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Effects of extended deboning time on the breast meat quality of fast-growing big broilers

Abstract

Fast-growing big broilers breast muscle often exhibits wooden breast and white striping myopathies causing meat quality issues such as high cook loss, tough texture, and lower marinade retention. Toughness of the meat and subsequent meat quality issues can also be due to unresolved rigor mortis and slow rate of post-mortem proteolysis. The objective of this study was to investigate the effects of extended deboning times and storage on the quality of broiler breast meat. Broiler breast fillets (total n=810) obtained from a local poultry processor included freshly deboned (2-3h post slaughter) wooden and normal breast butterfly fillets from broilers>8 lbs, breast fillets from medium sized birds (6-8lbs) as well as fillets deboned at extended post-slaughter times (16, 20 and 24h). Carcasses deboned at extended times (n=90/treatment) were stored at 4˚C. The left-side of the butterfly breast fillet was analyzed for color and cook loss immediately after deboning. Texture of cooked fillets was measured using the Blunt Meullenet-Owens Razor Shear (B-MORS) method. Statistical differences between the freshly deboned, extended deboned and stored fillets were determined using ANOVA with Tukey's HSD at $P<0.05$. Data indicated that the wooden breast fillets had a higher cook loss than normal fillets and the ones from medium sized broilers. Texture (peak force and shear energy) of the fillets from all the extended debone times was lower compared to the freshly deboned (2-3h post-slaughter) breast fillets indicating an increase in tenderness due to proteolysis. Results from the study can be used by the poultry companies to reduce the breast meat texture issues from fast-growing big broilers.

Keywords: deboning times, meat quality, broilers, texture, cook loss

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Introduction

The demand for poultry in the US has increased from 34.2lbs. per capita in 1960 to approximately 91lbs. per capita in 2016.[1] The increase in demand for poultry meat, especially white breast meat, is due to its perceived health status, reasonable price in the marketplace, and adaptability to multiple types of cooking methods for modern families.[2] The increased demand for breast meat in the US marketplace has led the poultry industry to develop high breast meat yielding broiler strains with a shorter growout period.[3] Currently, breast meat yield comprises approximately 20% of the total weight of the bird.[3] The genetic improvements achieved in recent decades have brought about a shorter growing period by approximately 50% to obtain a market weight bird of about eight pounds in eight weeks, as compared to previous genetic strains.[4] Selection of strains for a faster growth rate and breast size has shown to increase the muscle fiber length and diameter (hypertrophy) but does not affect muscle fiber type present or number of muscle fibers (hyperplasia).[5] Increasing fiber size associated with a scarce amount of capillarization could potentially cause an insufficient supply of nutrients and oxygen to the muscle cells.[6] The poultry industry has seen an emergence of wooden breast (WB) myopathy in fast-growing high-breast meat yielding broiler strains.[7,8] Breast muscle affected with WB exhibits abnormal development of muscle fibers and extraneous amounts of collagen in the muscle, rendering the meat tough and chewy.[8] WB affects breast meat quality attributes especially decreased water-holding capacity (WHC), and increased toughness of cooked meat.[9]

In addition to WB, tough texture of breast meat can also be attributed to incomplete resolution of rigor prior to deboning.[10,11] Current industry deboning times are approximately 2-4hours, based on live broiler weights of 4-6lbs, which may not be suitable for the modern fast-growing high-breast meat yielding varieties weighing>8 lbs live weight. For birds of a 4-6lb live weight, a 4-6h time frame has been established as the adequate debone period for proteolytic enzymes to break down muscle structure components, thus alleviating meat toughness and producing an adequately tender breast fillet.[12,13] The major proteolytic enzymes responsible for post-mortem (PM) meat tenderization are calcium activated cysteine proteases, μ and m-calpains, and their specific inhibitor, calpastatin,[14] which target troponin-I, troponin-T, desmin, nebulin, titin, Z-line, M-line, and intermediate filaments.[15]

In beef, rigor development takes approximately 24h PM[16] and 4-6h PM for a 4-6lb broiler.[17] However, broilers with faster growth rates have a greater glycolytic fiber content and larger fiber diameters causing faster rigor development.[18] The rigor resolution in the fast-growing broilers is slower due to more time required for the depletion of glycogen stores.[18,19] Therefore, proteolysis will not begin as quickly in broiler strains with a higher growth rate.[18] Further the proteolysis in fast growing broilers is inhibited due to the presence of excess amounts of calpastatin, an inhibitor of the proteolytic enzyme, calpain.[18] Hence, it can be concluded that slow rate of proteolysis will increase the time for rigor resolution and ultimately the deboning time will be impacted. The existing practice of deboning within 2-3h post-slaughter might lead to incomplete resolution of rigor resulting in tough textured meat with shear values above 220.72N.mm, according to Xiong et al,[20] when using the Meullenet-Owens Razor Shear (MORS) method.

Providing ample amount of time for the proteolytic enzymes to resolve rigor in the fast-growing big broilers can be a potential

solution to improve tenderness of breast meat from those broilers. The process called, aging, has been used in the beef industry wherein beef carcasses are allowed to undergo complete rigor to obtain tender meat.[21] Aging the meat on carcass physically restrains the muscle, avoiding sarcomere shortening during rigor.[22,23] Moreover, restraining the muscle causes less overlapping of myofibril thick and thin filaments and a weaker muscle structure, producing a more tender product.[24] Additionally, another commercial tenderization process known as Electrical Stimulation (ES) sends low or high electric pulses throughout the carcass immediately after slaughter, induces muscle contraction, and speeds up rigor development.[25] ES accelerates ATP depletion in the muscle, quickens the muscle pH decline, and uses physical disruption of the muscle fibers to increase tenderness.[25] Companies often combine ES with aging to meet their specific plant and consumer needs.[26]

Aging is common to the beef industry but not to the poultry processors mainly because the post-slaughter time of 2-3h was traditionally sufficient to obtain tender meat from 4-6lbs broilers. With modern broilers weighing 8-10lbs, it might be beneficial for the poultry industry to consider the effects of aging broiler carcasses on breast meat quality, especially texture. We hypothesize that tough texture of breast meat from fast-growing high-meat yielding broilers is due to presence of WB myopathy compounded with incomplete rigor mortis prior to deboning. There is a need to research methods to alleviate the tough breast meat texture to improve meat quality and help the poultry industry to satisfy consumer demands.

Materials and methods

Broiler breast meat treatments

Breast fillets (n=30/trial in 3trials) from medium-sized broilers (6-7lbs live wt) (Normal Medium) and big broilers (8-9lbs live wt) (Normal Jumbo and Wooden Jumbo) deboned at 2h post-mortem were obtained from local commercial processors. All the breast fillets were hand-palpated for detecting woody breast severity at the deboning location (Normal=absence of woody/tough texture and Wooden=tough texture throughout the fillet). Normal fillets were relatable to a score of 0 (Normal) represented breast fillets that were flexible throughout and 1 (Mild) represented breast fillets that were hard mainly in the cranial region.[27] Wooden fillets were relatable to a score of 2 (Moderate) represented breast fillets that were hard throughout but flexible in the caudal region, and 3 (Severe) represents breast fillets that were extremely hard and rigid from the cranial region to caudal tip.[27] Further, commercially slaughtered, big broiler carcasses (n=90/trial) were stored on ice at 4°C and randomly selected carcasses were deboned at 16, 20 and 24h post-mortem. Breast fillets collected at each debone time (n=30/trial) were labeled as treatments 16h, 20h and 24h. All the broilers used in this study belonged to the same broiler strain and were delivered to the lab on the same day.

Color

Immediately after arrival to the lab, the initial weight of each left breast fillet was taken and color (CIE system values L*, a*, and b*) was analyzed on the dorsal side. One color measurement was taken on the cranial portion of each breast fillet using a Minolta colorimeter (model DP-301, Minolta Corp., Ramsey, NJ). All samples were evaluated after calibration with a white reference tile (Y=92.3, x=0.3138, y=0.3198). Each breast fillet was measured immediately after its respective debone time.

Cook loss

Breast fillets from each treatment were analyzed for cook loss immediately following debone. Cook loss values were stated as a percentage weight loss with respect to initial weight. A convection oven (Vulcan, HEC5D, Troy, Ohio 45374 U.S.A.) was preheated to 177°C before cooking the breast samples. Individual breast fillets were placed on raised wire racks inside stainless steel table pans (Vollrath, 20049, 20-7/8" x 12-13/16" x 4") and the pans were covered with aluminum foil (Daily Chef Heavy Duty Food Service, 51808BC). The fillets were cooked to an internal temperature of 74°C, measured in the cranial portion of the sample continuously using a stainless steel digital thermometer.[28] After cooking, the breast fillets were cooled to room temperature (22±2°C) in the covered pans and re-weighed. Cook loss was calculated using the formula given below:

$$Cook\ loss\ (\%) = \frac{(Pre-cook\ fillet\ wt.\ -\ Post-cook\ fillet\ wt.)x100}{Pre-cook\ fillet\ wt.}$$

Cooked fillets were stored in re sealable bags overnight in walk-in cooler maintained at 4°C for further analysis.

Texture

The following day, all cooked fillets were taken out of refrigeration and placed in a single layer on a flat surface to temper up to room temperature (20°C). Texture (TA. XT plus Texture Analyzer, Texture Technologies, Scarsdale, NY) of cooked fillets was measured using the Blunt Meullenet-Owens Razor Shear (BMORS) method on a platform in a 50-kg load cell using a blunt razor blade (carbon steel, 1.5" x 0.25" x 0.021") calibrated to a penetration depth of 20mm. Texture analyzer was calibrated for force (2kg) and height (55mm). Crosshead speed and contact force were calibrated at 20mm/sec and 1-g, respectively. Five measurements were taken perpendicular to the muscle fibers in the cranial portion of each breast fillet as discussed by Lee et al,[29] BMORS force (N) (maximum force recorded from beginning to end of test), BMORS energy (N.mm) (area under the force curve from beginning to end of test), and BMORS peak count (number of peaks on shear curve from beginning to end of test) were found and utilized as instrumental measurements of meat tenderness.

Statistical analysis

Statistical differences between treatments were determined by SAS (SAS version 9.1 SAS Institute Ino., Cary, NC) for the parameters analyzed using one-way ANOVA with Tukey's HSD at $P \leq 0.05$ to separate means. Deboning time was determined as the main effect to evaluate the influence of deboning time on meat characteristics (color, texture, cook loss). There were no significant ($p \leq 0.05$) effects due to experiment replication.

Results and discussion

Color

Meat color is important criteria for consumer acceptability and retail sales.[10] Consumers expect breast fillets to be a pink color when raw, otherwise, they are considered unsatisfactory.[30] Variation in broiler breast fillet color, commonly affected by processing method (Froning, 1995; Petracci and Fletcher, 2002), may cause consumers to believe the meat is defective (Kerth, 2013). Thus, it is important to examine the effect of extended debone times on breast fillet color.

L*, lightness, values range from 0 (black) to 100 (white).[30,31] Data indicated that L* values (lightness) increased significantly ($p \leq 0.05$) in fillets deboned at 16, 20, and 24h compared to Normal Medium breast fillets deboned 2-3h post-mortem (Table 1). No significant ($p \leq 0.05$) differences in lightness value were found in Wooden Jumbo or Normal jumbo fillets when compared to fillets deboned at 16, 20, and 24h. These findings are similar to Petracci and Fletcher,[32] who observed an increase in the L* values until 6h post slaughter due to rigor affecting color development. The increasing lightness values are most likely due to rapid pH decline during rigor and muscle structure.[19,33] Lightness values in Wooden Jumbo fillets were significantly ($p \leq 0.05$) greater than Normal Jumbo fillets and Normal Medium fillets. WB is frequently compounded with white striping, a breast myopathy involving white stripes on the breast fillet surface,[34] potentially contributing to the lighter color in WB fillets. The current study did not assess the fillets for presence or absence of white striping.

Redness (a*) values for Wooden Jumbo fillets were significantly higher ($p \leq 0.05$) when compared to all other treatments. Petracci et al,[35] reported that color variation among normal broiler breast meat showed decreasing a* values as lightness values increased. Researchers studying WB in broiler chickens found greater redness values in WB fillets when compared to normal breast fillets or less severe WB fillets.[34,36] Increasing redness in WB fillets is most likely due to hemorrhaging or tissue damage because of oxidative stress in fast-growing broilers.[37] There is potential for increasing redness values associated with WB fillets due to muscle degeneration causing a switch from fast to slow twitch muscle fibers, according to data from Mutryn et al,[38] when looking at RNA-sequencing.

B*(yellowness) values were variable among treatments, with Wooden Jumbo fillets being the most yellow and significantly ($p \leq 0.05$) different from all treatments. No significant ($p \leq 0.05$) differences were found between extended debone b* values. Previous studies show that WB fillets are more yellow when compared to normal fillets.[37,39,40] Increased yellowness is most likely due to the excess formation of connective tissue in the WB muscle in response to muscle degeneration, known as fibrosis.[39]

Cook loss

Cook losses were measured to assess the water-binding properties of breast fillets under different treatments (Table 1). Wooden Jumbo fillets had a significantly higher ($p \leq 0.05$) cook loss compared to Normal Jumbo and Normal Medium fillets (Table 1). Normal Medium and Normal Jumbo fillet values were not significantly different ($p \geq 0.05$) to each other and had the least amount of cook loss at 31.26±5.97 and 29.54±5.44, respectively. Findings from the current research are consistent with Trocino et al,[34] and Mudalal et al,[41] who found that WB fillets had significantly higher cooking losses ($p \leq 0.05$) when compared to normal breast fillets.

WB myopathy in poultry increases the collagen content of the *Pectoralis major* (breast muscle) as well as causes degeneration[8] and replacement of myofibrillar proteins that bind water in muscle.[4,9] These alterations in the WB muscle lead to decreased water holding capacity which is exhibited in increased cook losses and reduced marinade pick up of the meat.[41,42]

Cook loss for fillets deboned at extended times (16, 20, and 24h) were significantly higher ($p \leq 0.05$) when compared to the Normal Jumbo treatment (Table 1) potentially due to longer duration of proteolysis leading to increased loss of the myofibrilar proteins to hold water. Moreover, the fillets deboned at 16, 20 and 24h were not categorized as per woody breast severities and possibly contained some fillets with woody breast characteristics thus increasing the cook loss of the treatment population compared to the specifically categorized Normal Jumbo fillets.

Table 1 Effect of extended debone times on color and cook loss of breast meat under various treatments (n=90/trt)

Treatment	L*	a*	b*	Cook Loss (%)
Debone 2-3h PM				
Wooden Jumbo	63.78±3.64^{a}	2.08±1.39^{a}	8.04±2.46^{a}	34.30±8.28^{a}
Normal Jumbo	62.36±4.11^{bc}	0.32±0.80^{c}	5.04±2.22^{c}	29.54±5.44^{c}
Normal Medium	61.08±3.19^{c}	1.09±0.95^{b}	4.91±2.03^{c}	31.26±5.97^{bc}
16h Debone*	63.37±2.67^{ab}	1.36±1.00^{b}	6.26±2.19^{b}	32.47±4.19^{ab}
20h Debone*	63.21±2.89^{ab}	1.55±1.24^{b}	6.32±2.02^{b}	33.25±4.68^{ab}
24h Debone*	63.43±2.92^{ab}	1.55±0.91^{b}	6.61±1.99^{b}	32.53±4.49^{ab}

a–c values within a row lacking a common superscript differ ($p \leq 0.05$)
*fillets deboned at extended times 16, 20, 24h.

Texture

The texture attributes, shear energy, peak force, and peak count of cooked fillets from each treatment, were analyzed using Blunt-Meullenet Owens Razor Shear method (BMORS) (Table 2). BMORS, a modification of the original Meullenet-Owens Razor Shear (MORS) method, utilizes a blunt blade to distinguish toughness between cooked breast fillets[29] and has been used in breast texture studies.[29,43,44]

Extended debone times of 16, 20 and 24h significantly ($p \leq 0.05$) reduced the peak force and shear energy compared to the other treatments which were deboned 2-3h PM (Table 2) indicating increased tenderness. 16, 20 and 24h debone treatments reduced peak counts of breast fillets significantly ($p \leq 0.05$) when compared to the Wooden Jumbo treatment only. Extended deboning times allowed for complete rigor resolution and sufficient time for proteolytic enzymes to tenderize meat.[45,46] As stated previously, the tenderness effect

was probably enhanced as aging the meat on the carcass physically restrained the muscle and prevented the sarcomere from shortening during rigor.[13,22,23,24] In addition, improved tenderness might be due to increase in sarcomere length which has been shown to increase with post-mortem debone times.[45]

One major factor that influenced texture of breast meat in the current study is aging of the meat. Aging meat during PM storage is a common practice that has been used in the beef industry for years to improve product tenderness by the breakdown of key proteins [21]. Key proteins in the muscle tissue include myofibrillar proteins myosin, actin, desmin, nebulin, and titin, and connective tissue (primarily collagen). The degradation of the proteins directly affects texture of the meat due their contribution to muscle structure and stability,[47,48,49] supporting the results found in this study. Researchers have documented that tenderness of broiler breast meat increases as PM debone time increases.[50,51] Additionally, Parrish et al,[21] found that as PM beef aging time increased, the degradation of Z disks within the myofibril increased.

Table 2 Effect of extended debone times on texture (Shear Energy, Peak Force, and Peak Count) of breast meat under various treatment (n=90/trt)

Treatment	Shear Energy (N.mm)	Peak Force (N)	Peak Count
Debone 2-3h PM			
Wooden Jumbo	256.87±62.62^{b}	19.00±4.61^{b}	9.92±2.70^{a}
Normal Jumbo	297.82±64.31^{a}	21.90±5.39^{a}	5.41±3.00^{d}
Normal Medium	232.18±73.21^{c}	18.00±5.25^{b}	6.95±2.76^{c}
16h Debone*	195.47±45.04^{d}	15.47±4.26^{c}	8.44±2.62^{b}
20h Debone*	195.64±45.11^{d}	15.70±3.22^{c}	8.53±2.62^{b}
24h Debone*	189.48±41.93^{d}	15.54±2.65^{c}	8.47±2.62^{b}

Means with different superscript in the same column for each parameter are significantly different (p≤ 0.05).
Means with different superscript in the same column for each parameter are significantly different (p>0.05).
a–d values within a row lacking a common superscript differ (p≤0.05)
*fillets deboned at extended times 16, 20, 24h.

PM meat tenderization and protein breakdown are mainly attributed to proteolysis by calcium-activated proteases calpain and calpastatin.[52] In the present study, data indicates that proteolytic enzymes acted in breast fillets deboned at extended times of 16, 20, and 24h, leading to the significantly (p≤0.05) higher tenderness values.[18,53,54] Because consumers consider tenderness to be the most important meat characteristic, it is essential to understand the process, so the procedures can be developed and applied to the industry. The popularity of poultry products has caused the industry to produce meat faster, bringing on myopathies[8] and not allowing time for rigor development or completion in bigger birds.[10,11] Additional research shows that higher growth rates in birds leads to a reduced proteolytic potential and less activity from calpains, affecting the rate of tenderness development.[18] The present texture data indicates that tenderness can be achieved in bigger birds (8-9lb) by increasing the debone time from the industry standard, which allows time for rigor completion and proteolytic activity to occur.[10,11]

In conclusion, results from this study can be used by the poultry companies to reduce the breast meat texture issues from fast-growing big broilers. Additionally, this study confirms that meat aging, a technique used for decades, can benefit the poultry industry. Increasing the debone time from the industry standard (2-3h PM) increased breast fillet tenderness. Data is verified by objective measurements of shear energy, peak force, and peak count from modern broilers.[55–58] Cook losses were not significantly (p≤0.05) affected by the treatments. Furthermore, prolonged debone treatments were not categorized by WB severity or treatment to represent a true population, allowing comparison between fillets deboned at 16, 20, and 24h and fillets deboned at 2h (Wooden Jumbo, Normal Jumbo, and Normal Medium treatments). The extended times used in this study present processors with economic losses due to extra time and energy spent on storage of carcasses. However, this technique could be utilized by companies that transport their carcasses from a slaughter plant to a separate debone or further processing plant. Further studies should focus on optimizing these extended debone times to obtain an acceptable texture, testing them in a sensory study, and feasibly applying them in the poultry industry.

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Conflicts of interest

The author declares that there was no conflict of interest.

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