Cold-batter mincing of hot-boned and crust-freezing air-chilled turkey breast improved meat turnover time and product quality

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ABSTRACT The purpose of this research was to evaluate the combined effects of turkey hot-boning and cold-batter mincing technology on acceleration of meat turnover and meat quality improvement. For each of 3 replications, 15 turkeys were slaughtered and eviscerated. Three of the eviscerated carcasses were randomly assigned to water-immersion chilling for chill-boning (CB) and the remaining were immediately hot-boned (HB), half of which were used without chilling whereas the remaining were subjected to crust-freezing air chilling (CFAC) in an air-freezing room (1.0 m/s, −12°C) with/without ¼ sectioning (HB-¼CFAC, HB-CFAC). As a result, CB and HB breasts were minced using 1 of 5 treatments: (1) CB and traditional mincing (CB-T), (2) HB and mincing with no chilling (HB-NC), (3) HB and mincing with CO2 (HB-CO2), (4) HB and mincing after CFAC (HB-CFAC), and (5) HB and mincing after quarter sectioning and CFAC (HB-¼CFAC). Traditional water-immersion chilling took an average of 5.5 h to reduce the breast temperature to 4°C, whereas HB-CFAC and HB-¼CFAC took 1.5 and 1 h, respectively. The breast of HB-CFAC and HB-¼CFAC showed significantly higher pH (6.0–6.1), higher fragmentation index (196–198), and lower R-value (1.0–1.1; \( P < 0.05 \)) than those of the CB controls. No significant differences (\( P > 0.05 \)) in sarcomere length were seen between CB-T and HB-CFAC filets regardless of quarter sectioning. When muscle was minced, the batter pH (5.9) of CB-T was significantly lower (\( P < 0.05 \)) than those (6.1–6.3) of HB-NC, HB-CO2, and HB-¼CFAC, with the intermediate pH (6.0) seen for the HB-CFAC. When meat batters were cooked, higher cooking yield (90 – 91%; \( P < 0.05 \)) was found in HB-CFAC, HB-¼CFAC, and HB-CO2, followed by HB-NC (90%) and finally CB-T (86%). Stress values (47–51 kPa) of HB-CFAC gels were significantly higher (\( P < 0.05 \)) than those of CB-T (30 kPa) and HB-NC (36 kPa). A similar trend was found in strain values.

Key words: turkey, hot boning, crust freezing, cold-batter mincing, protein functionality

INTRODUCTION

Accelerated animal processing is always desirable to meat processors and packers. Hot-boning (HB) or pre-rigor processing removes muscles from an animal carcass before the body temperature is substantially chilled or before rigor mortis developed. The HB process has many advantages, such as energy savings, high throughput, improved processing yield, and reduced chilling time and space (Lyon and Hamm, 1986; McPhail, 1995; Troy, 2006). In addition, HB muscle produces superior quality meats compared with chill-boned (CB) muscle (Kastner, 1977; Cuthbertson, 1980; Dibble, 1993; Claus and Sorheim, 2006; Sorheim et al., 2006). When HB muscle was minced, more protein was extracted and higher water-holding capacity was obtained from that of CB muscle (Bernthal et al., 1989). The meat batter made with HB meat exhibited both higher emulsifying capacity and emulsion stability than that of CB muscle (Froning and Neelakantan, 1971; Hamm, 1982). Wyche and Goodwin (1974) reported a higher cooking yield for hot-cut broiler than for the chill-cuts.

The HB technique, however, has not been fully adapted by the red meat and poultry industries, except for fresh pork sausage, mainly due to the issues of synchronizing (HB line is faster than the typical further processing line), safety (fast microbial growth in hot and warm muscles), and extra cost (initial investment, facility modification, employee training, and so on; Pisula and Tyburcy, 1996; Troy, 2006). In poultry processing, HB has been further challenged because muscles have to be obtained and processed no later than ~30 min after slaughter due to the rapid onset of rigor mortis (Alberle et al., 2001).
In sausage mincing, raw meats are chopped with sodium chloride to extract tacky and adhesive muscle proteins. Regarding chopping, Brown and Toledo (1975) recommended that batter-mincing temperature should not be higher than 15°C at the end of chopping for a good quality of protein extraction. Upon reaching over 16°C, both water and fat are released from the batter, which resulted in finished product quality loss (Deng et al., 1976).

Comparing 5 temperatures, from −3.9 to 23.9°C, during a 6-min paste-mixing period, Gillett et al. (1977) reported that the optimum mincing temperature for protein extraction was 7.2°C. A loss of protein functionality from over-chopping was likely associated with irreversible protein denaturation. Conversely, Hamm (1966) stated that no major changes occurred in chemical-colloidal or binding properties of protein at mixing temperatures below 30°C. When prerigor meats were salted and ground in the presence of carbon dioxide, Sørheim et al. (2006) observed that the resulting patty had higher pH, lower cooking loss, and firmer texture than those of postrigor controls.

Cold-batter mixing is an emerging technology that improves protein functionality when meat is minced at subfreezing temperatures for a long period. Cold-batter mincing of hot-boned and crust-freezing-air-chilled muscles (HB-CFAC) appears to have 4 major advantages: (1) rapid meat turnover for high throughput, (2) no synchronization issues through rapid chilling of the muscles, (3) availability of prerigor quality meat at any time and any place, and (4) no issues of muscle thawing and thaw-rigor contraction. Regarding batter mincing at different temperature and time, Bard (1965) reported 3 interesting results of protein extraction: (1) the extraction of salt-soluble proteins from postrigor meat proportionally increased as the extraction time was extended up to 15 h, (2) protein extraction dramatically increased in the range of −5 to 2°C compared with temperatures higher than 2°C, and (3) muscle protein extraction from prerigor meat during 15 min of mixing was greater than that of postrigor muscle extracted for 15 h. The purpose of the current research was to evaluate the potential for HB-CFAC filets to improve meat turnover and the effect of cold-batter mincing on protein functionality of the HB-CFAC gels.

**MATERIALS AND METHODS**

**Turkey Slaughter and Carcass Chilling**

In each of 3 visits, on 3 different days, 15 Nicholas tom turkeys (approximately 16 wk old, ~18 kg of turkey in live weight) were obtained locally and processed in the Michigan State University Meat Laboratory on 3 different days. The birds were electrically stunned for 6 s (80 mA, 60 Hz, 110 V) and bled for 90 s by severing both the carotid artery and jugular vein on one side of the neck. The turkeys were then scalded (59°C, 120 s), mechanically defeathered (25 s), and manually eviscerated. After washing, carcasses were weighed and their internal temperatures were recorded from the center of the turkey breast using a digital thermometer and logger (model 800024, Sper Scientific Ltd., Scottsdale, AZ). Three out of 15 carcasses were randomly subjected to an ice slurry tank (0.5°C) for water-immersion chilling (WIC; Figure 1A, A') with mechanical agitation (0400–025GV1S portable agitator, GrovTac Inc., Brookfield, WI). The breasts of the remaining birds were HB, half of which was subject to immediate grinding with and without CO₂ addition, whereas the remaining half was delivered to an air-freezing room (1.0 m/s, −12°C) for crust-freezing and air-chill without (Figure 1B, B') and with quarter sectioning of the breast half (Figure 1C, C'). The core temperatures of breasts water chilling (whole carcass) and air chilling (breast half and quarter breast half) were recorded every 5 min until reaching 4°C. Breast samples (1 cm thickness at one-third from the anterior) were obtained before and after chilling and immediately quick frozen (IQF) for analyzing pH, R-value, and fragmentation index (FI), as described below.

**pH, R-value, Sarcomere Length, and FI**

The pH value of breast muscle was measured with a pH electrode (model 13–620–631, Fisher Scientific Inc., Houston, TX) attached to a pH meter (Accumet AR15, Fisher Scientific Inc., Pittsburgh, PA) using the iodoacetate method of Sams and Jancky (1986). R-value (ratio of inosine:adenosine) was assessed as an indicator of adenosine triphosphate (ATP) depletion in the muscle using the method of Thompson et al. (1987). Sarcomere length was evaluated for the status of muscle contraction using a laser diffraction method (Cross et al., 1980). Fragmentation index was measured for the degree of muscle aging using the method of Olson et al. (1976).

**Breast Mincing and Gel Preparation**

In the current study, turkey breast muscle was selected because it is the most valuable and largest muscle in turkey. Immediately after HB, the breast meat (78% of batch weight) was minced for 7 min with 2% salt and 20% tap water for no-chill mincing or 4% ice and 16% water and dry ice (enough for maintaining at about −2°C) for CO₂ chill mincing using a food cutter (256 rpm, model 84181, Hobart, Troy, OH). Similarly, CB breast halves were minced with 2% salt and 4% ice and 16% water for traditional-mixing, whereas HB-CFAC breasts (breast halves or quarter breast halves) were minced with 2% salt and 20% ice for cold mincing. As a result, breast filets were minced in 1 of 5 different mincing treatments: (1) CB and minced traditionally (CB-T), (2) HB and minced with no chilling (HB-NC), (3) HB and minced with CO₂ (HB-CO₂), (4) HB and

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minced after crust-freezing air chilled (HB-CFAC), and (5) HB and minced after quarter sectioning and crust-freezing air chilled (HB-¼CFAC). Samples (50 g) of minced batters were subjected to IQF for pH evaluation. After mincing, batters were turned into cooked gels using the method of Jeong et al. (2011b). Briefly, batters were stuffed into preweighed stainless steel cylindrical tubes, reweighed, and put into a water bath (model 25, Precision Scientific Co., Chicago, IL) at 80°C for 20 min. After cooking, the tubes were immediately chilled in ice/water slurry, sealed in plastic bags, and stored overnight in a refrigerated room (3°C).

Cooking Yield and Torsion Test

After chilling, the 4 parts of cooked tube (stuffed tube, empty tube, removed gel, and tube cap) were individually weighed to determine cooking yield, which was calculated by (cooked gel weight)/(raw gel weight) × 100. For the torsion test, the chilled gels were warmed at room temperature for 2 h and then cut perpendicularly by 3.0 cm, to which styrene disks were glued. The samples were then milled into a dumbbell shape (10 mm in diameter at the midsection) by using a shaping machine (KCI-24A2, Bodine Electric Co., Raleigh, NC). Each specimen was placed on the sample holding apparatus in a viscometer (DV-III Ultra, Brookfield Engineering Laboratories Inc., Middleboro, MA) and twisted at 2.5 rpm. At the breaking point, both shear stress and shear strain were calculated with the recorded torque and elapsed time using the equations of Hamann (1983). Ten samples were evaluated for each treatment for 3 separate replications.

Statistical Analysis

All experiments were conducted for 3 times. Data were evaluated by one-way ANOVA, using PASW 18 statistic program and a completely randomized design. A post-hoc analysis was performed using Duncan’s multiple range test to evaluate difference among treatments (P < 0.05; SPSS, 2011).

Figure 1. Water immersion chill (WIC) of whole turkey carcass and crust-freezing air chill (CFAC) of hot-boned (HB) breast with and without a quarter section. A = whole turkey carcass; A’ = WIC; B = HB breast half; B’ = HB/CFAC; C = HB quarter-sectioned breast; C’ = HB quarter-sectioned-CFAC breast. Color version available in the online PDF.
RESULTS AND DISCUSSION

The carcass temperature after evisceration was 40.5°C, which continuously decreased in ice slurry chilling to 4°C with an average chilling time of 5.5 h (approximately 0.2°C; Figure 1A, A'). When breasts were HB and chilled in the air-freezing room (1 m/s, −12°C), the average chilling times were 1 and 1.5 h, respectively, for the HB-CFAC filets without (Figure 1B, B') or with quarter sectioning (Figure 1C, C'). Sams (1999) indicated that turkeys take 3 to 6 h to reduce the postmortem carcass temperature to 4°C in WIC depending on their body size. Sams and McKee (2011) reported that air is 25 times less efficient than water in heat exchange, which explains why air chilling took longer than WIC for turkey and broiler meat (James, 2003; Jeong et al., 2011a,b). The heat removal from the food surface is a direct function of the surface heat transfer convection coefficient (h), which ranges from 5 W/m²°C for slow-moving air to 500 W/m²°C for agitated water (James, 2003). Nevertheless, one of major advantages of air chilling is the temperature adjustment to the levels of water freezing or lower by varying the air speeds.

The reduction of traditional turkey chilling time from 4 to 6 (whole carcasses) to 1 h (HB filets) can accelerate the turkey processing so producers can minimize or eliminate the synchronizing issue between the slaughtering and processing lines, with reduced labor, lowered maintenance costs, and minimized chilling space (personal communication, plant manager, Michigan Turkey producers co-op). More interestingly, the rapid-chilling method may reduce the occurrence of the pale, soft, and exudative (PSE)-like condition in turkey, which is induced by the combination of high postmortem muscle temperature and rapid pH reduction, causing the annual loss of over $200 million in the turkey industry (Owens et al., 2000). McKee and Sams (1998) reported that pale meat was seen in turkey when immersed in water at 40 rather than 0°C. Alvarado and Sams (2002) also found that product integrity was negatively affected in turkey carcasses when chilling was delayed or conducted slowly.

Turkey breast pH ranged from 6.28 to 6.35 immediately after HB (Table 1), indicating that they are normal (pH > 6.0 at 15 min postmortem) rather than rapid glycolyzing breasts (pH ≤ 5.80) according to the report of Rathgeber et al. (1999). After 5.5 h of WIC, the breast pH decreased to 5.82, which was significantly lower (P < 0.05) than those of 1.5-h HB-CFAC (5.99) and 1-h HB-¼CFAC (6.12; Table 1). Owens et al. (2000) indicated that the breast pH (6.09) of normal turkey (47 L*) was higher than that (5.72) of pale turkey (56.9 L*) at 1.5 h postmortem. Marsh and Thompson (1958) reported that glycolysis proceeds slowly with ATP depletion in lamb muscle at −5°C, which supports the higher muscle pH seen in turkey breast at −12°C as opposed to 0°C in our study. The combination of rapid early pH decline (0.5–1 h) and high body temperature (~37°C) is detrimental to protein functionality (water-holding capacity and texture cohesiveness) and visual appearance (Bendell and Wismer-Pedersen, 1962; Warriss and Brown, 1987; Offer, 1991).

The R-value (the ratio of inosine:adenosine-containing compounds) of HB breasts ranged from 0.87 to 0.98 (Table 1). After CFAC, the value increased to 0.99 to 1.08, which is significantly lower (P < 0.05) than that (1.31) of WIC filets, indicating that ATP was less depleted in the air-chilled breasts at −12°C (Table 1). In accordance with our results, Owens and Sams (1997) reported that the R-value of turkey breasts after 2 h of WIC was 0.94, which increased to 1.11 and 1.21, respectively, at 8 and 24 h postmortem. McKee and Sams (1998) indicated that a higher R-value was seen in the turkeys subjected to 40°C water than those subjected to 20 and 0°C water from 15 min through 4 h postmortem.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CB-T</th>
<th>HB-NC</th>
<th>HB-CO₂</th>
<th>HB-CFAC</th>
<th>HB-¼CFAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH before chill</td>
<td>n/a</td>
<td>6.28 ± 0.14</td>
<td>6.25 ± 0.15</td>
<td>6.22 ± 0.09</td>
<td>6.35 ± 0.13</td>
</tr>
<tr>
<td>pH after chill</td>
<td>5.82 ± 0.18</td>
<td>n/a</td>
<td>5.99 ± 0.09</td>
<td>6.12 ± 0.16</td>
<td></td>
</tr>
<tr>
<td>R-value before chill</td>
<td>n/a</td>
<td>0.97 ± 0.21</td>
<td>0.98 ± 0.13</td>
<td>0.93 ± 0.10</td>
<td>0.87 ± 0.28</td>
</tr>
<tr>
<td>R-value after chill</td>
<td>1.31 ± 0.13</td>
<td>n/a</td>
<td>1.08 ± 0.10</td>
<td>0.99 ± 0.28</td>
<td></td>
</tr>
<tr>
<td>Sarcomere length after chill</td>
<td>1.84 ± 0.11</td>
<td>1.24 ± 0.10</td>
<td>1.32 ± 0.02</td>
<td>1.82 ± 0.08</td>
<td>1.85 ± 0.06</td>
</tr>
<tr>
<td>Fragmentation index after chill</td>
<td>179 ± 3.05</td>
<td>194 ± 7.22</td>
<td>298 ± 4.70</td>
<td>196 ± 7.52</td>
<td>198 ± 18.72</td>
</tr>
</tbody>
</table>

*Means within a column with different superscripts are different (P < 0.05).
**The number of observations in each chilling (n = 10–15).
1CB-T = chill-boned filets (after water immersion chilling) for mincing traditionally.
2HB-NC = hot-boned filets for mincing with no chilling.
3HB-CO₂ = hot-boned filets for mincing with CO₂.
4HB-CFAC = hot-boned and crust-freezing air-chilled filets for mincing in cold temperatures.
5HB-¼CFAC = hot-boned, quarter-sectioned, crust-freezing air-chilled filets for mincing in cold temperatures.
6n/a = not applicable.
were not different from each other (Table 1). Muscles of high ATP or low R-value are likely to be shortened during chilling due to the high energy requirements for muscle contraction. It is also known that bone-attached muscles are less shortened than deboned muscles before rigor mortis development. Regarding aging temperature, Papa and Fletcher (1988) indicated that the least muscle shortening occurred at 16°C, whereas most shortening was seen at 0 or 40°C at 2 h postmortem. The rapid air-chilling at −12°C was reported to induce cold shortening in broiler carcasses with pH values ≥6.70 at 15 min postmortem, although shear force value of the carcass was 1.00 kg/cm² lower than those chilled in air at 0°C (Dunn et al., 1995). Owens and Sams (1997) noticed that electrically stimulated turkey filets had significantly longer sarcomere lengths than those of the unstimulated control due to the fast depletion of ATP during stimulation. After chilling, no sarcomere difference was found between the filets of WIC control at 0.5°C and HB-CFAC at −12°C regardless of quarter sectioning. These results are partially explained by the gravimetric stretch during hanging for crust-freezing of HB filets (Figure 1C’), in addition to the least exposure to the most muscle-shortening temperatures (0, 40°C) and the most exposure to the least muscle-shortening temperature (16°C; Papa and Fletcher, 1988; Figure 2). Prevention or mitigation of sarcomere shortening was noticed when breast muscle was physically stretched by tying both wings toward back of carcasses (Papa et al., 1989; Janky et al., 1992; Walker et al., 1994). In beef, Simmons et al. (1999) also reported that the longissimus thoracis muscle had a significantly lower shear force, when stretched by 20%, than the nonstretched control.

Fragmentation index is inversely related with the level of muscle aging or protein degradation rather than physical tearing of muscle fibers (Birkhold and Sams, 1993, 1995). The FI (178.6) of CB filets was significantly lower than the FI (193.5–200) of HB filets, regardless of CFAC (Table 1). The low value expected from the aging that occurred during 5.5 h of WIC, whereas the HB and HB-CFAC filets had almost no or short aging times, respectively. Owens and Sams (1997) reported that FI was reduced from 186.9 to 164.5 as the harvest of turkey breast was delayed from 2 to 24 h postmortem. Veeramuthu and Sams (1999) showed that both calpain activity and FI were gradually decreased as broiler carcasses were aged up to 24 h.

During batter mincing for 7 min, the initial temperature (2°C) of CB filets gradually increased to 10°C, whereas the initial temperature (−2.5°C) of HB-CFAC filets remained similar (−2.0°C) regardless of quarter sectioning. In HB filets, the filet temperature (40°C) significantly reduced during mincing, to −2.0 and 25°C with and without CO2 addition, respectively (Table 2). Upon the completion of batter mincing, the pH (5.87) of CB-T batter was lower (P < 0.05) than those (6.07–6.26) of HB-NC, HB-CO2, and HB-¼CFAC, with the intermediate pH (6.0) seen for HB-CFAC (Table 3). Sorheim et al. (2006) reported that the pH of CB beef batter was slightly lower (P < 0.05) than that of HB batter mixed with CO2. When the minced batters were stored at 4°C overnight, the pH (5.90–5.92) of CB-T and HB-¼CFAC were lower (P < 0.05) than those (6.06–6.10) of HB-WC and HB-CO2, with the intermediate pH (5.97) seen for HB-CFAC (Table 3).

When the batters were cooked, the cooking yield was increased in a step-wise manner from 86.1% in CB-T
to 89.7% in HB-WC, and to 90.2 to 91.3% in the rest of the HB filets. Similarly, higher cooking yield (~97%) was reported in beef patties from prerigor and CO₂ chilling as opposed to that (88.8%) of the postrigor control (Sørheim et al., 2006). The property of cooked gels was assessed using a torsion test, in which the failure shear stress (a measure of gel strength) and the true shear strain (a measure of gel deformability) are correlated with sensory hardness and cohesiveness, respectively (Hamann and Lanier, 1987). The stress values (47.7–50.9 kPa) of HB and chilled meat gels (HB-CO₂, HB-CFAC, and HB-¼CFAC) were greater ($P < 0.05$) than those (29.6–36.0 kPa) of CB or HB and nonchilled meat gels (Table 3). Similarly, the strain values (1.58–1.67) of HB and chilled meat gels were higher than that (1.21) of the CB control, with the intermediate (1.52) seen for the HB nonchilled.

In support of our findings in CB gels, Rathgeber et al. (1999) indicated that stress and strain values for normal glycolyzing turkey breasts (pH > 6.0 at 15 min postmortem) were significantly higher than those of rapid glycolyzing breast (pH ≤ 5.8 at 15 min postmortem). Alvarado and Sams (2004) showed that slow rates of turkey chilling at 30°C resulted in reduced gel strength, greater cook loss, greater lightness (L* value), and lower pH that those of filets chilled at 0°C. Jeong et al. (2011b) also reported stress (25.6 kPa) and strain (1.3) values from CB broiler breast gels that were similar to our findings in turkey gels. Delaying of initial carcass chilling reduced both stress and strain values of turkey breast gels, potentially due to low protein extractability for protein to form gels (Rathgeber et al., 1999). The strength of PSE meat gels was reported to be 45% of that from normal pork gels in the same protein concentration (Camou and Sebranek, 1991).

The results of our study indicated that the combination of HB and crust-freezing air chill on turkey breast provides various advantages, such as an accelerated HB process, rapid meat turn-over, high-quality meat, high cooking yield, and superior protein functionality. Based on these results, the combination of cold-mincing and crust-freezing air chill could be a viable processing method for academic research and industrial application. Additional research is required to evaluate how effectively and practically the technology can be further developed and implemented for the purposes of superior quality meats at any time and any place, improved protein functionality, sodium reduction, PSE prevention, cure penetration and distribution, and cost savings.

In conclusion, commercial availability of prerigor meat has been a key issue in adapting prerigor technology. The quality of prerigor meat, although superior in protein functionality, declines as rigor mortis develops when meat processing is delayed. No method has been developed to maintain the prerigor quality except rapid processing, grinding with high salt, or freezing of the meat. The results of this study indicate that the combination of muscle portioning and crust-freezing and air chilling maintained the quality of prerigor muscle.

### Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CB-T</th>
<th>HB-NC</th>
<th>HB-CO₂</th>
<th>HB-CFAC</th>
<th>HB-¼CFAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before mincing (raw meats)</td>
<td>2 ± 2</td>
<td>40 ± 2</td>
<td>40 ± 2</td>
<td>−2.0 ± 1</td>
<td>−2.0 ± 1</td>
</tr>
<tr>
<td>After 7 min of mincing (batter)</td>
<td>10 ± 1</td>
<td>25 ± 1</td>
<td>−2.0 ± 1</td>
<td>−2.0 ± 1</td>
<td>−2.0 ± 1</td>
</tr>
</tbody>
</table>

1 The number of observations in each chilling and mincing (n = 10–15).
2 Chilling and mincing conditions as in Table 1.
3 CB-T = chill-boned filets (after water immersion chilling) for mincing traditionally.
4 HB-NC = hot-boned filets for mincing with no chilling.
5 HB-CO₂ = hot-boned filets for mincing with CO₂.
6 HB-¼CFAC = hot-boned, quarter-sectioned, crust-freezing air-chilled filets for mincing in cold temperatures.

### Table 3

<table>
<thead>
<tr>
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<th>HB-NC</th>
<th>HB-CO₂</th>
<th>HB-CFAC</th>
<th>HB-¼CFAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batter pH after mincing</td>
<td>5.87 ± 0.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.12 ± 0.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.26 ± 0.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.00 ± 0.09&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>6.07 ± 0.13&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Batter pH after overnight storage</td>
<td>5.90 ± 0.18&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.06 ± 0.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.10 ± 0.13&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.97 ± 0.09&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.92 ± 0.16&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cooking yield (%)</td>
<td>86.1 ± 0.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.7 ± 0.21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>90.3 ± 0.13&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>90.2 ± 0.10&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>91.3 ± 0.28&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Stress (kPa)</td>
<td>29.6 ± 0.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>36.0 ± 0.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.7 ± 0.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>48 ± 0.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>51 ± 0.28&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Strain</td>
<td>1.21 ± 0.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.52 ± 0.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.67 ± 0.10&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.58 ± 0.10&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.61 ± 0.10&lt;sup&gt;ab&lt;/sup&gt;</td>
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<sup>a</sup>–<sup>c</sup>Means within a column with different superscripts are different ($P < 0.05$).
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6 HB-¼CFAC = hot-boned, quarter-sectioned, crust-freezing air-chilled filets for mincing in cold temperatures.
As a result, the prerigor quality meat becomes a more flexible solution in various applications, especially for the cold-mixing process. Previously, the processing of prerigor muscle has been conducted rapidly on site, which creates many problems, such as line speed synchronization, microbial growth upon delay, chilling cost with dry ice, and facility modification with employee training. The new method suggested in the current study appears to solve many issues while maintaining the functional property of prerigor meats.

ACKNOWLEDGMENTS

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REFERENCES


