Research Note: Texture characteristics of wooden breast fillets deboned at different postmortem times

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ABSTRACT The study aimed to understand whether deboning time contributes to the altered texture attributes of wooden breast (**WB**) fillets. To this purpose, 30 unaffected (NORM) and 30 severely affected (WB) carcasses were selected at 15 min postmortem (**PM**) and allotted into treatments with different deboning times: A (5 NORM + 5 WB; right fillets deboned at 15 min PM), B (5 NORM + 5 WB; right fillets deboned at 3 h PM), and C (5 NORM + 5 WB; right fillets deboned at 6 h PM). Left fillets from each carcass were deboned at 24 h PM. Multiple instrumental texture analyses were performed on the cranial-middle portion of the *Pectoralis major* muscles. Irrespective of deboning time, all fillets were subjected to a single 30% compression in the raw state at 24 h PM. All fillets were cooked at 24 h PM and subjected to shear force assessments at 48 h PM using blunt Meullenet-Owens razor shear, Meullenet-Owens razor shear, and Warner-Bratzler shear force. Using an ANOVA mixed model, deboning time was evaluated as a fixed effect within muscle condition (sampling session and carcass ID as random effects). Compression force assessment of raw meat at 24 h PM showed that WB fillets exhibited the greatest hardness when they were deboned at 6 h PM (15 min = 35.4 N; 3 h = 30.9 N; 6 h = 48.0 N; 24 h = 30.6 N; $P < 0.05$). Differently, deboning time had no effect ($P > 0.05$) on raw compression force values in NORM fillets. In cooked NORM fillets, shear force values were the greatest in fillets deboned at 15 min, and shear force gradually declined with deboning time through 24 h PM. On the contrary, no changes ($P > 0.05$) in shear values due to different deboning times were observed in cooked WB meat regardless of shear method. These results suggest that early PM changes in breast muscles and their influence on meat texture are different between normal and WB fillets.

Key words: wooden breast, deboning time, instrumental texture attributes, BMORS, Warner-Bratzler shear force

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INTRODUCTION

“Wooden breast” (**WB**) is an emerging defect of chicken *Pectoralis major* muscle, which is characterized by remarkably hard consistency upon palpation (Sihvo et al., 2014), notable decrease of meat functionality, as well as impairment of the texture of cooked meat (Mudalal et al., 2015; Sanchez-Brambila et al., 2018). The stiffness of WB meat has been considered so far as the consequence of an intense fibrotic response to muscle tissue degeneration (Sihvo et al., 2014; Clark and Velleman, 2016). However, the reasons for muscle hardness development are still unclear, as some cases of WB without significant collagen accumulation have been documented (Sihvo et al., 2017a,b). To acquire further knowledge about the mechanisms leading to hard consistency, the evolution of WB hard texture has been recently investigated during a short-term refrigerated storage through the determination of compression force as well as the evolution of proteolytic indicators and sarcomere length. From these studies, it emerged that the hard texture characterizing WB progressively softens during storage, although the aging period *per se* did not solve the hardness issue of affected raw meat (Soglia et al., 2017; Sun et al., 2018). According to Soglia et al. (2018), a greater stiffness in WB cannot exclusively be explained by differing proteolytic processes taking place in the postmortem period, as only slight discrepancies were detected between the normal and WB fillets over a 7-D storage time. Interestingly, previous literature also pointed out that WB muscles possess longer sarcomere than their normal counterparts, despite also exhibiting stiffness and a contracted appearance (Tijare et al., 2016; Sun et al., 2018). This phenomenon indicates that the relationship between sarcomere shortening and hardness is dissimilar between normal and WB conditions. As extensively documented in the literature, during the conversion from muscle to meat, deboning time has a

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large impact on texture, as it influences the contractile state of the breast muscle. To date, the influence of deboning time on the development of the hard WB texture has never been reported. As a result, the aim of the present experiment was to investigate the texture response to different deboning times in WB meat. To this purpose, the texture characteristics of fillets deboned at different times PM were assessed through different instrumental methods.

MATERIALS AND METHODS

A total of 30 unaffected (NORM) and 30 severely affected (WB) broiler carcasses (from Ross male broilers, average live weight 4.1 kg) were sampled during 2 trials. For each trial, carcasses were selected from a commercial processing line immediately after evisceration. Selection criteria were based on the direct palpation of the cranial and caudal ends of *Pectoralis major* muscles. Butterfly fillets exhibiting a normal, soft consistency were classified as normal, while those displaying a diffuse hard consistency throughout the entire muscle together with other descriptors (outbulging shape, viscous fluid, hemorrhages) were considered severe WB (Sihvo et al., 2014; Tijare et al., 2016). Only carcasses having right and left fillets with uniform NORM or WB traits were chosen. Carcasses were identified and allotted into treatments with different deboning times: treatment A (5 NORM + 5 WB; right fillets deboned at 15 min PM), treatment B (5 NORM + 5 WB; right fillets deboned at 3 h PM), and treatment C (5 NORM + 5 WB; right fillets deboned at 6 h PM). Left fillets from each carcass were deboned at 24 h PM and considered as controls for their right counterparts. Both the deboned fillets (in sealed plastic bags) and the remainder of the carcasses were placed in chilling tanks with an ice-water slush. Breast muscle temperature was measured for each carcass using a thermocouple to ensure that proper chilling (4°C by 3 h postmortem) had occurred. After water chilling, samples were stored in plastic bags overnight at 4°C. Multiple instrumental texture analyses were performed on the skin-side surface of the cranial-middle portion of the *Pectoralis major* muscles using a texture analyzer (Model TA-XT-plus; Texture Technologies Corp., Hamilton, MA) equipped with Texture Exponent Version 4.0.13.0 software. Irrespective of the deboning time, all fillets were subjected to a single 30% compression in the raw state at 24 h PM (1 measurement × fillet) exerted perpendicular to fiber orientation using a 50-kg loading cell connected to an aluminium cylinder probe of 12-mm diameter (Zhuang and Bowker, 2018). Pretest and posttest speed were set at 3.00 mm/s, test speed was 1.00 mm/s, and trigger force was 20 g. Thereafter, all fillets were cooked in a Henny Penny MCS-6 Combi oven (Henny Penny Corp., Eaton, OH) set at 83.9°C until a core temperature of 76°C was reached (Zhuang and Savage, 2008). At 48 h PM, all cooked fillets were subjected to Meullenet-Owens razor shear (**MORS**), blunt Meullenet-Owens razor shear (**BMORS**), and Warner-Bratzler shear force analyses. First, MORS force was determined using the MORS blade (0.5-mm thick, 8.9-mm wide, and 30 mm in height). Then, BMORS test was carried out using the BMORS blade (0.5-mm thick × 8.9-mm wide). Samples were sheared perpendicularly to the muscle fibers with 3 shears × fillet × method and a distance of 2 cm between shears. The penetration depth was 20 mm for both methods (Cavitt et al., 2005; Lee et al., 2008). Thereafter, a strip of meat not previously punctured was removed (1.9 cm), and 2 Warner-Bratzler shear force measurements were taken at a test speed of 4 mm/s as described by Zhuang and Savage (2009). SAS (2004 version 9.3) statistical software package (SAS Institute, Cary, NC) was used to perform an ANOVA mixed model that evaluated muscle condition as a fixed effect with trial and carcass as random effects. An ANOVA mixed model was also used to evaluate deboning time as a fixed effect within muscle condition. Means were separated using Bonferroni adjustments with significance set at $P < 0.05$.

RESULTS AND DISCUSSION

Texture data were first analyzed according to the muscle condition effect (data not shown in the tables). In accordance with published literature (Chatterjee et al., 2016; Sun et al., 2018; Tasoniero et al., 2019), raw WB fillets were characterized by higher compression values than the normal ones (NORM = 20.2 N vs. WB = 36.9 N; $P < 0.0001$). As a result, the instrumental compression force measurements confirmed the hardness differences between normal and affected breasts empirically detected at the processing plant. For the cooked WB and NORM fillets, the different shearing methods exhibited diverse trends. Although BMORS values (NORM = 14.6 N vs. WB = 17.1 N; $P = 0.0173$) confirmed the compression test data, unaffected fillets exhibited greater shear values than WB fillets using both MORS (NORM = 12.4 N vs. WB = 11.3 N; $P = 0.0051$) and WBSF (NORM = 49.9 N vs. WB = 42.4 N; $P = 0.0254$).

To determine the effect of PM deboning time on WB texture, data were evaluated within muscle condition according to deboning time. The compression force values of raw NORM and WB fillets are displayed in Table 1. While deboning time had no effect ($P > 0.05$) on raw compression force values in NORM samples, it significantly influenced the compression force test when evaluated within WB condition. Interestingly, the highest force required to compress WB fillets was observed in samples deboned at 6 h PM (15 min = 35.35 N; 3 h = 30.94 N; 6 h = 48.03 N; 24 h = 30.56 N; $P < 0.05$). The values of BMORS, MORS, and Warner-Bratzler shear force assessed on cooked NORM and WB fillets are displayed in Table 2. In NORM fillets sheared with BMORS and WBSF, those deboned at 15 min PM possessed the highest shear values followed by a gradual reduction of the shear force through the 24-h PM deboning (15 min = 16.37 N; 3 h = 15.65 N; 6 h = 12.76 N;

Table 1. Compression force measured at 24 h PM on raw unaffected (NORM) and wooden breast (WB) affected *Pectoralis major* muscle, evaluated within muscle condition according to the deboning time effect.

	Compression force (N)	
Deboning time	NORM	WB
15 min	18.53	$35.35^{a,b}$
3 h	20.48	30.94^{b}
6 h	21.06	48.03^{a}
24 h	19.04	30.56^{b}
SEM	1.56	3.50
P-value	NS	<0.05

Means within the same column followed by different lowercase superscript letters differ $P < 0.05$.

24 h = 12.80 N, $P < 0.05$ for BMORS and 15 min = 65.88 N; 3 h = 55.14 N; 6 h = 44.11 N; 24 h = 37.71 N, $P < 0.05$ for Warner-Bratzler shear). On the contrary, the MORS test did not detect any texture changes due to deboning time in NORM breast meat. Overall, the effect of deboning time on cooked meat shear values was different between NORM and WB fillets. Unlike NORM fillets, no changes ($P > 0.05$) in shear values due to different deboning times were observed in cooked WB meat regardless of shear method.

In this study, the effects of deboning time on shear force in NORM fillets were consistent with previous data. Cavitt et al. (2004, 2005) found that breasts deboned at 0.25 h and 1.25 h PM possessed the highest shear force values (in correspondence with the shortest sarcomere length) compared with fillets deboned later PM. Deboning breast muscles before the development of rigor mortis causes the muscle to contract and shorten, as adenosine triphosphate is still present at the time of cutting. In addition, the breast muscle is no longer limited by skeletal restraints, thus the extent of contraction and the degree of shortening are typically greater in early deboned fillets. Another interesting aspect is represented by the discrepancies among the 3 shearing methods. A possible explanation to this phenomenon could be that different forces are applied to the samples under the diverse shearing techniques. To this respect, García-Segovia et al. (2014) documented that the Warner-Bratzler shear force method exerts compression, tensile, and shear forces. The BMORS method is based on a blunt blade forcing its way into the meat sample while the MORS method uses a sharp blade (Lee et al., 2008). Thus, it is likely that BMORS values represent both compression and shear forces, while MORS values represent primarily shear forces. Consequently, fillets probably experienced diverse deformation and behavior under the 3 tests, which reflected slightly different physical characteristics within the meat or a different sensitivity toward muscle shortening or connective tissue. As for WB fillets, the data obtained in this study suggested that the timing of early postmortem changes could be different in WB fillets compared with normal fillets. Previous metabolic studies conducted on WB meat indicated an impaired energetic status for affected muscles, characterized by reduced glycogen content and altered utilization of the glycolysis intermediates (Abasht et al., 2016; Zambonelli et al., 2016) causing improper meat acidification. In light of these metabolic findings, it appeared reasonable to hypothesize that adenosine triphosphate depletion and thus the formation of stable bridges between thin and thick filaments occurred earlier in WB fillets than in the normal ones. The observation of an unexpected hardness peak in WB fillets with 6-h PM deboning pointed out the necessity to investigate the evolution of energy metabolism in WB during the conversion from muscle to meat, to determine the timing of rigor mortis onset. From the first set of surveys on WB meat until more recent studies, a hypothesis to explain WB stiffness and contracted appearance was the increased deposition of collagen and proteoglycans around the muscle fibers and within the interstitial spaces (Sihvo et al., 2014; Clark and Velleman, 2016), which provides inherent strength and prevent myofibrils from shortening (Tijare et al., 2016; Soglia et al., 2017). However, some cases of hard breasts without a significant accumulation of collagen were also documented (Sihvo et al., 2017a,b; Dalle Zotte et al., 2017). Another key issue to consider is the contribution of sarcomere shortening to WB texture. From the previous studies of Tijare et al. (2016) and Sun et al. (2018), it can be presumed that the relationship between sarcomere shortening and instrumental hardness measurements is different between normal and WB fillets in the raw state. Indeed, the degree of overlapping of the contractile filaments is an important contribution to meat toughness in normal fillets, while raw WB fillets were found to exhibit both higher

Table 2. BMORS, MORS, and Warner-Bratzler shear values measured in cooked unaffected (NORM) and WB affected *Pectoralis major* muscle, evaluated within muscle condition according to the deboning time effect.

	NORM			WB		
Deboning time	BMORS force (N)	Warner-Bratzler shear force (N)	MORS (N)	BMORS force (N)	Warner-Bratzler shear force (N)	MORS (N)
15 min	16.37^{a}	65.88^{a}	12.77	17.51	40.24	10.96
3 h	$15.65^{a,b}$	$55.14^{a,b}$	12.78	17.61	43.19	11.92
6 h	12.76^{b}	$44.11^{b,c}$	12.44	16.31	48.03	11.59
24 h	12.80^{b}	37.71^{c}	11.89	17.37	44.15	11.33
SEM	0.84	2.90	0.48	1.15	4.91	0.70
P-value	<0.05	<0.05	NS	NS	NS	NS

Means within the same column followed by different lowercase superscript letters differ $P < 0.05$.
Abbreviations: BMORS, blunt Meullenet-Owens razor shear; WB, wooden breast.

compression force and longer sarcomere than normal fillets. Therefore, a good understanding of what is physically causing the abnormally hard texture in WB fillets is currently lacking. Data from this experiment suggest that the processes taking place during the conversion from muscle to meat and their influence on texture characteristics might differ between normal and WB breast muscles. To date, however, the time of rigor mortis onset and the contribution of the associated shortening to the altered texture attributes characterizing WB remain to be understood. Future investigations of early postmortem energy metabolism and muscle structural changes in combination with texture assessments will provide a more complete picture of how early postmortem changes in the muscle influence raw and cooked WB meat texture characteristics.

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