EFFECTS OF CHILLING TIME AND BELT FLATTENING ON PHYSICAL CHARACTERISTICS, YIELD, AND TENDERNESS OF BROILER BREASTS

C. E. LYON
USDA, Agricultural Research Service, Russell Research Center, Poultry Processing & Meat Quality Research Unit, P.O. Box 5677, Athens, GA 30604-5677
Phone: (706) 546-3418
FAX: (706) 546-3633

S. F. BILGILI
Poultry Science Department and Alabama Agricultural Experiment Station, Auburn University, AL 36849-5416

J. A. DICKENS
USDA, Agricultural Research Service, Russell Research Center, Poultry Processing & Meat Quality Research Unit, P.O. Box 5677, Athens, GA 30604-5677

Primary Audience: Quality Assurance Personnel, Researchers, Plant Managers

SUMMARY

Removing the large breast muscle from broiler carcasses prior to the resolution of rigor mortis results in tough cooked meat. However, the practice of holding carcasses or front halves 8 to 24 hr after chilling prior to deboning to ensure tenderness in the cooked meat is costly with regard to refrigerated space, equipment, and labor. This study determined the effects of extending the chilling time (1, 2, or 3 hr) and subjecting the deboned breast muscles to belt flattening on subsequent physical dimensions (length and width), yield, and tenderness of the cooked meat. Maximum length, width, and weight of each muscle were recorded before and after flattening, and cooked yield and objective texture (tenderness) were evaluated to determine if a combination of the two treatments would eliminate the need to age carcasses for prolonged times prior to deboning.

For objective texture, increasing the chilling time resulted in less force necessary to shear the cooked meat, and flattened breasts required less force to shear than did the unflattened breasts. Belt flattening resulted in a loss in weight and an increase in surface area (length and width) of the raw muscle. The combination of carcass chilling for 2 hr followed by belt flattening resulted in cooked meat that would be considered "very tender."

Key words: Belt flattening, chicken breasts, extended chilling, length, tenderness, width, yield

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1 To whom correspondence should be addressed
DESCRIPTION OF PROBLEM

Toughness of intact broiler breast meat continues to be a major problem for further processors. The large Pectoralis major muscles need to remain attached to the skeleton for at least 4 hr post-mortem prior to deboning to allow the progression of rigor mortis and to prevent fiber contraction and ultimate toughness in the cooked meat [1, 2, 3, 4]. The space, utility, equipment, and labor costs associated with storing or tanking front halves for up to 24 hr is prohibitive. Accordingly, various alternatives to "tanking" have been tried. Among these alternatives are deboning the breast muscles as the carcasses come out of the chiller and holding the deboned fillets to allow cessation of rigor prior to product fabrication or during shipment; damaging the muscle fiber integrity by physically flattening the deboned fillets; and extending the chilling time [5, 6, 7].

The degree of gross muscle shortening due to hot boning (i.e., deboning immediately after feather removal) is extensive; muscle area losses total from 16 to 20% after chilled aging for 24 hr, and 42% after cooking [8]. These results illustrate that early removal of the large breast muscles will cause both gross shortening of the intact muscle and shortening of the sarcomere, the smallest functional unit of the muscle. Holding deboned fillets to achieve tenderization has also been reported [5]. Breasts from commercially processed broilers were removed at three post-chill times: 0, 1, or 24 hr. The 0 hr post-chill group was deboned immediately after chilling. The 1 and 24 hr groups were held at 35°F until muscle removal. After deboning, the fillets were aged at 35°F for 0, 12, or 24 hr prior to freezing to determine if holding the fillets for extended periods of time resulted in more tender cooked meat. Increasing post-chill deboning time to 1 hr resulted in less tough cooked meat, but shear values were still too high to be considered acceptable based on research that established the relationship between shear values and a sensory panel's perception of broiler breast meat tenderness [9]. Holding fillets for 24 hr prior to freezing had very little effect on ultimate tenderness of the cooked meat.

Some processors utilize belt flatteners to reduce variation in raw breast muscle thickness. The effects of flattening commercially processed breasts, deboned shortly after chilling for 45 min, on structure of muscle fiber and the texture of the cooked meat have been reported [6]. Flattened breast muscles were held at 35°F for various times prior to cooking (2, 6, 12, or 24 hr) in order to determine the effects of holding time after flattening on the tenderness of the cooked meat. Belt flattening fillets deboned within 15 min of chilling resulted in muscle fiber damage and lower shear values when compared to unflattened samples. However, once again, all of the shear values were too high to be considered acceptable [9].

Intact muscle height or thickness at a point adjacent to the wing insertion was also measured before and after cooking. Cooking resulted in an increase in height for all of the breasts regardless of treatment. The loss of breast area was expected for the unflattened muscles, but it was also noted for the flattened muscles regardless of fillet holding time after flattening. This "rebounding" of the flattened muscle due to cooking could limit the usefulness of the physical treatment. It was concluded that belt flattening has a role in reducing the time after chilling needed to tenderize breast meat, but by itself was not sufficient to tenderize breast meat deboned shortly after chilling.

There has recently been an increased interest in extending the traditional chilling time from 45 min to as long as 3 hr. Some of the benefits claimed include a firmer, colder carcass that is more receptive to automatic portioning, a decrease in bacteria due to a longer time in the presence of chlorine during chilling, and more tender cooked breast meat. Under pilot plant conditions, a combination of electric stimulation (200 VAC) during bleeding and chilling for 2 hr resulted in cooked breast meat that would be considered "very tender"[9]. There was no significant difference in shear values due to extended chilling time from 2 to 3 hr [7]. The results again illustrate the importance of leaving the breast muscles intact on the skeletal frame during the early post-mortem period. The combination of treatments (electric stimulation and extended chilling) also indicates that more than one approach can be used to shorten the time that the muscles need to remain on the frame.

The present study considered the combination of extended chilling times (1, 2, or
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3 hr) and belt flattening on the physical characteristics of raw and cooked breasts (weight, length, and width), yield, and tenderness (shear values) of the cooked meat. Physical characteristics were recorded to document the effects of flattening both before and after cooking.

MATERIALS AND METHODS

Mixed sex broiler chickens were grown under commercial conditions at the Auburn University Poultry Farm. Birds were reared in floor pens during grow-out, and were processed at 7 wk of age [10]. Birds were identified by colored wing bands with numbers based on carcass chilling time treatments, and processed at the Auburn University Processing Facility using automated in-line equipment [11]. Eviscerated carcasses were chilled in a paddle-type chiller (10 ft x 4 ft) charged with ice and water, with the temperature maintained at 34°F.

Three chilling times were evaluated in the study: 1, 2, and 3 hr. Each chilling time was denoted by the color of the wing band. After 1 hr in the chiller, the exit auger was engaged and the appropriate carcasses removed. Carcasses from the 2 or 3 hr chilling treatment were placed back in the chiller until the appropriate time for removal. After chilling, the Pectoralis major muscles were removed and skin discarded [12].

The right breast muscle from each carcass was subjected to flattening [13] within 15 min of exiting the chiller. Left breasts were evaluated as unflattened controls. The deboned breasts were placed on a pan with the wing band numbers copied on tape to retain the identity of the bird. All breasts were weighed at the time of deboning. Breasts were reweighed immediately after flattening. Maximum length and width of all breasts were recorded after deboning. Raw treated breasts were also remeasured after flattening [14].

After weight, length, and width measurements were recorded, the individual breast muscles were placed in labeled heat-and-seal bags, covered with ice in insulated containers, and transported to the Russell Research Laboratory. Upon arrival, the containers were placed in a 35°F cooler. The following day, breasts were removed and cooked by immersing the bags in 185°F (85°C) water for 30 min. The 40 breasts subjected to each chilling time (20 flattened and 20 unflattened) were cooked at one time. After cooking, the samples were cooled in tap water for 15 min prior to recording cooked weights and maximum length and width. A strip was then removed from each intact meat sample for objective texture evaluation [15].

The data were subjected to Analysis of Variance using the General Linear Models Procedure of Statistical Analysis Systems [16, 17]. When treatments were significant (P < .05), means were separated by Tukey's Test.

RESULTS AND DISCUSSION

MUSCLE WEIGHTS AND DIMENSIONS

The weights and dimensions of breast muscles from the study are presented in Table 1. The initial weights of the left and right breast halves within a chill time were similar, with carcasses from the 2-hr chill yielding slightly lower breast weights (132 and 136 g for the left and right sides, respectively). Raw breasts subjected to the belt flattening treatment (right side) lost weight and increased length and width. Cooking resulted in a loss of weight and area for all samples. The data in subsequent tables are based on individual weights and dimensions presented as means in Table 1.

The effects of extending chill time on weight, length, and width of raw flattened breast muscles are presented in Table 2. Chilling for 2 or 3 hr prior to flattening the deboned breasts resulted in a significant loss in weight compared to chilling for 1 hr prior to flattening. Chilling for 3 hr prior to flattening resulted in a significant increase in width compared to chilling for 1 hr. Chilling for 2 hr prior to flattening resulted in a width increase intermediate to the 1- and 3-hr chilling treatments. The increase in muscle length was not significantly affected (P > .05) by time of chill. It is interesting to note that the muscles from the 2 hr chilled, flattened group weighed less initially (mean of 136 g, Table 1) but lost more weight due to flattening than the muscles from the 1- and 3-hr groups. For overall area, the increase due to flattening was more pronounced in width than in length. These results indicate a separation or flattening of myofibrils and muscle bundles instead of a breaking or fragmenting, which would have resulted in an increase in length.
The influence of chill time and flattening on weight loss, and decrease in length and width due to cooking is presented in Table 3. Values in the table are calculated on the basis of measurements made before cooking. Chilling carcasses for longer periods resulted in smaller decreases in width during cooking. The smallest decrease in breast width (1.9%) was noted for carcasses chilled 3 hr prior to flattening; however, the decrease was not statistically different from the decrease for carcasses chilled for 2 hr. For the raw muscles, chilling for 3 hr prior to flattening resulted in a significant increase in width compared to chilling for 1 hr (Table 2), and this pattern continued through cooking. Muscles that were not flattened decreased in width by 15% upon cooking, while muscles subjected to flattening did not decrease in width. The decrease in length was not affected by either chill time or flattening, and averaged 21.9%.

There was a significant interaction between chill time and flattening on weight loss after cooking (Figure 1). The interaction was caused by the lower weight loss for muscles chilled for 1 hr and flattened (34%) compared to the 2 and 3 hr chill times prior to flattening (43 and 40%, respectively). Extending the chill time did not have a significant effect on the weight loss of the unflattened breasts, which ranged from 19 to 21%. Flattening the deboned breasts resulted in a significant increase in weight loss during cooking compared to the unflattened muscles.
TABLE 3. Influence of extended chill time and belt flattening on weight and dimensions of cooked broiler breast meat (Cooking changes are noted as proportions of pre-cooked measurements)*

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>WEIGHT LOSS (%)</th>
<th>LENGTH DECREASE (%)</th>
<th>WIDTH DECREASE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chill Time (Hr)</td>
<td>**</td>
<td>NS</td>
<td>*</td>
</tr>
<tr>
<td>1</td>
<td>27.6</td>
<td>22.8</td>
<td>12.7^a</td>
</tr>
<tr>
<td>2</td>
<td>32.7</td>
<td>22.6</td>
<td>6.0^b</td>
</tr>
<tr>
<td>3</td>
<td>30.2</td>
<td>20.3</td>
<td>1.9^b</td>
</tr>
<tr>
<td>SEM^B</td>
<td>0.83</td>
<td>1.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Flattened</td>
<td>***</td>
<td>NS</td>
<td>***</td>
</tr>
<tr>
<td>Yes</td>
<td>40.0</td>
<td>21.4</td>
<td>-1.3</td>
</tr>
<tr>
<td>No</td>
<td>20.4</td>
<td>22.4</td>
<td>15.0</td>
</tr>
<tr>
<td>SEM^B</td>
<td>0.61</td>
<td>1.03</td>
<td>1.02</td>
</tr>
</tbody>
</table>

Interaction ** NS NS

^a NS = Nonsignificant (P > .05); *P < .05; **P < .01; ***P < .001.

^b Standard error of the mean

^a,b Means in a column with no common superscript are different (P < .05).

FIGURE 1. Influence of carcass chilling time and belt flattening of breast muscle on weight loss due to cooking (Weight loss is expressed as a percentage of the raw breast weight)
There was a significant interaction between chill time and flattening on height of the strip after cooking at the point of shearing (Figure 2). Muscles from carcasses chilled for 1 hr prior to flattening were thicker (1.65 cm) after cooking than muscles from carcasses chilled either 2 or 3 hr prior to flattening. This significant difference in height (thickness) for the carcasses chilled for 1 hr prior to muscle removal and flattening may indicate that there was still sufficient ATP present to induce contraction of the sarcomeres and subsequent gross thickening of the intact muscle. The thicker muscle for the 1 hr carcass chilling and flattening treatment may also account for the higher percentage of weight loss from this group compared to carcasses chilled 2 or 3 hr prior to flattening (Figure 1). The thickness of the cooked meat from carcasses chilled 2 or 3 hr prior to flattening was essentially the same, 0.9 cm. Non-flattened muscles all exceeded 2 cm in height, regardless of carcass chilling time.

The Warner-Bratzler (W-B) shear values expressed as kilograms of shear force (kg) and as kilograms of shear force per square centimeter (kg/cm²) are presented in Table 4. The kg/cm² value was derived by multiplying the height at the point of shearing by the width of the strip (1.9 cm). The shear force value was then divided by this cm² value. Shear values, expressed either way, decreased as chill time increased. The shear values for the 1 hr chilled carcasses were significantly higher than for the 2 and 3 hr chilled carcasses, which were not statistically different from each other.

**Figure 2.** Influence of carcass chilling time and belt flattening of breast muscle on the height of cooked meat at the point of shearing for objective texture evaluation.
TABLE 4. Influence of chill time and belt flattening on objective texture of broiler breast meat

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>W-B HEIGHT(^a) (cm)</th>
<th>W-B SHEAR(^c) (kg)</th>
<th>W-B SHEAR(^c) (kg/cm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chill Time (Hr)</td>
<td>NS</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>1</td>
<td>1.86</td>
<td>14.74(^a)</td>
<td>4.18(^a)</td>
</tr>
<tr>
<td>2</td>
<td>1.60</td>
<td>4.52(^b)</td>
<td>1.56(^b)</td>
</tr>
<tr>
<td>3</td>
<td>1.66</td>
<td>2.95(^b)</td>
<td>1.01(^b)</td>
</tr>
<tr>
<td>SEM(^d)</td>
<td>0.07</td>
<td>0.92</td>
<td>0.28</td>
</tr>
<tr>
<td>Flattened</td>
<td>***</td>
<td>*</td>
<td>***</td>
</tr>
<tr>
<td>YES</td>
<td>1.17</td>
<td>6.72</td>
<td>2.55</td>
</tr>
<tr>
<td>NO</td>
<td>2.24</td>
<td>8.08</td>
<td>1.95</td>
</tr>
<tr>
<td>SEM(^d)</td>
<td>0.03</td>
<td>0.48</td>
<td>0.12</td>
</tr>
<tr>
<td>Interaction</td>
<td>***</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

\(^a\)NS = Non-significant (P > .05); \(^b\)P < .05; \(^c\)P < .01; \(^d\)P < .001.

\(^b\)Height of the cooked strip at the point of shearing was recorded by using a pair of calipers.


\(^d\)Standard error of mean

\(^a\)Means in columns with no common superscript are different (P < .05).

other. The effects of flattening were also significant on the shear values, but the direction of the difference was dependent on the way the results were expressed. When shear force was expressed as kg, muscles subjected to belt flattening prior to cooking required significantly less force to shear than the unflattened muscles: 6.72 compared to 8.08 kg. When the dimensions of the strip were considered (height x width), the kg/cm\(^2\) values were higher for the flattened samples. This is due to the fact that the flattened strips had a smaller area (cm\(^2\)) than the unflattened strips, which resulted in a smaller denominator value for calculating the shear force values.

The effects of extended chilling time and flattening are also illustrated in Figure 3. The sensory tenderness scale ranging from "very tough" to "very tender" with accompanying W-B shear values (presented as kg) illustrate the significance of lower objective values to the sensory perception of tenderness. This relationship was established in earlier research using post-mortem deboning times to facilitate a broad spectrum of cooked tenderness in broiler breast meat [9].

The shear values noted for unflattened breast meat emphasize the importance of post-mortem aging time on the ultimate tenderness (lower shear values). The 1 hr chill time in this study closely simulates deboning without additional aging after a traditional 45 min to 1 hr chill time that is commonly used in the poultry industry. The 14.7 kg shear value for carcasses chilled for 1 hr and then deboned is in the "very tough" portion of the sensory scale. There was a significant reduction in shear values between 1 and 2 hr chilling for the unflattened samples, with a smaller statistically nonsignificant reduction between 2 and 3 hr. This reduction in shear values with increasing chill time has been reported in an earlier study [7]. In that study, carcasses were subjected to electric stimulation during bleeding as well as extended chilling, and the combination resulted in cooked breast meat in the "very tender" portion of the sensory scale.

Subjecting the muscles to the belt flattener after carcass chilling for 1 hr did not result in any significant difference in shear values from the unflattened muscles (Figure 3). The benefit of the flattening treatment is evident in muscles from carcasses chilled 2 and 3 hr. The combination of carcass chilling for 2 hr followed by breast flattening resulted in "very tender" cooked meat, while the unflattened meat from carcasses chilled 2 hr would be considered "slightly to moderately tender." The significance for the processor is that the combination of 2 hr carcass chilling followed by breast flattening produces the same results as 3 hr of carcass chilling. Yet the cost difference between an additional hour in the chiller and flattening could be substantial.
CONCLUSIONS AND APPLICATIONS

1. The increase in surface area due to flattening is more pronounced in muscle width than length.
2. Muscles subjected to flattening and cooking lost more weight than cooked unflattened muscles.
3. Overall, shear values decreased (meat was more tender) as chill time increased.
4. The benefit of belt flattening on texture was evident when the carcasses were chilled for 2 hr, then flattened. The cooked meat from this combination treatment (2 hr chill and flatten) is in the “very tender” portion of a sensory scale.
5. The increase in tenderness (lower shear values) for the muscles subjected to belt flattening must be judged against the increase in tissue loss (lower yield).
6. None of the muscles in this study were marinated. The ability of flattened muscles with damaged fiber structure to absorb and retain marinade solution compared to unflattened muscles might offset the initial weight loss.
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REFERENCES AND NOTES


10. Birds were raised in 12 pens (100 birds/pen) equipped with individual feeders and drinkers. A total of 60 birds were randomly chosen for the study (5 birds/pen; 4 replicate pens/chill time).

11. Birds were electrically stunned (50 V DC for 7 sec), manually cut and bled for 90 sec, scalded for 2 min at 134°F, and mechanically picked for 42 sec. Following singeing and washing, the feet and neck were removed and carcasses transferred to the evisceration room. Evisceration consisted of vent opening, opening cut, automated draw of the viscera, lung removal with vacuum, and final carcass wash prior to chilling.


13. Johnson Food Equipment Belt Flattener. The flattener has two settings, one at each end of the set of rollers. The settings represent the distance between the rollers, and there is a graduated scale and crank to adjust the distance for each location. Settings used in the study were established by subjecting a group of chilled breasts of the same approximate weight and size to various settings and observing the effects. If the settings were so narrow that the breasts were torn or the muscle tissue stuck to the belts, then the distances were increased. Final distances for the front and rear settings were 3 24/64 and 4 12/64, respectively. The breasts were flattened one at a time so that identity was maintained. Immediately after flattening, each breast was reweighed, and length and width measurements taken.

14. Length and width of each breast was recorded after deboning, after cooking, and after flattening for the treatment group. The measurements were made by placing a ruler on the breast at the longest and widest points. The same person was responsible for all of the measurements.

15. A template was placed on the meat, and a 1.9 cm (0.75 in) wide strip was removed from the anterior region. The template was oriented from the wing insertion to the front of the keel. This placement insured that the fiber direction was uniform. A bench top Warner-Bratzler shear apparatus manufactured by G-R Electric Co., Manhattan, KS was used to shear the strip. Shear force was applied perpendicular to the direction of the fibers, and the shear force was noted as kg. Each strip was sheared twice, and the average of the two shear values were used for analysis. The height of the strip at the point of shearing was also noted so that the force could be noted on a cm² basis (1.9 cm wide x height). Because the shear values are compared to sensory/Warner-Bratzler values reported by Lyon and Lyon, 1991, only the shear values noted in kg are shown in Figure 3.

16. The model consisted of a 3 x 2 factorial arrangement of chill time and flattening. Pen (chill time) was used as the error term to test chill time and pooled residual error was used to test flattening and interaction effects.