Early Postmortem Injection and Tumble Marination Effects on Broiler Breast Meat Tenderness

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ABSTRACT Several processors use inline injection and tumble marination practices to decrease labor costs and product handling. However, the stimulation of this early postmortem (PM) muscle may cause increased toughness. Therefore, the objective of this study was to compare marination of early PM meat by using injection, vacuum tumbling, or both to determine their effects on tenderness of broiler breast fillets. Breast fillets from 45 broilers were deboned at 3 h PM and injected, tumbled (30 min, 635 mmHg, 14 rpm), or injected + tumbled with a 10% solution of 0.54% NaCl + 0.42% sodium tripoly phosphate (STPP). Nonmarinated controls deboned at 3 and 6 h PM were also included. Shear value, sarcomere length, and cook loss were determined on each of the fillets. The control and tumbled fillets had the highest shear value compared with the remaining 3-h treatments. The injected + tumbled and tumbled fillets had the highest cook loss followed by 3-h control and injected treatments. Tumble marination at 3 h PM produced significantly tougher meat than the injection treatment.

Experiment 2 was conducted to test marinade penetration through the fillets because penetration could have affected the results of the previous study. Broiler breast fillets were deboned from 60 broilers at 3 h PM and were vacuum tumbled (30 min, 635 mmHg, 14 rpm) with a 15% solution of 0.54% NaCl and 0.42% STPP. We determined shear value and cooked meat moisture of the fillets and sodium ion migration into the fillets. Although there were no significant differences in shear value between control and tumbled fillets, the cooked meat moisture was significantly higher in tumbled fillets when compared with the controls. Sodium ion concentration was significantly higher on the surface (especially the lateral surface) of the fillets when compared with the center, which suggested some uneven distribution.

(Key words: broiler, marination, pectoralis, phosphate, tenderness)

INTRODUCTION

There has been an increase in further-processed poultry products during the last 20 yr due to consumer demands. With this shift, it has become necessary for industry to age carcasses for at least 4 h prior to deboning to prevent toughening (de Fremery and Pool, 1960; Stewart et al., 1984; Dawson et al., 1987; Zocchi and Sams, 1999). Stimulation of muscle, such as deboning, prior to completion of rigor mortis has been shown to decrease tenderness. However, there are increased labor costs and product handling concerns associated with early postmortem (PM) product storage. Therefore, research has focused on methods to improve tenderness with early deboning.

Marination of broiler breast meat has become an integral part of the poultry industry due to the increase in consumer, retailer, and restaurant demand for further-processed, ready-to-eat, convenience foods. Marination has also been used as a method of tenderization (Young et al., 1991; Young and Lyon, 1997). A typical marinade solution contains salt and phosphates with sodium tripoly phosphate (STPP) being the most common phosphate (Barbut et al., 1988). Palladino and Ball (1979) found that sodium ions in marinades produced a tenderizing effect, and Goodwin and Maness (1984) reported a tenderizing ability of phosphates. Hamm (1960) postulated that dispersion of ions into the muscle provided a tenderizing effect due to the repulsion caused by association of the ions with the proteins. This repulsion allowed increased water uptake and, therefore, increased moisture content of the cooked meat and increased tenderness. However, incomplete dispersion of the ions through the meat can possibly affect the water-holding capacity and tenderization potential of the marinades.

Abbreviation Key: PM = postmortem; STPP = sodium tripoly phosphate.
Xiong and Kupski (1999) used a dye tracing method to determine penetration of the marinade into tumbled broiler breast fillets; however, water-soluble dye may migrate at a different rate from the ions that are responsible for increased tenderization. Also, these authors did not use a vacuum when tumbling the fillets, possibly affecting marinade penetration into the meat. Because there have been few studies relating early PM marination and tenderness, the objectives of these studies were to determine tenderness differences with several inline marination techniques (experiment 1) and to determine sodium ion migration through vacuum-tumbled fillets to determine if complete dispersion occurs (experiment 2).

MATERIALS AND METHODS

Experiment 1

We obtained ninety 2-wk-old broilers in 2 trials from a commercial grower and fed them an NRC-approved broiler diet ad libitum. At 6 wk of age, the birds were removed from feed 12 h prior to processing but were allowed access to water until 2 h prior to processing. The birds were stunned (13 mA, 500 Hz pulsed DC, 12 s), exsanguinated, scalced\(^3\) (61°C, 45 s), picked (rotary drum picker,\(^4\) 30 s), manually eviscerated, chilled (4°C, 1 h), and stored on ice in a 4°C cooler until deboning. Broiler breast fillets were deboned at 3 or 6 h PM. Treatments included injected (0.172 MPa, 10%), vacuum tumbled (635 mmHg, 14 rpm, 10%), injected + tumbled, nonmarinated controls deboned at 3 h PM, and nonmarinated controls deboned at 6 h PM. The 6-h PM control was included to determine post rigor tenderness levels.

The fillets were marinated with a 10% solution at a final concentration of 0.54% NaCl and 0.42% STPP, which was a standard industry solution obtained from a commercial processor. All fillets were then placed in aluminum-lined pans on raised-wire racks to allow for drip and were stored in a 4°C cooler overnight to allow for marinade equilibration. At 24 h PM, the fillets were cooked in an air-convection oven\(^5\) to an internal temperature of 72°C and analyzed for shear value using an Allo Kramer shear cell as described by Sams (1990). Cook loss (%) was determined as a percentage of the initial (precook) weight. Sarcomere length was measured using a laser diffraction method (Cross et al., 1980) as modified by Sams and Janky (1986).

All data was subjected to ANOVA using the GLM procedure (SAS Institute, 1990). The means were separated using Duncan’s multiple range test with a significance level of \(P < 0.05\) (SAS Institute, 1990). Because no significant trial by treatment or replication by treatment interactions were detected in any parameter measured, the data were pooled by treatment.

\(^3\)Model SS-36-SS, Brower Corp., Houghton, IA.
\(^4\)Model SP3055, Brower Corp., Houghton, IA.
\(^5\)Model SS-36-SS, Brower Corp., Houghton, IA.
\(^6\)Blodgett Zephyre G-1 speed, Blodgett Oven Co., Burlington, VT.
\(^6\)Orion Sodium Probe Model 86-11, Orion Research, Inc., Beverly, MA.

Experiment 2

We obtained sixty 2-wk-old broilers in 2 trials from a commercial grower and fed them an NRC-approved diet ad libitum. At 6 wk of age, the birds were removed from feed 12 h prior to processing but were allowed access to water until 2 h prior to processing. The birds were conventionally processed as described previously and stored on ice in a 4°C cooler until 3 h PM, the time of deboning. At deboning, each fillet was randomly assigned to control or tumbled treatments. The tumbled fillets were vacuum tumbled (635 mmHg, 14 rpm) with a 15% solution of 0.54% NaCl and 0.42% STPP. All fillets were placed in aluminum-lined pans on raised-wire racks to allow for drip and were stored in a 4°C cooler overnight to allow for marinade equilibration. At 24 h PM, half of the fillets were cooked and sheared according to the procedures of Sams 1990. Cooked meat moisture (%) was also determined by the oven-dry method (AOAC, 1983). From the remaining halves, two 2.54-cm (diameter) cores were cut from the centers of the fillets (Figure 1), wrapped in plastic wrap to prevent moisture loss, and placed in the freezer (−24°C) for 1 h. The frozen samples were then sliced in 2 mm thick slices (Figure 1) with a vegetable slicer and stored at 4°C in plastic zip-seal bags for 24 h until analysis. The slices were homogenized with 50 mL of distilled, deionized water, and the concentration (ppm) of sodium ion was determined using an ion selective sodium probe.\(^6\) The percentage of sodium ion was calculated for each slice based on the weight of each slice.

Data was subjected to ANOVA using the general linear means of SAS software (1990). Differences between means for control and tumbled shear value and cooked meat moisture were determined using the ANOVA F-test (SAS Institute, 1990) at a significance level of \(P < 0.05\). Differences in sodium ion migration through the breast fillet as well as slice differences between control and tumbled fillets were
determined by Duncan’s multiple range test with a significance level of $P < 0.05$ (SAS Institute, 1990). Because there were no significant trial by treatment or replicate by treatment interactions in any of the parameters measured, the data were pooled by treatment.

## RESULTS AND DISCUSSION

### Experiment 1

Shear value is an indirect measurement broiler breast fillet tenderness. Lower shear values indicate more-tender meat (Herring et al., 1967). The vacuum tumbled (14.49) and control 3 h (14.09) fillets had the highest shear values followed by injected + tumbled (9.05) and injected (7.81), which were not significantly different (Table 1). A shear value of 6.0 to 8.8 kg/g, in relation to consumer perceptions, would be considered “slightly tender” to “moderately tender” (Simpson and Goodwin, 1974; Lyon and Lyon, 1990). A value $< 8.0$ would be classified by consumers as “tender” to “very tender.” The injected fillets were significantly more tender than the tumbled fillets, possibly due to greater fiber disruption from fluid pressure, more extensive brine penetration and distribution, and the actual injector needles decreasing the integrity of the fiber network. Tumbling and early PM injection stimulate the muscle. However, the fiber disruption maybe greater in the injected fillets when compared with the tumbled fillets, thus decreasing toughness associated with early PM muscle stimulation in the injected fillets. Tumbling fillets in the early PM state may increase the physical stimulation of the muscle and cause increased toughening. Also, the penetration and distribution of the marinade may be less in the tumbled fillets when compared with the fillets that had the brine injected into them. The control 6 h fillets were the most tender. This result was expected because at least 4 h of aging is required to allow for rigor mortis to develop, which prevents toughening associated with physical muscle stimulation (Stewart et al., 1984; Dawson et al., 1987; Zocchi and Sams, 1999).

Sarcomere length is an indicator of contractile state of the muscle and is a contributor to toughness. Shorter sarcomeres are strongly correlated with increased toughness and occur when the muscle is stimulated prior to the completion of rigor mortis (Herring et al., 1967). The control (6 h) fillets had the longest sarcomeres when compared with the remaining treatments, which were not significantly different (Table 1). The longer sarcomeres observed in the control (6 h) fillets were expected because rigor mortis had developed before the muscle was removed from its skeletal restraint. The lack of differences between the injected and tumbled fillets is inconsistent with the shear value results but suggests that sarcomere length is just one factor influencing tenderness. Other factors such as hydration and protein interaction may also be involved (Hamm, 1960).

Cook loss, or weight loss during cooking, is a measurement of water-holding capacity of the muscle. Marinating with salt and phosphate increases the pH and ionic strength, which increase the ability of the muscle to retain water during cooking. There were no differences ($P > 0.05$) among any of the 3-h treatments. The numerical distinctions among these means may simply reflect the variable nature of measuring small weight changes in individual fillets. Likewise, there were no significant differences between the 6 h control fillets and the 3 h control or the 3 h injected fillets. Although the magnitude of these mean differences may be large enough to be practically important, statistical conclusions from this data set may not be possible.

### Experiment 2

Shear value was measured in this study to determine tenderness differences between control (nontumbled) and vacuum-tumbled marinated fillets. There were no significant differences in shear value between control and tumbled fillets (Table 2). In both treatments the shear values were above the “slightly to moderately tender” threshold of 6 to 8.8 kg/g (Lyon and Lyon, 1990). Previous research has indicated that any stimulation to the breast muscle prior to completion of rigor development (4 to 6 h PM)

<table>
<thead>
<tr>
<th>Parameter measured</th>
<th>Control 3 h PM$^1$</th>
<th>Tumble 3 h PM</th>
<th>Pooled SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear value (kg/g)</td>
<td>13.23</td>
<td>12.21</td>
<td>0.64</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>70.31$^a$</td>
<td>71.46$^b$</td>
<td>0.21</td>
</tr>
</tbody>
</table>

$^a$$^b$Means within a row differ ($P < 0.05$).

$^1$Postmortem deboning time.
results in increased toughness (Stewart et al., 1984; Dawson et al., 1987). Even though it has been shown that sodium ions have a tenderizing effect in postmigror broiler breast meat (Palladino and Ball, 1979), early PM stimulation caused by early deboning and tumbling in the present experiment might have masked this effect. Similar treatment effects were observed in experiment 1.

Cooked meat moisture (%) was measured in this study to determine any differences in water-holding capacity between tumbled and nontumbled broiler breast meat. Tumbled fillets had higher cooked meat moisture than control fillets (Table 2). These results agree with previous data that indicate marinating broiler breast meat with salt and phosphates improves water-holding capacity and cook meat moisture (Farr and May 1970; Hamm, 1975; Young et al., 1991).

Sodium ion migration through the vacuum-tumbled fillets was also measured in this study to determine if complete Na⁺ distribution occurs throughout the fillets. Sodium ion concentration was significantly higher in the medial and lateral surfaces of the fillets when compared with the center (Figure 2). There were also significant differences between the control and marinated fillets in slice locations. Marinated fillets had a higher concentration of sodium ions, and sodium concentration decreased as the slice location became more central. These differences indicate that sodium ions migrate from the lateral and medial surfaces toward the center of the fillet. Also, the tumbled fillets had significantly higher sodium ion concentration on the lateral side compared with the medial side of the fillet. This difference might be due to the presence of the epimysium on the lateral surface of the fillet.

The results of these studies indicate that inline tumble marination at 3 h PM without injection produces significantly tougher meat than the injection treatments. This result may be due to the noninjected, tumble marination treatments having less fiber disruption and marinade penetration or distribution than the injection marination treatments. Also, vacuum tumbling early PM broiler breast meat allows for sodium ion penetration to the center of the fillet but with increased concentrations on the surfaces of the fillet. Such marination inconsistencies may result in product variation.

FIGURE 2. Migration of Na⁺ ions from the lateral and medial surfaces in tumble marinated broiler breast fillets (14mm). a, b, c, d = P < 0.05 indicated differences between slices. * = P < 0.05 indicates difference within a treatment.

REFERENCES


