Use of Cold-Set Whey Protein Gelation to Improve Poultry Meat Batters

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ABSTRACT

The effect of using preheated whey protein isolate (WPI) to replace part of the poultry meat proteins in batters formulated with different salt levels was studied. Substitution with 2% preheated whey proteins followed by cold set gelation (16 h at 1 °C) significantly \((P < 0.05)\) improved binding and water holding capacity of the raw batters. In the cooked state, WPI substitution reduced cook loss and improved textural parameters, especially at \(\leq 1.5\%\) salt. Unheated whey proteins (i.e., lacking the ability to gel at low temperature) did not exhibit a negative effect on the texture of the cooked batters, but reduced water holding capacity of the raw batters. Overall, cold setting of WPI improved the binding of raw and cooked meat batters, particularly at low salt level.

(Key words: whey protein isolate, meat batters, cook loss, texture, water holding capacity)

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INTRODUCTION

Salt-soluble myofibrillar proteins, such as myosin and actin, are responsible for the formation of an elastic gel matrix in meat products (Lanier, 1991). Factors affecting gel characteristics include pH, ionic strength, protein extractability, amount of connective tissue, and heating conditions. Modifying these parameters can change the microstructural and viscoelastic properties of the meat products (Aguilera and Stanley, 1993). Nonmeat ingredients such as carbohydrates and plant proteins may be used to alter the type of gel formed (Lanier, 1991). Such ingredients are used to improve yield, modify textural properties, and reduce costs of various meat formulations (Hung and Smith, 1993). Nonmeat proteins such as soybeans, egg, and whey, can usually enhance the gel characteristics; however, sometimes they exhibit negative effects (Foegeding and Lanier, 1989). Burgarella et al. (1985) reported that egg white and whey protein substitutions interfered with fish protein gelation in surimi. The workload values required to penetrate the fish + egg white and fish + whey gels were lower than those obtained for each single protein gel system by itself. This reduction in gelation could have been a dilution effect of the nonfish proteins or may have resulted from the fact that whey and egg white proteins become reactive at temperatures above the gelation temperature of fish (65 to 75 °C vs 45 to 55 °C, respectively), and therefore formed mixed gels that were weaker (Foegeding and Lanier, 1989). Lanier (1991) reported that substituting whey protein concentrate for surimi proteins increased gel strain at failure, suggesting a synergistic interaction between the two proteins. The same substitution with whole milk proteins destabilized the gel structure (lower rigidity and strain values), indicating incompatibility. Therefore, studies focusing on the contribution of specific nonmeat proteins in meat batters are needed.

“Gluing” meat particles together is essential in the production of minced and restructured meat products. Surimi production relies on a cold set phase in which an endogenous transglutaminase polymerizes some of the actomyosin molecules (Numakura et al., 1985) and improves the textural characteristics of the final product. However, transglutaminase is not functional in poultry or red meat at the level present in the muscle. In restructured red meat products, gums such as alginate (i.e., carbohydrate gum) have been used for binding at cold temperature (U.S. Patent 4,603,054, 1986; Ensor et al., 1989), which is important in holding the product together prior to cooking. The ability of whey proteins to form cold set gels has been demonstrated more recently (U.S. Patent 5,217,741, 1993). Preheated whey protein isolate (WPI) can form a gel at a low protein concentration (5 to 6%) and low temperature (1 to 3 °C) in the presence of salt (Hongsprabhas and Barbut, 1997). Therefore, it should be possible to benefit from cold gelation in a meat system in which, preheated WPI could provide some binding prior to cooking. Whey protein gels formed at low temperature and salt level...
are more transparent and less rigid than gels formed at higher temperatures and salt concentration. This difference indicates that the mechanism of WPI gelation could be manipulated by modifying the ionic strength of the system and, hence, change the gel characteristics. Thus, the objective of this study was to examine the effect of salt concentration and preheated WPI on the characteristics of poultry meat batters.

**MATERIALS AND METHODS**

**Sample Preparation**

Hand-deboned chicken breast meat (12 kg) obtained from a local processing plant was trimmed of all visible fat and connective tissue. The meat was chopped in a bowl chopper at low speed for 5 min; temperature did not exceed 8 C. The homogeneous mass was vacuum packed in 3-kg bags and kept frozen (−20 C) for up to 4 wk prior to use. Proximate analysis of the raw meat (AOAC, 1984) were determined in duplicate. Average moisture, protein, fat, and ash contents were 75.33, 21.84, 1.61, and 1.05%, respectively.

Whey protein isolate (90.5% protein by Macro Kjeldahl using the N factor of 6.38) suspensions (10% protein wt/vol) were prepared in double distilled water at pH 7 and degassed to remove air bubbles. Half of the suspensions were preheated in 25-mm diameter test tubes at 80 C for 30 min and then cooled to room temperature for 2 h; the other half were kept unheated (control) at 1 C. Prior to each experiment, the meat was thawed overnight at 1 C. Salt (NaCl; 0 to 2%) was added to the meat (400 g per treatment) and mixed by hand for 1 min followed by adding chilled double distilled water or WPI suspensions (preheated or unheated) and mixed for another 4 min. Treatments consisted of: 1) meat only, formulated with 16% protein; 2) preheated whey protein:meat protein = 2:14; and 3) unheated whey protein:meat protein = 2:14. All mixtures contained 16% protein (wt/wt). Twenty gram portions were stuffed into 50-mL polycarbonate centrifuge tubes. The tubes were divided into two sets. The first was used for precooking and the second for postcooking evaluation. Both sets were kept for 16 h at 1 C to allow cold-set gelation of the WPI.

**Water Holding Capacity**

Water holding capacity (WHC) was evaluated by centrifuging 20 g samples at 15,000 × g for 20 min. The supernatant was weighed and percentage WHC was calculated as the ratio of supernatant to sample weight prior to centrifugation.

**pH**

The pH of the raw and cooked batters was determined by a spear tip probe attached to a Chemcadet J-598 pH meter.

**Color**

Hunter “L” (lightness), “a” (redness) and “b” ( yellowness) values of the raw and cooked batters were determined with a Chroma Meter CR-200b using the method described by McCurdy et al. (1996). Briefly, the Chroma Meter’s glass window was placed in direct contact with either the raw meat batters or a fresh cut surface of the cooked product (n = 2 per treatment).

**Rheological Properties**

The back extrusion method (Hickson et al., 1982) was used to evaluate penetration force. A 20-mm diameter steel rod mounted on a Nene Texture Analyzer was used to penetrate the raw and cooked meat batters stored in the polycarbonate test tubes (inside diameter 25.85 mm) at a constant speed of 10 mm/min to a depth of 10 mm. Penetration force is expressed as the force (Newtons) required to rupture the batter. In addition, distance the probe traveled prior to breaking the sample is reported as distance to rupture (millimeters).

**Cooking**

The second set of samples were heated in a water bath equipped with a temperature programmer at 1 C/min to 78 C, cooled down to room temperature for 2 h, and stored overnight at 1 C.

**Cook Loss**

Liquid separating from the batters was measured immediately after heating and expressed as the ratio of moisture expelled to sample weight prior to cooking × 100.

**Statistical Analysis**

A randomized complete block design was used with two replicates. Results were analyzed by the ANOVA procedure of SAS® (SAS Institute, 1990). Differences among treatment were determined by the Least Significance Differences procedure using P ≤ 0.05, the treatment by replicate interaction was used as the error term.

**RESULTS AND DISCUSSION**

Statistical analysis indicated that WPI substitution, either in the preheated or unheated form, significantly
(P < 0.05) affected pH, WHC, color, cook loss, and rheological properties of the raw and cooked meat batters. Salt concentration significantly (P < 0.05) affected WHC, color, cook loss, and penetration force of the raw and cooked batters. There was no significant difference between replications (P > 0.05).

The preheated WPI went through a cold gelation phase during the incubation period (16 h, 1 C) and significantly (P ≤ 0.01) increased the penetration force of all the raw meat batters to which it was added (Figure 1). This is a desirable characteristic in the production of restructured meat products as it can bind the small meat particles prior to cooking. In the past, one way to achieve binding prior to heating was by using a carbohydrate gum such as alginate (Ensor et al., 1989), which can gel at low temperature in the presence of calcium salt; however, this is a patented process (U.S. Patent 4,603,054, 1986). Data in the present study suggest that preheated WPI can also be used to provide binding prior to cooking. The binding seen in Figure 1 was significantly higher in the no salt added treatment. This effect occurs mainly because high salt content induces the formation of large WPI aggregates in a pure WPI system (Barbut, 1995). The large aggregates (size determined by scanning and transmission electron microscopy) form softer gels than the fine protein strands induced by low salt concentration. Adding unheated WPI showed a trend (Figure 1) of lowering the gel strength of the control treatments (i.e., no WPI added). The treatment in which no salt was added to unheated WPI is not presented on the graph because it was too soft (< 0.2 N) to obtain a reading.

Water holding capacity significantly increased when preheated WPI was added to the no and low salt meat batters (Figure 2). A 23% increase was observed in the no salt treatment and an 8% increase was observed for the 1% salt treatments. At the 1.5 or 2.0% salt level, there was no significant improvement in WHC, mainly because enough salt soluble proteins (actin, myosin) were extracted by these salt levels. Schults and Wierbicki (1973) have also shown that raising the salt from 0 to 1% reduced cooking shrunk of minced chicken meat from 35 to 18%; however, using 2 or 5% salt resulted in 16% shrink. Adding unheated WPI to the meat batters significantly decreased WHC in the raw stage compared to the control with no WPI or the preheated WPI added treatments (Figure 2). The reduction might have been caused by interference of the unheated (non-gelling) WPI within the meat matrix.

Distance to rupture decreased when salt was added to either the no-WPI or preheated-WPI added treatments (Table 1), indicating that the gels became less elastic as salt was added. This result is in agreement with Barbut and Mittal (1989), who indicated that when more salt-soluble proteins are extracted, raw poultry meat batters become more rigid.

The color of the raw meat batters became darker with increasing salt levels in all treatments, as evident by the decrease in “L” values (Table 1). The reason for this color change is most likely the extraction of more myofibrillar proteins as salt level increased (Gordon and Barbut, 1992; Smith and Rose, 1995). The intact structure of the proteins within the sarcomere scattered more light before extraction (Swatland, 1989) and scattering was reduced as the proteins were gradually dissolved (Swatland and Barbut, 1999). This protein dissociation also seems to contribute to the decrease in the “b” values (Table 1). The “a” value (redness), which is mainly a function of the red pigment myoglobin, was hardly affected by either the salt or WPI treatments. It should be mentioned that the pH was not significantly (P > 0.05) changed by salt addition (5.93 for the no salt and 6.00 for the 1.0, 1.5, and 2.0% salt in the raw meat batters). The pH of both the un- and preheated WPI added treatments was slightly higher (6.04 to 6.07). After cooking, there were no significant color differences among the treatments; the values ranged from 80 ± 1.5 for “L”, 1.6 ± 0.4 for “a”, and 6.3 ± 1.2 for “b”.
Cook losses were greatest in the control treatments (no WPI added), followed by the unheated and the preheated WPI groups (Table 2). Cook loss was significantly reduced when preheated WPI was used. This result is similar to the trend observed for WHC in the raw batters. The most pronounced reduction was in the case of the 1.5% salt treatment with preheated WPI substitution (a 15 times reduction; from 19.67 to 1.23%).

The low cook losses of treatments with preheated WPI demonstrates again the beneficial effect of using cold-set gelation in minced poultry meat batters. Cooking the meat batters significantly increased the penetration force and distance to rupture of all treatments (Table 2). Distance to rupture the cooked batters was not appreciably affected by salt and WPI substitution level. The highest penetration force values were obtained for the preheated WPI treatments. The greatest contribution of the preheated WPI was seen in the no salt added group (i.e., 15.11 vs 39.47 N for the no WPI and the preheated WPI treatments, respectively), followed by the 1.0, 1.5, and 2.0% salt treatments. The penetration force required for the preheated WPI treated samples with no salt was not significantly different from all the other salt added treatments. This result highlights the contribution of cold gelation to the texture development of no salt meat batters. Hongsprabhas and Barbut (1997) have indicated that a 2% preheated WPI solution does not form a self-supporting gel by itself even after...

### Table 1. Effect of whey protein isolate (WPI) substitution and NaCl concentration on functional properties of incubated (16 h, 1 C) raw chicken breast meat batters.

All treatments formulated with 16% protein

<table>
<thead>
<tr>
<th>Treatment</th>
<th>NaCl (%)</th>
<th>Distance to rupture (mm)</th>
<th>“L”</th>
<th>“a”</th>
<th>“b”</th>
</tr>
</thead>
<tbody>
<tr>
<td>No substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td></td>
<td>2.62^b</td>
<td>62.15^a</td>
<td>3.05^a</td>
<td>8.75^a</td>
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<tr>
<td>1.0</td>
<td></td>
<td>1.83^b</td>
<td>52.40^cd</td>
<td>2.85^ab</td>
<td>6.35^bc</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>1.73^b</td>
<td>49.05^e</td>
<td>2.65^b</td>
<td>5.90^d</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td>1.49^b</td>
<td>44.35^f</td>
<td>2.25^c</td>
<td>3.95^c</td>
</tr>
<tr>
<td>Substituted with 2% preheated WPI</td>
<td>0.0</td>
<td>5.77^a</td>
<td>61.15^a</td>
<td>1.05^ef</td>
<td>7.05^b</td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td>2.43^b</td>
<td>54.35^c</td>
<td>1.05^ef</td>
<td>6.30^bc</td>
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<tr>
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<td></td>
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<td>50.90^de</td>
<td>1.20^ef</td>
<td>5.95^d</td>
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<tr>
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<td></td>
<td>2.39^b</td>
<td>49.10^e</td>
<td>1.20^ef</td>
<td>5.40^d</td>
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</tbody>
</table>

### Table 2. Effect of whey protein isolate (WPI) substitution and NaCl concentration on functional properties of incubated (16 h, 1 C) and cooked (78 C) chicken breast meat batters.

All treatments formulated with 16% protein

<table>
<thead>
<tr>
<th>Treatment</th>
<th>NaCl (%)</th>
<th>Cook loss</th>
<th>Penetration force (N)</th>
<th>Distance to rupture (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td></td>
<td>25.59^a</td>
<td>15.11^d</td>
<td>5.53^bc</td>
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<td></td>
<td>25.33^a</td>
<td>27.30^d</td>
<td>5.73^bc</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>19.67^ab</td>
<td>30.17^ed</td>
<td>5.90^bc</td>
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<td></td>
<td>12.16^c</td>
<td>30.18^ed</td>
<td>6.04^bc</td>
</tr>
<tr>
<td>Substituted with 2% preheated WPI</td>
<td>0.0</td>
<td>15.93^bc</td>
<td>39.47^bc</td>
<td>6.15^bc</td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td>3.87^f</td>
<td>50.83^ab</td>
<td>7.63^p</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>1.23^d</td>
<td>52.90^d</td>
<td>6.56^ab</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td>1.58^d</td>
<td>39.61^bc</td>
<td>6.33^bc</td>
</tr>
<tr>
<td>Substituted with 2% unheated WPI</td>
<td>0.0</td>
<td>21.82^ab</td>
<td>14.32^d</td>
<td>5.36^e</td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td>19.20^b</td>
<td>31.22^c</td>
<td>5.58^bc</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>17.47^bc</td>
<td>33.74^c</td>
<td>5.50^bc</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td>15.92^bc</td>
<td>35.81^bc</td>
<td>5.98^bc</td>
</tr>
</tbody>
</table>

^a-dColumn means (n = 4) with no common superscript differ significantly (P < 0.05).

^1Color: “L” = lightness; “a” = redness; “b” = yellowness.

^2NA = not available; samples too soft.
induction with salt at 1 C for 4 d. Thus, the structure formed in this case (i.e., meat batter with no salt) was due to interactions between the WPI and meat proteins in the presence of salt naturally occurring within the muscle. It is possible that the preheated WPI, which have more exposed negative charges than unheated WPI (Hongsprabhas and Barbut, 1998), reacted with the meat proteins to form cold set gels. After cooking, the preheated WPI produced more firm gels. Hung and Smith (1993) studied gels composed of 4% isolated chicken salt-soluble proteins and 12% whey proteins in 0.6 M NaCl and 0.05 M phosphate buffer. They suggested that the whey proteins formed a filled gel in which the whey aggregates existed as dispersed particles within the SSP gel matrix. It is possible that a filled gel was also formed during the present experiment; however, its structure might have been more complex and less homogeneous than the system studied by Hung and Smith, as chopped meat particles (e.g., connective tissue fragments) were also present. In addition, the preheated WPI in this study were exposed to a preheating stage prior to cooking the meat proteins.

In summary, the results indicate that using unheated WPI for substituting 2% of the meat proteins did not cause any detrimental effect on the meat system. Using preheated WPI substitution was very beneficial in destroying any detrimental effect on the meat system. Using preheated WPI substitution was very beneficial in increasing WHC, reducing cook loss, and increasing gel strength of the raw and cooked products, particularly at the low salt levels.

REFERENCES


