WOODY BREAST CONDITION IN BROILER BREAST MEAT

Brian Bowker* and Hong Zhuang
USDA-ARS, U.S. National Poultry Research Center
950 College Station Road, Athens, GA 30605
Phone: (706)546-3610; Email: brian.bowker@ars.usda.gov

Introduction

To meet the high demands for boneless breast meat, the broiler industry has effectively utilized genetic selection and improvements in nutrition to achieve substantial gains in average bird size, growth rate, feed efficiency, and carcass yield. In response to markets shifting to consumers buying cut-up parts rather than whole bird carcasses and an increase in further processed meat products, an increasing proportion of broilers are being raised to heavier weights. Unfortunately, with the increases in bird growth rate and breast meat yield there has also been an increase in the incidence of breast myopathies, such as the woody breast (WB) condition in the *Pectoralis major* muscle. Breast fillets with the WB condition exhibit abnormal hardness and rigidity upon palpation and a ridge-like bulge on the tail end of the fillet[1]. Frequently, breast fillets with the WB condition also exhibit white striping (WS)[2], a related breast myopathy characterized by visible white striations running parallel to muscle fibers mainly on the skin-side surface of the breast meat (Figure 1). Although industry-wide incidence rates are difficult to assess, it has been estimated that approximately 5-10% of commercially produced breast fillets exhibit severe WB with even greater rates of moderate WB[3]. Even at low incidence rates, the costs to the industry can be substantial as breast fillets with the WB condition are often downgraded and sold at a discount, used for further processing, or in extreme cases discarded. This paper briefly reviews what is currently known about the effects of the WB myopathy on the muscle tissue, meat quality, and its associated factors and potential causes.

Effects on muscle tissue

The WB condition is a growth related myopathy that causes significant histological lesions to appear in the *Pectoralis major* muscle. Fillets with the WB condition show evidence of increased muscle fiber degeneration and regeneration, necrosis, fiber size variability, lipid infiltration, increased fibrosis, and inflammatory cell invasion[1,4-7]. The histological characteristics of the WB and WS conditions are very similar. Although recent reports show that nearly all breast muscles from heavy broilers exhibit some histological lesions[8], the proportion of affected fibers is much greater in WB fillets. The changes that occur at the muscle tissue level result in WB fillets having increased levels of fat and connective tissue, slightly increased moisture levels, and decreased muscle protein content[5]. Such changes in the composition of the WB fillets are thought to decrease the nutritional quality of the meat, similar to what has been observed in breast fillets with WS[9]. Fillets with the WB condition also exhibit altered mineral profiles with increased levels of intracellular sodium and calcium[5,10].

Effects on meat quality and processing

The compositional changes in WB fillets have an overall negative effect on meat quality attributes. From a visual perspective, the white striations on the ventral surface of skinless WB fillets can give the consumer the perception that the product is high in fat and less healthy, which negatively impacts purchasing decisions[2]. Although the fresh meat color of the dorsal surface (bone-side) of fillets seems to be unaffected, the skin-side surface of WB fillets often display a pale lean color, viscous fluid, and petechial hemorrhagic lesions[1]. For severe WB fillets notable discolorations have also been observed on the skin-side surface after cooking.

The WB condition is known to impair water-holding capacity in the breast meat. Fresh WB fillets exhibit more drip loss during refrigerated storage and greater cook loss[11]. Furthermore, when marinated as whole muscles or portioned cuts, WB meat has reduced marinade uptake and retention (Table 1). Moisture enhanced WB meat also has a lower cook yield than breast meat without the WB condition (Table 2). Because WB fillets typically have higher meat pH values than normal fillets[12], the reduced water-holding capacity of WB meat is thought to be related to the reduced muscle protein content of the tissue. Additionally, nuclear magnetic resonance data suggest that the WB condition increases the proportion and mobility of the extra-myofibrillar water fraction within the muscle, which decreases the ability of the muscle to retain inherent water[13].

Instrumental measurements of various texture attributes in both the raw and cooked meat are generally consistent with the tactile hardness and rigidity observed in raw WB fillets. Raw compression force increases with the severity of the WB condition in all portions of the breast meat (Figure 2). Likewise, in both raw and cooked breast meat, razor shear force is greater in fillets with moderate and severe WB than normal fillets at 1 day postmortem[12]. Consumer and descriptive sensory panel evaluations have demonstrated altered texture attributes and observed "rubbery" characteristics in WB fillets.

Various breast fillet storage and further-processing techniques can be used to minimize the negative effects of WB on meat texture attributes. Similar to normal fillets, the hardness (raw compression force) of WB fillets decreases with storage from day 0 to day 4 postmortem[14]. Instrumental shear force[12] and sensory tenderness differences between WB and normal fillets have been found to lessen but still persist through freezing and thawing. Similarly, marination decreases toughness in WB fillets but does not completely eliminate tenderness differences between normal and WB fillets (Table 2). The altered texture attributes of WB fillets are likely due to their high connective tissue content and damaged muscle fiber structure rather than increased muscle fiber shortening during rigor development as evidenced by the fact that shorter sarcomere lengths have not been observed in WB fillets[15]. Although objectionable texture characteristics of WB fillets can be overcome by grinding the breast meat, the compositional changes in the tissue can result in impaired functionality in further-processed products.

Associated factors and causes

Although many factors associated with the occurrence of the WB condition have been reported, the specific etiology of this breast myopathy is unknown. Factors influencing the growth, muscularity, and size of the birds such as slaughter age, gender, genetics, and feeding have all been associated with the incidence and severity of the WB condition[4,15,16]. The WB condition occurs most frequently in fast-growing, high breast yielding strains of broilers. The incidence of WB also seems to be higher in broilers that are male, on high nutrient diets, or slaughtered at older ages and heavier weights. Although the WB myopathy can result in histopathological and compositional characteristics within the muscle similar to other myopathies, such as hereditary muscular dystrophy, nutritional myopathies, and deep pectoral myopathy, the available research does not indicate a direct connection[17].

Several recent studies have compared the muscle gene expression, proteome, and metabolite profiles of normal and WB fillets as an initial step to delineate the underlying causes of the WB myopathy and to develop biomarkers for the condition. These genomic, proteomic, and metabolomics studies observed differences related to muscle hypoxia, oxidative stress, intracellular calcium levels, protein degradation, cellular repair, fibrosis, and glucose utilization in myopathic fillets[18-21]. Although the results of these studies are consistent with the histological and biochemical characteristics of WB muscle, they do not clearly identify the trigger that initiates the onset of the WB myopathy. Combined histological and gene expression data indicate that the WB myopathy is not uniform throughout the entire *Pectoralis major* muscle[6] and even suggest that the etiology of the myopathy may vary between fast-growing commercial broiler lines[7]. These data indicate that the WB condition seems to have a multi-faceted and complex etiology. It has been shown that the muscle fiber degeneration associated with the WB and WS myopathies can be observed as early as 14 days of age and that it increases dramatically with age[22]. Thus, future research using "omics" techniques at different time points during broiler growth may help to uncover the causes of the WB myopathy and identify biomarkers.

Conclusions

The WB myopathy in broiler breast fillets significantly alters the composition and histological characteristics of the muscle tissue which results in poor meat quality attributes in fresh products and reduced functionality properties for further-processed products. Due to its close link to economically important live production and carcass yield traits, the WB myopathy poses a substantial challenge to the poultry industry. To date much of the research on this condition has focused on characterizing the changes that occur at the muscle tissue level and their implications on meat quality, composition, and processing functionality. To help manage this problem in the short-term, rapid non-invasive techniques are needed to objectively identify the presence and severity of the WB myopathy for online monitoring and product sorting. However, in the long-term, fundamental research to understand the underlying causes of the WB myopathy and the development of biomarkers for the condition will likely be the key to developing genetic, nutritional, and management strategies for reducing the incidence of WB.

References

1. Sihvo, H., Immonen, K., and Puolanne, E. 2014. *Vet. Path.* 51:619-623.
2. Kuttappan, V., Lee, Y., Erf, G., Meullenet, J., McKee, S., and Owens, C. 2012. *Poult. Sci.* 91:1240-1247.
3. Gee, K. 2016. *Wall Street Journal.* Mar 29. CCLXVII:B1.
4. Trocino, A., Piccirillo, A., Birolo, M., Radaelli, G., Bertotto, D., Filiou, E., Petracci, M., and Xiccato, G. 2015. *Poult. Sci.* 94:2996-3004.
5. Soglia, F., Mudalal, S., Babini, E., Di Nunzio, M., Mazzoni, M., Sirri, F., Cavani, C., and Petracci, M. 2016. *Poult. Sci.* 95:651-659.
6. Clark, D., and Velleman, S. 2016. *Poult. Sci.* 95:2930-2943.
7. Velleman, S., and Clark, D. 2015. *Avian Dis.* 59:410-418.
8. Mazzoni, M., Petracci, M., Meluzzi, A., Cavani, C., Clavenzani, P., and Sirri, F. 2015. *Poult. Sci.* 94:123-130.
9. Petracci, M., Mudalal, S., Babini, E., and Cavani, C. 2014. *Ital. J. Anim. Sci.* 13:179-183.
10. Tasoniero, G., Cullere, M., Cecchinato, M., Puolanne, E., and Dalle Zotte, A. 2016. *Poult. Sci.* 95:2707-2714.
11. Mudalal, S., Lorenzi, M., Soglia, F., Cavani, C., and Petracci, M. 2015. *Animal* 9:728-734.
12. Chatterjee, D., Zhuang, H., Bowker B., Rincon, A., and Sanchez-Brambila, G. 2016. *Poult. Sci.* 95:2449-2454.
13. Soglia, F., Laghi, L., Canonico, L., Cavani, C., and Petracci, M. 2016. *Food Res. Int.* 89:1071-1076.
14. Sun, X., Yang, F., Tijare, V., Solo, J., Li, Y., and Owens, C. 2015. Poultry Science Association Annual Meeting, *Poult. Sci.* 94(E-Suppl. 1), pg. 92. Abstract 270.
15. Tijare, V., Yang, F., Kuttappan, V., Alvarado, C., Coon, C., and Owens, C. 2016. *Poult. Sci.* 95:2167-2173.
16. Cruz, R., Vieira, S., Kindlein, L., Kipper, M., Cemin, H., and Rauber, S. 2017. *Poult. Sci.* 96:501-510.
17. Kuttappan, V., Hargis, B., and Owens, C. 2016. *Poult. Sci.* 95:2724-2733.
18. Mutryn, M., Brannick, E., Fu, W., Lee, W., and Abasht, B. 2015. *BMC Gen.* 16:399.
19. Abasht, B., Mutryn, M., Michalek, R., and Lee, W. 2016. *PLoS ONE* 11(4): e0153750.doi:10.1371
20. Kuttappan, V., Ramnathan, R., Escobar, J., Hartson, S., Owens, C., Coon, C., Kong, B., Vazquez-Anon, M., Bottje, W., and Hargis, B. 2016. International Poultry Scientific Forum, *Poult. Sci.* 95(E-Suppl. 1), pg. 200. Abstract M18.
21. Zambonelli, P., Zappaterra, M., Soglia, F., Petracci., M., Sirri, F., Cavani, C., and Davoli, R. 2016. *Poult. Sci.* 95:2771-2785.
22. Radaelli, G., Piccirillo, A., Birolo, M., Bertotto, D., Gratta, F., Ballarin, C., Vascellari, M., Xiccato, G., and Trocino, A. 2017. *Poult. Sci.* 96:309-319.
23. Bowker, B., and Zhuang, H. 2017. Manuscripts in preparation.

Figure 1. Percentage of breast fillets that are categorized as normal, moderate, and severe white striping (WS) within each woody breast (WB) category (Normal-WB n=1051; Moderate-WB n=893; Severe-WB n=484).[23]

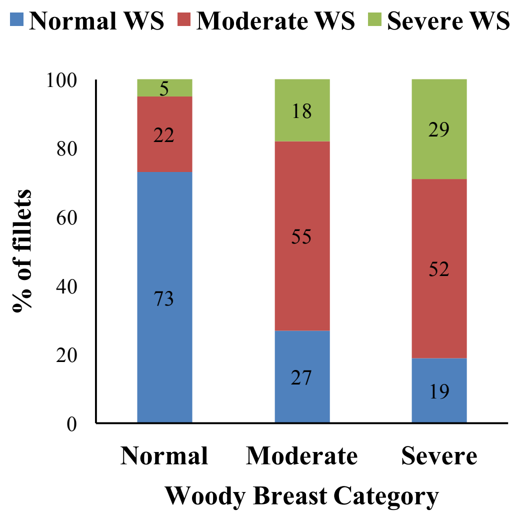

Figure 2. Compression force (g) on the cranial, middle, and caudal portions of raw breast fillets based on the severity of woody breast condition (1 = normal, 2 = moderate, 3 = severe). Each data point represents the mean of 49-76 fillets.[23]

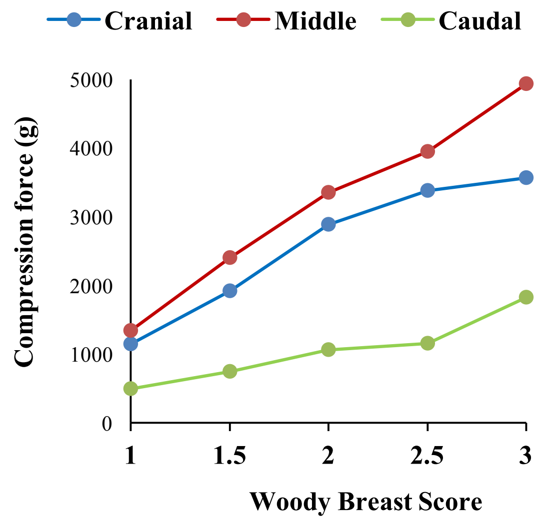

Table 1. Marinade uptake and retention in normal and severe WB meat vacuum-tumble marinated as whole muscle breast fillets or portioned breast cuts.[23]

Trait	Whole Fillets		Ventral Portion of Fillets (skin-side)		Dorsal Portion of Fillets (bone-side)	
	Normal	Severe WB	Normal	Severe WB	Normal	Severe WB
Marinade Uptake %	9.0^{a}	6.2^{b}	7.7^{a}	4.2^{b}	18.7^{a}	11.7^{b}
Marinade retention %	74.8^{a}	61.4^{b}	73.8^{a}	43.1^{b}	80.1^{a}	72.9^{b}

^{ab} Means within each type of sample (whole fillet, ventral portion, dorsal portion) with no common superscripts are significantly different (P < 0.05).

Table 2. Shear force and cook yield of non-marinated and marinated breast fillets that are categorized as normal and severe WB meat.[23]

Trait	Non-Marinated Fillets		Marinated Fillets	
	Normal	Severe WB	Normal	Severe WB
Warner-Bratzler Shear Force (kg)	4.0^{b}	4.7^{a}	3.3^{c}	3.6^{bc}
Cook Yield %	77.9^{b}	68.1^{c}	84.7^{a}	78.9^{b}

^{abc} Means within a row with no common superscripts are significantly different (P < 0.05).