ABSTRACT  Hot-boned broiler breast fillets were tightly clamped between rigid aluminum plates during chilling to determine whether tenderness is increased if breast fillets are not allowed to shorten during rigor. In two experiments, 6-wk-old broilers were processed in a pilot plant. Approximately 5 min after evisceration, the breast fillets (pectoralis major) were deboned, and each fillet was subjected to one of two treatments while chilling for 2 h in ice slush. Fillets were placed in perforated plastic bags (hot-boned control) or clamped between rigid aluminum plates that compressed the meat to a uniform thickness of 7.2 mm during chilling. In Experiment 2, chilling time in ice slush was 1 h, and a third treatment was added to make an incomplete block design in which one breast half was left intact on the carcass and was deboned immediately after chilling. All breast fillets were sealed in plastic bags after the chilling period, held overnight at 4 °C, and then cooked at 85 °C for 30 min in a steam kettle. In Experiment 1, clamping for 2 h reduced Warner-Bratzler shear values of hot-boned fillets from 11.4 to 2.7 kg. In Experiment 2, shear values for the treatments were 13.0, 9.2, and 5.1 kg for the hot-boned, cold-boned, and hot-boned clamped treatments, respectively, with significantly lower shear values for the clamped fillets. Clamped fillets were significantly thinner than the control fillets in both experiments. Cooked yield as a percentage of postchill weight was significantly higher for the clamped compared to the hot-boned control pieces, 81.1 versus 77.3%, with cold-boned pieces being intermediate and not different from the other treatments. Shear values were reduced, and cooked yield was increased by clamping hot-boned fillets during chilling.

(Key words: breast meat, tenderness, hot boning, clamping, broiler)

INTRODUCTION

Meat research in the 1960s demonstrated that muscles removed from beef carcasses before or during rigor mortis are irreversibly tougher after cooking (Locker, 1960; Herring et al., 1965a). This rigor toughening is caused by contraction of muscle when it is cut free from the skeletal attachments, which otherwise limit the extent to which muscle can shorten. The same effect occurs to a lesser extent on intact beef carcasses. Muscles that are under some degree of tension during aging are more tender than muscles that are not under tension and can thus contract more freely (Herring et al., 1965b). Different methods of hanging carcasses during aging determine which muscles are under tension as a result of gravity, with greater tension providing greater tenderness for those muscles.

The effect of muscle tension on intact poultry carcasses was not shown experimentally until Papa and Fletcher (1988) tied the wings of poultry carcasses to increase tension on the breast muscle and showed that the resulting meat was more tender. Poultry carcasses are not affected by gravity in the way that suspended beef carcasses are, but fixing the wings in stretched positions during chilling affects the tenderness of cooked breast meat whether the treatment is applied in the laboratory (Papa et al., 1989; Janky et al., 1992) or in a commercial chiller (Lyon et al., 1992a). Securing the wings behind the back of the carcass causes tensioning or stretching of the pectoralis major muscles, with the result that less force is necessary to shear the cooked meat. A small but significant tenderizing effect of breast muscle opposition under normal processing conditions was demonstrated by Cason et al. (1997). In that experiment, the supracoracoideus tendon was cut to prevent the opposition between the p. major and p. minor that exists when rigor occurs with muscles still attached to the carcass.

Tension can also be applied to muscles after removal from a carcass. Studies on the effects of tension on excised muscles generally have focused on muscle strips that were clamped on the ends and then pulled. Changes in contraction and tenderness have been studied in beef

©2002 Poultry Science Association, Inc.
Received for publication February 5, 2001.
Accepted for publication August 24, 2001.
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Abbreviation Key: ATP = adenosine triphosphate; WB = Warner-Bratzler.
of 3 d. Carcasses were deboned within 5 min of evisceration were removed, and carcasses were manually eviscerated. Blood was drained for 90 s, scalded at 57°C for 2 min, and defeathered. The common carotid artery were cut on one side of the neck. Birds were placed in restraining cones and the jugular vein and carotid artery were tightly clamped by lowering the grounded spacers between the aluminum plates. Due to pressure from the wing nuts and resistance from the thickness of the fillets, there was a slight bowing of the aluminum, but the mean thickness of the meat was approximately equal to the 7.2-mm distance provided by the spacers between the aluminum plates.

Two experiments were conducted using 6-wk-old, mixed-sex broilers in each experiment. Birds were purchased from a local processing plant and transported in coops to the laboratory where they were processed within 2 h. Birds were hung in shackles and stunned with 50 V alternating current for 10 s by lowering the grounded shackles so that the heads contacted a salt solution containing an electrified grid. After stunning, the birds were placed in restraining cones and the jugular vein and common carotid artery were cut on one side of the neck. Birds were bled for 90 s, scalded at 57°C for 2 min, and defeathered in a commercial picker for 30 s. The heads, feet, and necks were removed, and carcasses were manually eviscerated.

**Experiment 1**

In Experiment 1, four broilers were processed on each of 3 d. Carcasses were deboned within 5 min of evisceration and all fillets were weighed. One fillet (p major) from each carcass was randomly assigned to be clamped immediately (hot-boned clamped treatment), and the other fillet was put in a perforated plastic bag, which made it possible to identify individual pieces. All fillets were chilled in a static chiller that contained an ice-water slush. After chilling for 2 h, fillets were removed from the clamps or the bags, weighed, and sealed in labeled heat-and-seal bags. After overnight storage at 4°C, the fillets were cooked and sheared.

**Experiment 2**

In Experiment 2, nine broilers were processed on each of 3 d. Breast fillets were randomly assigned to three treatments in an incomplete block design: hot-boned clamped and hot-boned control as in Experiment 1, plus a cold-boned control that was chilled on the carcass before deboning. Hot-boned clamped and hot-boned control breast fillets were chilled for 1 h in the same ice-water slush with carcasses that had one uncut breast half attached to the carcass. After chilling, those breasts were deboned, and the resulting cold-boned fillets were weighed. Hot-boned fillets were weighed before and after chilling. All fillets were sealed in labeled heat-and-seal bags, stored overnight at 4°C, and then cooked and sheared on the following day.

**Clamping**

Breast meat was clamped by placing each fillet on a 2.2 mm thick, rectangular piece of sheet aluminum larger than the fillet. Bolts were inserted through holes along the edges of the aluminum sheet and fastened with nuts and sufficient washers to leave the top surface of each nut 7.2 mm from the top surface of the aluminum sheet. An upper sheet the same size was then placed over the first sheet and was tightened against the spacers with wing nuts. Due to pressure from the wing nuts and resistance from the thickness of the fillets, there was a slight bowing of the aluminum, but the mean thickness of the meat was approximately equal to the 7.2-mm distance provided by the spacers between the aluminum plates.

**Cooking and Shearing**

All fillets were cooked for 30 min in a steam kettle containing 85°C water. Previous work using the same time-temperature treatment produced internal end-point temperatures of 75 to 80°C (Cason et al., 1997). After cooking for 15 min in ice, breast fillets were removed from the bags and weighed. A single 1.9 cm wide strip was removed from the anterior portion of each p. major (Lyon and Lyon, 1990) and cut into two pieces of approximately equal size. The thickness of each piece was measured at the point of shearing with calipers, after which each was sheared with a tabletop WB shear apparatus. Peak load (in kg) was recorded, and the mean value for the two pieces was calculated.

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1 Herring et al., 1967, rabbit (Jungk et al., 1967), turkey (Jungk and Marion, 1970), and chicken (Klose et al., 1970; Wood and Richards, 1974; Whiting and Richards, 1975). A few studies used thread to sew or tie muscle ends, but these studies also applied tension by pulling on the ends of the muscle (Khan, 1974; Dunn et al., 1993). Of these studies, Klose et al. (1970), Khan (1974), and Dunn et al. (1993) also tested the tenderness of the cooked meat.

2 Dazey Corporation, Industrial Airport, KS 66031.

3 C-R Electrical Manufacturing Co., Manhattan, KS 66502.
Statistical analysis was performed using PROC GLM of SAS software (SAS Institute, 1987). In Experiment 1, analysis of variance was performed using a random block design with carcasses as blocks (different treatments applied to the left and right breast fillets). In Experiment 2, analysis of variance was performed using an incomplete block design to allow imposition of three treatments within blocks (carcasses) having only two subdivisions (left and right breast fillets). Orthogonal contrasts were used to compare the hot-boned control and cold-boned control treatment means against the clamped treatment.

**RESULTS AND DISCUSSION**

Means and standard deviations of WB shear values and thicknesses of cooked fillets in Experiment 1 are shown in Table 1. Significantly less force was required to shear the hot-boned, clamped fillets compared to the hot-boned control. The hot-boned control meat was also significantly thicker than the hot-boned clamped meat. Tenderness was much improved in the clamped meat, as measured in kilograms (about 75% of the shear value required for fillets treated in the same way except for being clamped during chilling) or in kilograms per centimeter squared (about 59% of the shear value for controls), indicating that the lower shear value was not caused simply by the reduced thickness of the clamped fillets, which was about 40% of the thickness of the hot-boned control fillets after cooking. The 2.7-kg shear value of the clamped fillets is in the range considered “very tender” by sensory panels (less than 3.6 kg) (Lyon and Lyon, 1990), with the 11.4-kg shear value of the hot-boned fillets in the “moderately to slightly tough” range (12.6 to 9.6 kg).

Means and standard deviations of WB shear values and thickness of cooked fillets in Experiment 2 are shown in Table 2. Shear values were significantly lower in the hot-boned, clamped meat compared to the controls, whether hot-boned or deboned after 1 h of chilling on the carcass. Cooked meat from the hot-boned control and cold-boned control was significantly thicker than meat that was hot-boned and clamped. As in Experiment 1, tenderness was improved in the clamped fillets (measured in kg or in kg per cm²), indicating again that the lower shear value was not caused simply by the reduced thickness of the clamped meat. Clamping fillets for 1 h resulted in a mean shear value of 5.1 kg (in the “slightly tender to moderately tender” range, or 6.6 to 3.6 kg in Lyon and Lyon, 1990) versus 13.0 kg (in the “very tough” range, or more than 12.6 kg) for fillets treated in the same way except without clamping. Control breast fillets deboned after 1 h averaged 9.2 kg, in the “slightly tough to slightly tender” range between 9.6 and 6.6 kg. Fillets deboned for 1 h were sheared with about 40% less force compared to cold-boned fillets that spent 1 h on the carcass before deboning. The difference can probably be attributed to the limited contraction of the clamped fillets compared to the meat that was still on the carcass. Clamped fillets might have chilled more rapidly than meat on the carcass because of the higher surface-to-volume ratio and the close contact with the aluminum plates, with a possible effect on the rate of disappearance of adenosine triphosphate (ATP).

Prechill and postchill weights of the breast fillets and cooked meat yields as a percentage of prechill and postchill weights in Experiment 2 are shown in Table 3. Postchill weights of the fillets were significantly greater when breast meat was deboned after 1 h of chilling compared to the hot-boned, clamped fillets. After cooking, there was no difference in cooked yield as a percentage of postchill weight between cold-boned controls and hot-boned, clamped fillets. There was no difference in postchill weight between hot-boned fillets that were chilled either as-is or in a clamp. There was a significant difference in cooked yield between those two treatments, however, indicating that the water-holding capacity of the clamped meat might have been greater during cooking, and thus those fillets retained more weight.

Clamping breast fillets during rigor prevents contraction and toughening, as does application of tension to the ends of the muscle, but the clamp allows a greater amount of restriction and provides more tender fillets in the same length of time compared to hot-boned fillets or cold-boned fillets that were left on the carcass while the treated fillets were in the clamp. Clamped fillets were flatter and remained flatter after cooking, without the rebound usually observed with belt-flattening of raw breast meat, regardless of fillet holding time after flattening (Lyon et al., 1992b, 1997). Portions made from

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### Table 1: Means and standard deviations for Warner-Bratzler shear values and thickness of cooked breast fillets deboned 5 min after evisceration and chilled for 2 h in ice slush in Experiment 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Warner-Bratzler shear kg</th>
<th>Warner-Bratzler shear kg/cm²</th>
<th>Cooked thickness cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-boned control</td>
<td>12</td>
<td>11.4 ± 2.8</td>
<td>3.8 ± 0.9</td>
<td>1.6 ± 0.2</td>
</tr>
<tr>
<td>Hot-boned clamped</td>
<td>12</td>
<td>2.7 ± 1.8</td>
<td>1.2 ± 0.7</td>
<td>1.2 ± 0.1</td>
</tr>
</tbody>
</table>

### Table 2: Means and standard deviations for Warner-Bratzler shear values and thickness of cooked breast fillets subjected to three treatments during 1 h of chilling in ice slush in Experiment 2

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Warner-Bratzler shear kg</th>
<th>Warner-Bratzler shear kg/cm²</th>
<th>Cooked thickness cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot-boned control</td>
<td>18</td>
<td>13.0 ± 3.7</td>
<td>4.0 ± 1.4</td>
<td>1.8 ± 0.2</td>
</tr>
<tr>
<td>Cold-boned control</td>
<td>18</td>
<td>9.2 ± 3.5</td>
<td>2.9 ± 1.1</td>
<td>1.7 ± 0.2</td>
</tr>
<tr>
<td>Hot-boned clamped</td>
<td>18</td>
<td>5.1 ± 3.1</td>
<td>1.9 ± 1.1</td>
<td>1.4 ± 0.1</td>
</tr>
</tbody>
</table>

1Deboned fillets were chilled in perforated plastic bags (hot-boned control) or clamped between rigid aluminum plates that compressed the fillets to a thickness of 7.2 mm during chilling.
clamped fillets should have a more consistent appearance when cooked and might reach a more uniform temperature. The tenderizing effect may be roughly proportional to the length of time that fillets were left in the clamp (at least 1 to 2 h in this study) and probably related to the amount of ATP remaining in the fillets when they were removed from the clamp and how much contraction occurred after removal from the clamp. Future studies are planned to address the rate of biochemical reactions as related to the clamping treatment.

The clamping treatment increased the cooked yield of hot-boned fillets relative to hot-boned fillets that were not clamped. Under the pressure of clamping, fillets were probably unable to increase their weight by taking up water during chilling, and so the gain in cooked yield most likely comes only from reduced water loss during cooking. Early harvested breast meat usually has higher cooked yield than aged meat because of increased water-holding capacity (Froning and Neelakantan, 1971; Lyon et al., 1984), but clamping may compensate for the loss of yield and result in meat that would be considered tender.

Front halves of carcasses are often aged 8 to 24 h before deboning to allow adequate tenderization of breast meat. This delay allows for depletion of ATP in the muscle and avoids shortening and toughening but also involves expenses such as increased time in refrigerated storage, chilling of bones that will be discarded, and scheduling of labor on different shifts. The clamping apparatus used in these experiments was not suitable for industrial application, but the principle could be adapted for commercial application if the advantages outweigh the disadvantages in some industrial situations.

### REFERENCES


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**TABLE 3. Means and standard deviations for prechill and postchill weights (wt.) of pectoralis major fillets and cooked yields as a percentage of prechill and postchill weights of cooked fillets subjected to three treatments during 1 h of chilling in ice slush in Experiment 2**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Prechill wt. (g)</th>
<th>Postchill wt. (g)</th>
<th>Cooked yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>±</td>
<td>±</td>
<td>% of prechill wt.</td>
</tr>
<tr>
<td>Hot-boned control</td>
<td>77.2 ± 10.0</td>
<td>81.2 ± 10.3</td>
<td>80.4 ± 2.5</td>
</tr>
<tr>
<td>Cold-boned control</td>
<td>NA</td>
<td>86.4 ± 10.8</td>
<td>NA</td>
</tr>
<tr>
<td>Hot-boned clamped</td>
<td>80.2 ± 10.3</td>
<td>81.1 ± 10.5</td>
<td>82.0 ± 1.9</td>
</tr>
</tbody>
</table>

*1Hot-boned fillets were chilled in perforated plastic bags (hot-boned control) or clamped between rigid aluminum plates that compressed the fillets to a thickness of 7.2 mm during chilling. Cold-boned control breast fillets were deboned after 1 h of chilling on the carcass.

*2NA = not applicable.

*Significantly different (P < 0.05) from values for hot-boned clamped breast fillets.