Combined effects of presalted prerigor and postrigor batter mixtures on chicken breast gelation

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ABSTRACT We examined the combined effects of prerigor and postrigor batter mixtures on protein gelation. The postrigor batter was prepared with 2% salt, whereas the prerigor meat at 5 min postmortem was used to prepare postrigor batters at different salt levels. For 5 treatments, prerigor batters were mixed with postrigor batter that had 2% salt (control) as follows: T1: ground presalted (1%) hot-boned breast with 1% salt for 50% total batch; T2: ground presalted (2%) hot-boned breast with 1% salt for 50% total batch; T3: ground presalted (2%) hot-boned breast for 50% total batch; T4: ground presalted (3%) hot-boned breast for 30% total batch that was mixed with cold-boned batter for 50% total batch; and T5: ground presalted (4%) hot-boned breast for 25% total batch that was mixed with cold-boned batter for 50% total batch. Treatments with both presalted prerigor and postrigor muscle showed less cooking loss and lower emulsion stability than the control, except T5. The protein solubility and apparent viscosity of the control was the lowest. Thus, presalted hot-boned muscle combined with cold-boned muscle positively affected physicochemical properties.

Key words: prerigor, postrigor, presalted, model systems, gelation

INTRODUCTION

Hot boning involves butchering the chicken carcass in the prerigor condition, up to 1 h after slaughter, when the chicken muscles are still warm. This prerigor muscle is removed immediately from a postslaughter carcass, and it has been demonstrated in many countries to have several economic advantages and excellent processing qualities (Keenan et al., 2010; Toohey and Hopkins, 2006; Young and Lyon, 1997; Xiong and Brekke, 1991). Generally, many advantages have been claimed for prerigor muscle, including improved water-holding capacity, emulsion stability, and binding capacity (Choi et al., 2009; Coon et al., 1983). According to Kim et al. (2011), further advantages of prerigor muscles treated by hot-boned processing include reduced cooler space, decreased energy costs, increased final yield, and improved functional properties of the meat. Pisula and Tyburcy (1996) reported that the functional properties of hot-boned meat were better than those of cold-boned meat because of higher pH and adenosine triphosphate (ATP) levels.

Salt (sodium chloride) is the most commonly used functional ingredient in meat product manufacturing. It is used to promote processing aptitude in meat products due to increased water binding and reduced cooking losses (Kijowski and Mast, 1988). The simultaneous addition of sodium chloride (NaCl) to meat causes considerable modification of physicochemical features of myofibrillar proteins (salt-soluble proteins), which are the main contributors to meat functionality (Xiong and Brekke, 1991). Bernthal et al. (1989) reported that salted prerigor muscle had better physicochemical properties (i.e., processing quality) than postrigor muscle. Keenan et al. (2010) reported that the presalted hot-boned meat that is commonly used in meat product manufacturing has improved water-holding capacity because of the combined effects of ATP, high pH, and high ionic strength. This processing method is effective with prerigor muscle, and salt concentration, salt type, and salting time are important factors (Hamm, 1981; Keenan et al., 2010). Lee et al. (2012) reported that prerigor salting methods, especially the addition of 2% sodium chloride, were more efficient for improving cooking yield and textural properties.

Some researchers have reported that prerigor salting effects, evaluating various muscles (Choi et al., 2009;
Sadler and Swan, 1997; Sørheim et al., 2006). However, because most chicken meat is processed with cold boning, no study has been made of treatments that combine presalted hot-boned muscle and cold-boned muscle. Thus, there is a need to qualitatively evaluate the effects of combining presalted prerigor muscle and cold-boned chicken breast muscle so that the quality characteristics of chicken meat products may be improved.

Thus, this study sought to establish whether a combination of hot-boned and cold-boned meat can be used effectively in chicken meat processing by qualitatively evaluating treatments of prerigor muscle precured with various salt concentrations and then combined with postrigor muscle.

MATERIALS AND METHODS

Raw Materials and Sample Preparation

In total, 52 chicken (broilers, 30 d of age, 1.2 to 1.5 kg live weight) were obtained from a local poultry processor and transported to the Konkuk University Meat Science Laboratory. The chickens were removed from cages and laired in animal pens until slaughter. To minimize the effects of catching and handling, feed was removed 12 h prior to processing, but the broilers were allowed access to water until 2 h prior to processing (Alvarado & Sams, 2000). The birds were stunned electrically at 50 V for 10 s and then killed by bleeding from a single unilateral neck cut for 3 min. Breast fillet (pectoralis major) was removed at 5 min postmortem and divided into prerigor and postrigor groups. The prerigor portion was ground through a Φ 8 mm plate within 5 min and subdivided into 5 portions. Then into each subsample was mixed with 1, 2, 3, 4, or 5% salt (sodium chloride) within 5 min postmortem. The postrigor portion was vacuum packaged into polyethylene bags and then stored at 4°C for 48 h.

Preparation of Chicken Samples

Six different chicken meat emulsion treatments were produced. The experimental design and formulations are given in Table 1. The first chicken meat batter served as the control and was prepared with 48% postrigor muscle and 2% salt (sodium chloride). The 30% back fat and 20% ice water was added to all treatments, respectively. The second batter (T1) was prepared with 49% prerigor muscle pretreated with 1% salt and 1% salt. The third batter (T2) was prepared with 50% prerigor muscle pretreated with 2% salt. The next 3 batters were prepared with a combination of prerigor and postrigor muscle. The following combinations of prerigor and postrigor muscle were used: 30% prerigor muscle pretreated with 3% salt + 20% postrigor muscle (T3); 25% prerigor muscle pretreated with 4% salt + 25% postrigor muscle (T4); and 20% prerigor muscle pretreated with 5% salt + 30% postrigor muscle (T5).

For each type of batter, the mixed ground chicken meat was homogenized for 1 min in a silent cutter (963009, Hermann Schärfen GmbH & Co., Postfach, Germany) then chilled with added 20% ice water (2°C) and homogenized continuously for 5 min. A temperature probe (KM330, Kane-May, Harlow, UK) was used to monitor the temperature of the emulsion, which was maintained below 10°C throughout batter preparation. After emulsification, the batter was stuffed into cellulose casings (Nojax, Viskase Inc., Illinois, USA; approximate diameter 25 mm) using a stuffer (IS-8, Sirman, Marsano, Italy). Each encased batter was then heated to 75 ± 1°C for 30 min in a water bath (10-101, Dae Han Co., Seoul, Korea). The heated batters were then cooled in cold water (15°C) for 1 hr. This procedure was performed in triplicate for each batter treatment (Choi et al., 2010).

pH

The pH of 5 g samples blended with 20 mL distilled water for 60 s in a homogenizer (Ultra-Turrax T25,

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control</th>
<th>1% (T1)</th>
<th>2% (T2)</th>
<th>3% (T3)</th>
<th>4% (T4)</th>
<th>5% (T5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precured hot-boned chicken breast</td>
<td></td>
<td>49</td>
<td>50</td>
<td>30</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>Cold-boned chicken breast</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back fat</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Ice water</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Salt</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

1) Hot-boning chicken breast muscle was mixed with salt concentration of 1, 2, 3, 4, and 5% within post-mortem 5 min, respectively. Control: 48% cold-boning chicken breast + 2% salt, T1: 49% hot-boning chicken breast mixed with 1% salt within post-mortem 5 min + 1% salt, T2: hot-boning chicken breast mixed with 2% salt within post-mortem 5 min, T3: 30% hot-boning chicken breast mixed with 3% salt within post-mortem 5 min + 20% cold-boning chicken breast, T4: 25% hot-boning chicken breast mixed with 4% salt within post-mortem 5 min + 25% cold-boning chicken breast, T5: 20% hot-boning chicken breast mixed with 5% salt within post-mortem 5 min + 30% cold-boning chicken breast.
Janke and Kunkel, Staufen, Germany) was determined with a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland).

**Color**

The color of each batter was determined using a colorimeter (Minolta Chroma Meter CR-210, Minolta Ltd., Osaka, Japan; illuminate C was calibrated with a white plate; \( L^* = +97.83, a^* = -0.43, b^* = +1.98 \)). Seven measurements for each tripod were taken. Lightness (International Commission on Illumination CIE \( L^* \)), redness (CIE \( a^* \)), and yellowness (CIE \( b^* \)) values were recorded.

**Cooking Loss**

Each meat batter was stuffed into a casing and after heat processing at 75°C for 30 min, cooked samples were cooled to room temperature at 21°C for 3 h. The cooked batter was weighed, and the cooking loss was calculated by using the following equation.

Cooking loss \((g/100g) = [(\text{weight of raw meat batter (g)}) - \text{weight of cooked meat batter (g)})/\text{weight of raw meat batter (g)}] \times 100

**Emulsion Stability**

The meat batters of emulsion systems were analyzed for emulsion stability using the method of Blouka and Honikel (1992) with the following modifications. Preweighted graduated glass tubes were filled with batter at the middle of a 15 mesh sieve. The glass tubes were closed and heated for 30 min in a boiling water bath to a core temperature of 75 ± 1°C. After cooling to approximately 4 ± 1°C to facilitate fat and water layer separation, the total expressible fluid and fat separated at the bottom of each graduated glass tube was calculated (Choi et al., 2007).

Total expressible fluid separation \((\text{ml/g}) = [(\text{the water layer (ml) + the fat layer (ml)})/\text{weight of raw meat batter (g)}] \times 100

Fat separation \((\text{ml/g}) = [\text{the fat layer (ml)}/\text{weight of raw meat batter (g)}] \times 100

**Protein Solubility**

The samples’ protein solubility was determined using the method of Joo et al. (1999). The sarcoplasmic protein solubility of each sample was determined by dissolving 2 g batter in 20 mL ice-cold 25 mM potassium phosphate buffer (pH 7.2). The protein buffer were homogenized on ice with a homogenizer (AM-7, Nihonseiki Kaisha Ltd., Tokyo, Japan) at 1,500 \( \times g \) and were left to stand on a shaker at 4°C overnight. Each mixture was centrifuged at 1,500 \( \times g \) (4°C) for 20 min, and the supernatant protein concentrations were determined using the Biuret method (Gornall et al., 1949). Total protein solubility was determined by homogenizing 2 g batter samples in 20 mL ice-cold 1.1 mol/L potassium iodide in a 100 mol/L phosphate buffer (pH 7.2). The procedures for homogenization, shaking, centrifugation, and protein determination were as described above. Myofibrillar protein solubility was obtained by determining the difference between the total and the sarcoplasmic protein solubilities.

**Apparent Viscosity**

Emulsion batter viscosity was measured in triplicate with a rotational viscometer (Hakke Viscometer 550, Thermo Electron Corporation, Karlsruhe, Germany) set at 10 rpm. The standard cylinder sensor (SV-2) was positioned in a 25 mL metal cup filled with batter and allowed to rotate under a constant shear rate \((s^{-1})\) for 60 s before each reading was taken. Apparent viscosity values in centipoises were obtained. The temperature of each sample at the time of viscosity testing was also recorded (18 ± 1°C).

**Texture Profile Analysis**

Texture profile analysis (TPA) was performed using the method of Choi et al. (2010). TPA was performed at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems Ltd., Surrey, England). The batters were stuffed into casings and were heated (75 ± 1°C for 30 min), and the cooked samples were cooled to room temperature at 21°C for 30 h. Cooked samples sized 2.5 × 3.0 cm (diameter × length) were cut and were taken from the central portion of each sample. The texture analysis conditions were as follows: cylinder probe 20 mm in diameter, pretest speed 2.0 mm/s, posttest speed 5.0 mm/s, maximum load 2.0 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5.0 g. The calculation of TPA values was obtained by graphing a curve using force and time plots. Values for hardness (N), springiness, cohesiveness, gumminess (N), and chewiness (N) were determined as described by Bourne (1978).

**Statistical Analysis**

All tests were conducted at least 3 times for each experimental condition, and mean values were reported. The general linear model (GLM) procedure of the SAS statistical package (2000) was used to perform an
Table 2. Effects of prerigor salting concentration on pH and instrumental color values.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>1% (T1)</th>
<th>2% (T2)</th>
<th>3% (T3)</th>
<th>4% (T4)</th>
<th>5% (T5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw pH</td>
<td>5.90 ± 0.02&lt;sup&gt;D&lt;/sup&gt;</td>
<td>5.96 ± 0.04&lt;sup&gt;C&lt;/sup&gt;</td>
<td>6.04 ± 0.02&lt;sup&gt;A&lt;/sup&gt;</td>
<td>6.01 ± 0.02&lt;sup&gt;B&lt;/sup&gt;</td>
<td>5.94 ± 0.03&lt;sup&gt;C&lt;/sup&gt;</td>
<td>5.91 ± 0.03&lt;sup&gt;D&lt;/sup&gt;</td>
</tr>
<tr>
<td>L&lt;sup&gt;*&lt;/sup&gt;-value</td>
<td>82.53 ± 2.06&lt;sup&gt;B,C&lt;/sup&gt;</td>
<td>82.98 ± 2.45&lt;sup&gt;D&lt;/sup&gt;</td>
<td>85.22 ± 2.31&lt;sup&gt;A&lt;/sup&gt;</td>
<td>83.82 ± 1.09&lt;sup&gt;A,B&lt;/sup&gt;</td>
<td>83.27 ± 1.62&lt;sup&gt;B&lt;/sup&gt;</td>
<td>80.92 ± 1.20&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
<tr>
<td>a&lt;sup&gt;*&lt;/sup&gt;-value</td>
<td>4.23 ± 0.39&lt;sup&gt;A&lt;/sup&gt;</td>
<td>4.09 ± 0.59&lt;sup&gt;A,B&lt;/sup&gt;</td>
<td>3.69 ± 0.63&lt;sup&gt;B&lt;/sup&gt;</td>
<td>4.06 ± 0.53&lt;sup&gt;A,B&lt;/sup&gt;</td>
<td>3.76 ± 0.53&lt;sup&gt;A,B&lt;/sup&gt;</td>
<td>4.15 ± 0.40&lt;sup&gt;A,B&lt;/sup&gt;</td>
</tr>
<tr>
<td>b&lt;sup&gt;*&lt;/sup&gt;-value</td>
<td>12.48 ± 0.85&lt;sup&gt;A&lt;/sup&gt;</td>
<td>11.38 ± 1.10&lt;sup&gt;D&lt;/sup&gt;</td>
<td>10.23 ± 0.62&lt;sup&gt;C&lt;/sup&gt;</td>
<td>11.44 ± 0.77&lt;sup&gt;A&lt;/sup&gt;</td>
<td>12.24 ± 0.37&lt;sup&gt;A&lt;/sup&gt;</td>
<td>12.64 ± 0.93&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooked pH</td>
<td>6.08 ± 0.02&lt;sup&gt;D&lt;/sup&gt;</td>
<td>6.14 ± 0.03&lt;sup&gt;C&lt;/sup&gt;</td>
<td>6.21 ± 0.02&lt;sup&gt;A&lt;/sup&gt;</td>
<td>6.18 ± 0.02&lt;sup&gt;B&lt;/sup&gt;</td>
<td>6.14 ± 0.03&lt;sup&gt;C&lt;/sup&gt;</td>
<td>6.08 ± 0.02&lt;sup&gt;D&lt;/sup&gt;</td>
</tr>
<tr>
<td>L&lt;sup&gt;*&lt;/sup&gt;-value</td>
<td>84.19 ± 0.94&lt;sup&gt;B,C&lt;/sup&gt;</td>
<td>86.09 ± 0.28A</td>
<td>86.18 ± 0.63&lt;sup&gt;A&lt;/sup&gt;</td>
<td>85.60 ± 0.84&lt;sup&gt;A,B&lt;/sup&gt;</td>
<td>84.86 ± 1.11&lt;sup&gt;B&lt;/sup&gt;</td>
<td>83.75 ± 0.64&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
<tr>
<td>a&lt;sup&gt;*&lt;/sup&gt;-value</td>
<td>1.24 ± 0.27&lt;sup&gt;A&lt;/sup&gt;</td>
<td>1.00 ± 3.67&lt;sup&gt;A,B,C&lt;/sup&gt;</td>
<td>0.90 ± 0.28&lt;sup&gt;A,C&lt;/sup&gt;</td>
<td>0.79 ± 0.10&lt;sup&gt;C&lt;/sup&gt;</td>
<td>1.04 ± 0.46&lt;sup&gt;B&lt;/sup&gt;</td>
<td>1.22 ± 0.11&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>b&lt;sup&gt;*&lt;/sup&gt;-value</td>
<td>11.57 ± 0.42&lt;sup&gt;A&lt;/sup&gt;</td>
<td>10.38 ± 0.15&lt;sup&gt;C&lt;/sup&gt;</td>
<td>10.21 ± 0.44&lt;sup&gt;C&lt;/sup&gt;</td>
<td>11.06 ± 0.28&lt;sup&gt;B&lt;/sup&gt;</td>
<td>11.43 ± 0.39&lt;sup&gt;A&lt;/sup&gt;</td>
<td>11.38 ± 0.27&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

All values represent mean ± SD of 3 replicates.  
<sup>A–D</sup>Means sharing different letters in the same row are significantly different (P < 0.05).  
<sup>1</sup>Hot-boning chicken breast muscle was mixed with salt concentration of 1, 2, 3, 4, and 5% within post-mortem 5 min, respectively.  
Control: 48% cold-boning chicken breast + 2% salt, T1: 49% hot-boning chicken breast mixed with 1% salt within post-mortem 5 min + 1% salt, T2: hot-boning chicken breast mixed with 2% salt within post-mortem 5 min, T3: 30% hot-boning chicken breast mixed with 3% salt within post-mortem 5 min + 20% cold-boning chicken breast, T4: 25% hot-boning chicken breast mixed with 4% salt within post-mortem 5 min + 25% cold-boning chicken breast, T5: 20% hot-boning chicken breast mixed with 5% salt within post-mortem 5 min + 30% cold-boning chicken breast.

ANOVA on all the variables. Duncan’s multiple range tests (P < 0.05) were used to determine differences among treatments.

RESULTS AND DISCUSSION

pH and Color

The pH and color of the presalted prerigor muscle combined with post rigor muscle are given in Table 2. The pH of T2 was the highest (P < 0.05). Although the same salt concentration was present in all the final meat emulsion systems, the results depended on the amount of salt added and the state of the muscles. Bernthal et al. (1989) reported that higher salt concentrations contributed to the formation of higher ultimate pH values in prerigor meat homogenates. Hamm (1977) indicated that the higher pH of salted prerigor meat, compared to post rigor meat, was due to the denaturation of glycolytic enzymes. Kim et al. (2012) reported that higher pH affected the quality of processed prerigor muscle. This result may have been seen in the current study’s treatments especially because a high pH was maintained before the pH of the meat was lowered with added salt, and lower pH post rigor muscle was not used.

The effect on lightness (L<sup>*</sup>), redness (a<sup>*</sup>), and yellowness (b<sup>*</sup>) values of salting the prerigor muscle and combining it with post rigor muscle was partially significant (P < 0.05). T2 (with 50% prerigor muscle pre-treated with 2% salt) had the highest lightness value of the raw samples, and the lightness values of the cooked samples were highest in T1 and T2. The T2 sample showed significantly lower redness of raw and cooked than the control with 48% cold-boned meat and 2% salt (P < 0.05). The yellowness values of the raw and cooked samples were highest in the control, T4, and T5 (P < 0.05). According to Farouk and Swan (1997), prerigor salted minces were darker and less yellow than unsalted ground due to increased lipid oxidation and protein denaturation in the muscle. Kim et al. (2011) reported that prerigor ground muscle mixed with 2% sodium chloride showed higher redness and lower lightness and yellowness values than prerigor ground muscle. Lee et al. (2012) indicated that the lightness of prerigor duck breast muscle was affected by prerigor salting; however, prerigor salting did not affect redness or yellowness compared with post rigor salted samples. In our results, prerigor salting levels and the ratio of prerigor and post rigor muscle seemed to affect color values.

Cooking Loss and Emulsion Stability

The effects of presalted prerigor muscle combined with post rigor muscle on cooking loss and emulsion stability are shown in Figures 1 and 2. The samples prepared with presalted prerigor chicken breast had significantly lower cooking loss than the control, except T5. The cooking loss for T2 and T3 were the lowest (P < 0.05) because these presalted prerigor samples had a higher pH and water-holding capacity. These results are consistent with those of Hamm (1981), who found that 2 to 4% salt in prerigor muscle was sufficient to see salting effects, and cooking loss was decreased because the salt added to prerigor muscle inhibited actomyosin formation. Lee et al. (2012) reported that a prerigor salting (2% salt) treatment showed the lowest cooking loss among the treatments they studied, indicating that the increased water-binding capacity caused by adding salt to prerigor muscle altered the net myofibrillar protein charge. According to Farouk and Swan (1997), batters prepared with prerigor salted mince had a lower cooking loss than those formulated with unsalted mince. Choi et al. (2009) found that a higher pH resulted in a lower cooking loss for prerigor chicken muscle because the addition of 2% salt raised the pH. In our study, the final model systems with 2% salt content, the initial salt concentration with an excess of prerigor
state and combined postrigor muscle had increased cooking loss.

In our current study, the emulsion stability of the presalted prerigor muscle combined with postrigor muscle differed significantly ($P < 0.05$) (Figure 2). The total expressible fluid separation tended to be similar to the cooking loss; total expressible fluid separation and fat separation were the lowest in T2 and T3 ($P < 0.05$). Similar results were reported by Choi et al. (2009), who reported that immediate curing in 2% salt concentration after hot boning showed the lowest emulsion stability among all treatments they studied. Sadler and Swan (1997) suggested that salting of prerigor beef muscle resulted in a higher pH and thus higher emulsion stability. Thus, combined hot- and cold-boned meat can be used effectively in chicken meat processing. Among the treatments we studied, the optimum mixing ratio was hot-boned (prerigor muscle) chicken breast mixed with 3% salt within 5 min postmortem and cold-boned chicken meat.

### Protein Solubility

Protein solubility is an effective indication of the degree of protein denaturation during processing (Choi et al., 2011), and it has been used to study functional properties of meat products. Muscle proteins
Figure 3. Effects of prerigor salting concentration on the protein solubility in the chicken emulsion model systems. □: sarcoplasmic protein solubility (mg/g), ■: myofibrillar protein solubility (mg/g), ▲: total protein solubility (mg/g). \textsuperscript{1)}Hot-boning chicken breast muscle was mixed with salt concentration of 1, 2, 3, 4, and 5\% within post-mortem 5 min, respectively. Control: 48\% cold-boning chicken breast + 2\% salt, T1: 49\% hot-boning chicken breast mixed with 1\% salt within post-mortem 5 min + 1\% salt, T2: hot-boning chicken breast mixed with 2\% salt within post-mortem 5 min, T3: 30\% hot-boning chicken breast mixed with 3\% salt within post-mortem 5 min + 20\% cold-boning chicken breast, T4: 25\% hot-boning chicken breast mixed with 4\% salt within post-mortem 5 min + 25\% cold-boning chicken breast, T5: 20\% hot-boning chicken breast mixed with 5\% salt within post-mortem 5 min + 30\% cold-boning chicken breast. \textsuperscript{a–e}Means sharing different letters are significantly different ($P < 0.05$). \textsuperscript{A–E}Means sharing different letters are significantly different ($P < 0.05$).

generally can be divided into sarcoplasmic (water soluble), myofibrillar (salt soluble), and stromal (insoluble) proteins, based on solubility properties. The effects of presalted prerigor muscle combined with postrigor muscle on protein solubility are shown in Figure 3. Sarcoplasmic protein solubility was apparently not affected in the samples containing combined presalted prerigor muscle and postrigor muscle ($P > 0.05$). The samples with presalted prerigor muscle combined with postrigor muscle did show greater myofibrillar protein and total protein solubilities than the control ($P < 0.05$). Myofibrillar protein and total protein solubilities were the highest in T2, T3, and T4 ($P < 0.05$). These results are consistent with a study indicating that prerigor salted muscle affects protein solubility in meat batters (Choi et al., 2009) and another study reporting that 2 to 4\% salted homogenates had higher protein solubility than 0 to 1\% salted treatments (Bernthal et al., 1989). Farouk and Swan (1997) reported that the increased protein extractability of prerigor muscle is related to myofibrillar protein (actin and myosin) solubility, which is soluble in salt. According to Lee et al. (2012), no significant difference was observed among all studied prerigor treatments, but prerigor salting led to a higher solubility of salt-soluble proteins than did postrigor salting. Generally, prerigor presalting is more related to salt-soluble protein solubility than water-soluble protein solubility (Hamm, 1981). Some studies have shown that meat’s protein solubility was affected by status and the part of raw meat, concentration and type of salt, pH, processing time and temperature, and additives (Choi et al., 2009; Xiong and Brekke, 1991). Although in the current study, the largest prerigor salting effect was observed with 2\% salt (T2), 3\% presalted prerigor muscle combined with postrigor muscle (T3) as well as 4\% pre-salted prerigor muscle combined with postrigor muscle (T4) showed similar results to T2.

**Apparent Viscosity**

An increase in apparent viscosity is related to an increase in emulsion stability. It is well known that high viscosity meat emulsion systems are not readily broken (Choi et al., 2013). The apparent viscosity of presalted prerigor muscle combined with postrigor muscle is presented in Figure 4. The apparent viscosity of all emulsified samples was higher than the control, and apparent viscosity was highest in T3 ($P < 0.05$). All emulsified samples showed thixotropic behavior with an apparent viscosity that decreased with an increase in rotation time. Some studies have suggested that determining the rheological properties of an emulsion, such as measurements of apparent viscosity, is a better predictor than chemical analyses of final products’ textural properties (Choi et al., 2014; Lee et al., 2008), that is, the quality characteristics of food products are related to their rheological attributes. Thus, from an analysis of the apparent viscosity of the emulsion batters, all emulsion quality parameters could be readily compared and assessed. Based on our results, the apparent viscosities of T2 and T3 indicated the most desirable final product quality.

**Texture Profile Analysis**

Texture profiles have been shown to be affected by heating time and temperature, salt-solution protein concentrates, and several added hydrocolloids in meat emulsion systems, as well as their interactions.
Figure 4. Effects of prerigor salting concentration on apparent viscosity; all values are mean of three replicates. 1) Control (□): 48% cold-boning chicken breast + 2% salt, T1 (■): 49% hot-boning chicken breast mixed with 1% salt within post-mortem 5 min + 1% salt, T2 (∆): hot-boning chicken breast mixed with 2% salt within post-mortem 5 min, T3 (▲): 30% hot-boning chicken breast mixed with 3% salt within post-mortem 5 min + 20% cold-boning chicken breast, T4 (●): 25% hot-boning chicken breast mixed with 4% salt within post-mortem 5 min + 25% cold-boning chicken breast, T5 (○): 20% hot-boning chicken breast mixed with 5% salt within post-mortem 5 min + 30% cold-boning chicken breast.

Table 3. Effects of prerigor salting concentration on textural properties.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Control</th>
<th>1% (T1)</th>
<th>2% (T2)</th>
<th>3% (T3)</th>
<th>4% (T4)</th>
<th>5% (T5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (N)</td>
<td>3.92 ± 0.49</td>
<td>4.50 ± 0.38</td>
<td>4.63 ± 0.47</td>
<td>4.68 ± 0.35</td>
<td>4.21 ± 0.28</td>
<td>3.92 ± 0.45</td>
</tr>
<tr>
<td>Springiness</td>
<td>0.87 ± 0.03</td>
<td>0.84 ± 0.04</td>
<td>0.86 ± 0.04</td>
<td>0.86 ± 0.04</td>
<td>0.87 ± 0.04</td>
<td>0.87 ± 0.05</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.54 ± 0.02</td>
<td>0.54 ± 0.03</td>
<td>0.55 ± 0.03</td>
<td>0.56 ± 0.04</td>
<td>0.56 ± 0.03</td>
<td>0.54 ± 0.03</td>
</tr>
<tr>
<td>Gumminess (N)</td>
<td>2.16 ± 0.30</td>
<td>2.45 ± 0.26</td>
<td>2.64 ± 0.27</td>
<td>2.56 ± 0.38</td>
<td>2.14 ± 0.31</td>
<td>2.15 ± 0.29</td>
</tr>
<tr>
<td>Chewiness (N)</td>
<td>1.85 ± 0.27</td>
<td>2.06 ± 0.31</td>
<td>2.24 ± 0.19</td>
<td>2.16 ± 0.45</td>
<td>1.87 ± 0.24</td>
<td>1.88 ± 0.29</td>
</tr>
</tbody>
</table>

All values are mean ± SD of 3 replicates.

1) Means sharing different letters in the same row are significantly different (P < 0.05).

The effects of presalted prerigor muscle combined with postrigor muscle on textural properties are shown in Table 3. Treatment 2 (T2) had the highest hardness and gumminess (P < 0.05), but hardness and gumminess were not significantly different between T2 and T3. The chewiness of T2 and T3 was the highest (P < 0.05). Springiness and cohesiveness were not significantly different among the treatments (P > 0.05). These results are consistent with the results obtained by Lee et al. (2012), who reported that the physicochemical properties of ground salted prerigor duck muscle indicated higher hardness, gumminess, and chewiness than postrigor muscle. Claus et al. (1989) suggested that increasing salt-soluble protein tends to increase the hardness of meat products. Mann et al. (1990) reported that recombined precooked beef roasts formulated with hot-boned muscle had higher hardness and chewiness values compared with those formulated with cold-boned muscle. Our results indicate that prerigor salting contributes to increased hardness and a simultaneous increase in gumminess and chewiness; prerigor muscle precured with 3% salt immediately after slaughter and then combined with postrigor muscle showed improved textural properties, similar
to presalting prerigor muscle (2% salt) within 5 min postmortem (T2).

In conclusion, this study was carried out to qualitatively evaluate different treatments of prerigor muscle presalted at different concentrations within 5 min postmortem combined with post rigor muscle. Presalted prerigor muscle combined with post rigor muscle correlated positively with physicochemical properties. In particular, hot-boned chicken breast mixed with 3% salt within 5 min postmortem and then combined with cold-boned chicken breast showed optimal quality; the combination of presalted hot-boned muscle and cold-boned muscle positively affected quality characteristics.

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