the presence of satellite cells, characterized as stem cells that provide myoblasts for the growth, homeostasis and repair of muscle tissue (Scharner and Zammit, 2011). Vieira et al. (2006) studied anatomopathological aspects of DPM in broiler chickens and reported the presence of muscle lesions in both the *Pectoralis minor* and the *Pectoralis major* (though at a lower intensity) muscles, with presence of fibrovascular tissue and foci of regeneration in the area peripheral to the lesions. Because the third degree of the myopathy is the degree in which progressive tissue degeneration occurs, the degeneration of the *Pectoralis minor* muscle likely affected the *Pectoralis major*, resulting in tissue damage and onset of regeneration. During the process of regeneration of the injured tissue, the damaged fibers were probably replaced with adipose tissue, which may explain the increased fat content of the meat. In an anatomopathological study of DPM, Dinev and Kanakov (2011) reported adipose tissue deposition in substitution of injured fibers in the muscle tissue regeneration process.

The lack of changes in collagen concentration in the turkey breast meat is a positive factor in terms of meat quality, since collagen has low nutritional value due to high levels of nonessential amino acids (Watanabe-Kamiyama et al., 2010). High collagen concentrations cause the meat to toughen and lead to undesirable characteristics in the final quality of meat products which include it as a raw material.

Palmitic (C16:0), oleic (C18:1) and linoleic (C18:2) acids are the main fatty acids present in the fat of chicken meat (Chae et al., 2002), and, as observed here, they are also the predominating fatty acids in the fat of the breast meat from turkey breeder hens. In the present study, we observed that the samples classified as affected by the myopathy in degrees 2 and 3 showed higher concentrations of polyunsaturated fatty acids (34.65 and 34.38%, respectively) than the normal samples (30.99%). The n-3 and n-6 polyunsaturated fatty acids are essential and, as such, should be obtained from the diet, especially because of their important role in preventing heart disease (Wijendran and Hayes, 2004). Thus, the increase in the degree of severity of myopathy increases the lipid composition of the meat, which does not prevent its consumption, since despite increasing the lipid composition, the fat content of this meat has a higher concentration of PUFA, which does not harm human health.

From this study, can be concluded that the severe condition of deep pectoral myopathy which affects the *Pectoralis minor* muscle, causes variations in the quality of *Pectoralis major* muscle of turkey on disposal age. As a raw material, this type of meat has a higher fat content and greater capacity for retaining intracellular water, important attributes to the manufacture of processed products. In this way, the processing is an economically viable alternative to the commercialization of breast meat from birds affected by myopathy.

ACKNOWLEDGMENTS

The authors thank the Foundation for Research Support of São Paulo State (Fundação de Amparo à Pesquisa do Estado de São Paulo − FAPESP) by financial support provided to this research (Process FAPESP n° 2015/08471-8).

DISCLOSURES

The authors declare no conflicts of interest.

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