Effects of milk powder and its components on texture, yield, and color of a lean poultry meat model system

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ABSTRACT The effects of whole milk powder, 2 skim milk powders, caseinate, and 2 modified whey proteins (2% protein level in the final product) were evaluated in lean chicken meat batters and compared with controls with and without added lactose. All dairy proteins significantly \((P < 0.05)\) reduced cook losses when compared against the controls, with the 2 skim milk powders and modified whey-I showing the best results. Hardness and fracturability were also higher for all test batters compared with controls. Skim milk-II showed the highest fracturability value (21.9 vs. 7.1 N for the control) and was also found to be the most cost-effective ingredient for improving moisture binding and texture; skim milk-I and modified whey-I followed behind. Springiness and fracture distance were higher for all of the dairy proteins, except caseinate, indicating a positive contribution to the lean meat system’s elasticity. In terms of color, adding the skim milk powders, modified whey-II, and whole milk powder resulted in lighter cooked meat batters as evidenced by the higher \(L^*\) values and higher spectra curves.

Key words: milk powder, caseinate, whey protein, lean poultry meat

INTRODUCTION

Muscle foods contain various functional proteins that help to provide unique textures for different meat products. Most of these proteins are part of the myofibrillar group and are commonly referred to as salt-soluble proteins (SSP). In addition, the meat industry uses various nonmeat additives (e.g., dairy-soy proteins and hydrocolloid gums) to enhance binding, textural characteristics, and yield (Comer, 1979; Ensor et al., 1987; Kerry et al., 1999). Recent changes in dietary recommendations (e.g., low-fat and low-carbohydrate diets) have further increased the use of nonmeat ingredients, which can help bind supplementary moisture (used to replace some of the fat) as well as provide another gelling system that can enhance the texture (Kerry et al., 1999; Barbut, 2002a). Holding on to the lean meat’s original water (about 70%) on top of the supplementary moisture (can be 10 to 50%) is a challenge to the processing industry, especially because during cooking, the meat experiences progressive water losses due to the meat’s SSP denaturation (Offer et al., 1984). As moisture is lost, yield, juiciness, and tenderness are also affected. Therefore, there is a growing interest in ingredients that can enhance water binding or texture, or both, in a cost-effective way. Generally speaking, the nonmeat additives can be divided into 3 major groups: proteins (soy and dairy), carbohydrates (starch), and hydrocolloid gums (carrageenan), which are added individually or in combination (Endres and Monagle, 1987; Smith and Rose, 1995; Pszczola, 2006). Any nonmeat ingredients to be used must be compatible with the meat SSP; otherwise, they will disrupt the structure (e.g., crumbly product) and lower yield. Beuschel et al. (1992) showed that the contribution of whey protein concentrate to a SSP system depends on the pH, the solubility of the whey proteins, and heating temperature. They indicated that gel hardness increased as whey protein solubility decreased at pH 6.0, 7.0, and 8.0 and when heated to 65°C; however, the opposite trend was observed when heated to 90°C. They also mentioned that to optimize the contribution of nonmeat ingredients, and balance the benefit versus cost, it is essential to investigate the interaction(s) with the meat system. The objective of this study was to evaluate the effects of milk powder and its different components (whey and caseinate) used at a 2% protein-added level and examine their contribution to yield, color, and texture of a moisture-added (50%) lean poultry meat system.
MATERIALS AND METHODS

Meat Batter Preparation

Fresh skinless chicken breast meat was obtained from a local processing plant and brought to the University of Guelph meat laboratory within 12 h postmortem. The meat was trimmed of all visible connective tissue and skin, chopped (Schneidmeister SMK 40, Berlin, West Germany) for 30 s at the low speed setting (750 rpm with 6 blades) to obtain a homogenous mass, packed in 0.5-kg polyethylene bags, and frozen for up to 4 wk at -18°C before use. The chemical composition of the raw meat, determined in duplicates (AOAC, 1990), was 73.7% water, 22.4% protein, 2.6% fat, and 0.9% ash. Meat for each of the trials was tempered the night before, at 4°C. Each treatment consisted of the lean meat with 50% water added and 2.5% salt. The added water was used to bring the protein level down to 15%, which is common in lean poultry products on the market (Barbut, 2002a). The following milk proteins were used at a 2% protein-added level: whole milk protein powder (69% protein in the dry powder; Milk Pro 700, Parmalat, Toronto, Ontario, Canada), skim milk powder-I (36% protein; Herman Laue Spice Co., Uxbridge, Ontario, Canada), skim milk powder-II (35.5% protein; Parmalat), sodium caseinate (87% protein; Herman Laue), modified whey protein-I (57% protein; Eggstend 300, Parmalat), modified whey protein-II (35% protein; Dairy-Lo, Parmalat), and a treatment with 2.4% lactose (i.e., equivalent to the amount added with the modified whey protein to obtain the actual 2% dairy protein level). The latter was used to evaluate the potential effect of lactose on the formulation. The meat batters were prepared by mixing the meat and salt followed by adding the water with the various dairy proteins; total mixing time (by hand) was 3 min. The batters were allowed to equilibrate for 1 h at 4°C, mixed again, stuffed into three 50-mL test tubes (19-mm diameter; 35 g per tube), and centrifuged (model 225, Fisher Scientific, Pittsburgh, PA) for 30 s at the low speed setting to pack the meat and remove small trapped air bubbles.

Cooking and Cook Loss

The tubes were placed in a water bath (model W26, Haake, Dieselstraße, Germany) at 30°C and were set to heat at 0.66°C/min to 78°C so total cooking time to obtain a core temperature of 75°C was within 1.25 h. A thermocouple (model 52 K/J, Fluke Co. Inc., Everett, WA) was used to monitor the core temperature. Samples were then cooled under running water for 15 min and cooking loss was determined as the amount of released liquid decanted into 15-mL test tubes. Solid loss was determined as the volume of sediment settled in the 15-mL test tubes after an overnight refrigerated storage (i.e., seen as opaque accumulation of small particles).

RESULTS AND DISCUSSION

The addition of all dairy proteins helped reduce cook loss-increase yield of the poultry meat batters (Table 1). This is one of the main reasons the industry is using nonmeat additives (Comer, 1979; Barbut, 2002a). The rationale behind selecting these specific dairy ingredients was to see which component of the whole milk proteins has the best effect on the lean chicken meat product. The first additive was a whole milk protein powder, followed by 2 skim milk powders (i.e., fat removed and dried under 2 different commercial processes), caseinate (represents 80% of the milk proteins), and 2 modified whey protein preparations (represents 20% of the milk proteins).

Statistical Analysis

The experiment was designed as a complete randomized block with 3 independent replications. Statistical analysis was performed using a software package (SAS Version 8.02, SAS Institute Inc., Cary, NC). The SAS GLM procedure was used for ANOVA. Tukey multiple comparison analysis was performed to separate the means ($P < 0.05$).

Texture Analysis

After an overnight refrigeration period, texture profile analysis (TPA) parameters were determined using 6 center cores (16-mm diameter, 10-mm height) per treatment, which were compressed twice to 75% of their original height by a texture analyzer (Stable Micro Systems TA.XT2, Texture Technologies Corp., Scarsdale, NY) employing a moving round flat plate (10-cm diameter) descending at 1.5 mm/s. The TPA parameters of fracturability, hardness, springiness, cohesiveness, and chewiness were determined (Park et al., 1990).

Color

The color of 3 freshly cut surfaces from each cooked sample was evaluated (Minolta Spectrophotometer CM-1000, Osaka, Japan). Reflectance curves were obtained as well as the CIE L* (lightness), a* (redness), and b* ( yellowness) values.
indicating that they assisted in forming gels capable of retaining extra moisture and solids. When selecting an additive, industry personnel are also looking at the cost benefit in terms of each ingredient’s contribution to yield and texture. Comparing the relative costs of the 6 dairy ingredients tested here (based on current Canadian market values) and setting the skim milk powder-II as 100%, modified whey protein-II is 105%, skim milk powder-I is 112%, modified whey protein-I is 140%, milk protein powder is 250%, and caseinate is 300%. Therefore, the most cost-effective ingredients tested here, in terms of improving yield, were the 2 skim milk powders. The modified whey protein-I, which was prepared under a proprietary process to resemble egg white proteins, also performed very well (Table 1). According to the manufacturer, this process is intended to impart higher heat-induced gelation, water binding, foaming, and air cell strength. Overall, the modification provided a product that was superior to the other whey preparation (whey protein-II), indicating that meat processors should look for the most appropriate ingredient in each category (e.g., water binding and texture). Previous work has also indicated the beneficial effect of adding certain dairy proteins to a meat system. Atughonu et al. (1998) reported that adding 3.5% whey protein concentrate (34% protein content) improved the cooking yield by 1.6%, whereas 2% caseinate (93% protein) improved yield by 7% in beef and pork frankfurters. Tsai et al. (1998) showed a 6% reduction in cooking loss when 3.5% caseinate was added to a restructured beef product cooked to 65°C. In emulsion-type sausages (made from mechanically deboned meat with 11% fat), Barbut (2006) indicated that adding caseinate, whey, and milk powder helped increase yield. It is interesting to note that a dairy protein such as sodium caseinate, which is well known for its emulsifying capacity, was not as effective in reducing cook loss as in the lean meat system studied in the present experiment. This is probably because of the fact that caseinate has poor gelling properties and was unavailable to bind moisture.

In terms of texture, all dairy proteins increased fracturability, fracture distance, and hardness compared with the control and the lactose treatments (Table 2); there were no differences between the control and lactose treatments. Overall, the dairy proteins showed a positive effect, indicating that processors can use these additives and also might be able to cut back on the use of some meat proteins in the formulation. The highest increase in fracturability was obtained by skim milk-II, which showed a value 3 times higher than the control.

### Table 1. Effect of dairy proteins (2% protein content added) on cook loss and color of cooked lean chicken meat

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cook loss (g)</th>
<th>Solid loss (mL)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.45 ± 0.1a</td>
<td>0.45 ± 0.02a</td>
<td>78.9 ± 0.1cd</td>
<td>0.71 ± 0.04b</td>
<td>13.3 ± 0.04c</td>
</tr>
<tr>
<td>Milk powder</td>
<td>2.84 ± 0.2c</td>
<td>0.16 ± 0.04de</td>
<td>80.1 ± 0.1a</td>
<td>0.11 ± 0.02a</td>
<td>13.1 ± 0.04c</td>
</tr>
<tr>
<td>Skim milk-I</td>
<td>2.55 ± 0.1c</td>
<td>0.19 ± 0.03d</td>
<td>80.5 ± 0.2a</td>
<td>0.13 ± 0.05a</td>
<td>14.0 ± 0.05b</td>
</tr>
<tr>
<td>Skim milk-II</td>
<td>2.58 ± 0.2c</td>
<td>0.14 ± 0.02c</td>
<td>80.4 ± 0.1a</td>
<td>0.46 ± 0.02a</td>
<td>14.2 ± 0.03ab</td>
</tr>
<tr>
<td>Caseinate</td>
<td>2.92 ± 0.3c</td>
<td>0.30 ± 0.02b</td>
<td>79.4 ± 0.1bc</td>
<td>0.18 ± 0.05a</td>
<td>12.5 ± 0.05d</td>
</tr>
<tr>
<td>Modified whey-I</td>
<td>2.81 ± 0.1d</td>
<td>0.12 ± 0.03c</td>
<td>78.7 ± 0.2c</td>
<td>0.18 ± 0.03c</td>
<td>13.1 ± 0.05c</td>
</tr>
<tr>
<td>Modified whey-II</td>
<td>3.74 ± 0.3b</td>
<td>0.25 ± 0.02c</td>
<td>79.9 ± 0.1ab</td>
<td>0.95 ± 0.02a</td>
<td>14.6 ± 0.04a</td>
</tr>
<tr>
<td>Lactose</td>
<td>5.20 ± 0.1c</td>
<td>0.47 ± 0.04a</td>
<td>78.4 ± 0.2d</td>
<td>0.44 ± 0.04a</td>
<td>13.3 ± 0.03c</td>
</tr>
</tbody>
</table>

*Means (n = 9) ± SE in the same column followed by different superscripts are significantly different (P < 0.05).

![Figure 1. Color reflectance spectra (%) of lean chicken meat batters with 2% added dairy proteins. Color version available in the online PDF.](https://academic.oup.com/ps/article-abstract/89/6/1320/1547524)
This was followed by skim milk-I, modified whey-I, and whole milk powder (no statistical difference among these 3 treatments); all provided a value 2.5 times higher than the control. Caseinate addition doubled fracturability compared with the control, and modified whey-II increased it by 50%. The dairy proteins also showed an increase in fracture distance (i.e., making the meat batters more elastic); this was also seen for springiness for all additives except modified whey-II. The TPA test has been reported useful in various other studies dealing with evaluating meat batter’s reformulations. Park et al. (1990) used the test to develop frankfurters with elevated levels of oleic acid and moisture and identified formulations that were acceptable by a consumer panel. Ordonez et al. (2001) used TPA to develop low-fat (10%) frankfurters with soy and carrageenan that had similar texture to regular products (30% fat) on the market. The fact that the dairy proteins increased the TPA parameters (Table 2) indicates their positive contribution in co-gelling with the meat proteins. Aguiler and Kessler (1989) discussed the formation of a gel matrix using 2 different gelling systems. From the information gathered in this experiment, it cannot be verified exactly which kind of a gel matrix was formed (mixed, filled, or filled-mixed), but it is evident that both the meat and dairy proteins contributed to the enhanced structure.

In the present study, the highest fracturability values were provided by the 2 skim milk powders (Table 2), which in terms of cost were also the least expensive and most economical to use. This was followed by modified whey-I, whole milk powder, and caseinate, all more expensive (at the 2% protein level used here) than the 2 skim milk powders. Hung and Zayas (1992) have also reported that the addition of 2% caseinate significantly increased the hardness of beef frankfurters compared with a control, but 3.5% regular whey concentrate addition had no effect. Su et al. (2000) reported that 2% caseinate, added to reduced-fat frankfurters, significantly increased shear force values compared with the control. In emulsion-type meat products, whole milk powder, skim milk, and modified whey did not change the control’s hardness value, and only a 2% caseinate protein addition significantly increased the hardness value (Barbut, 2006).

The lightness of the cooked products increased by using the whole milk protein powder, the 2 skim milk powders, and the modified whey-II (Table 1), which was due to the addition of white powders to the batters. This effect was not clearly seen by the addition of caseinate and modified whey-I. The redness was not affected by any of the additives because there was no red component added-subtracted from the products. The yellowness was increased by the 2 skim milk powders and the modified whey-II, possibly because of some yellowness in these powders or the lactose added within these ingredients. The color values reported here are similar to results published by Fletcher et al. (2000) for cooked chicken breast meat (\(L^* = 79; a^* = 2; b^* = 13\)) and Barbut (2002b) for commercially produced chicken rolls (\(L^* = 78; a^* = 2; b^* = 9\)). The spectra reflectance curves (Figure 1) of all of the treatments show a typical profile of a lean chicken meat batter (Swatland, 1989; Barbut, 2002b). The modified whey-II with the high lightness and yellowness values produced the highest reflectance curve, and the modified whey-I with the lowest lightness value produced the lowest curve. Overall, all curves showed the same basic profile and aggregated in the same area.

In summary, when all additives were compared, the skim milk powders, and especially skim milk-II, were the most beneficial in improving yield and texture of the lean chicken meat batters. In terms of cost, the skim milk powders were also the most cost effective, although on a weight basis, they had to be used at twice the level of whole milk powder (i.e., skim milk powder comes as a 35% protein powder and whole milk as 69% protein). It is possible that using skim milk powder at a lower level would still provide similar results to the whole milk powder. However, further experimentation and fine-tuning will be required to determine the best cost-effective level to be used in each individual meat product.

## ACKNOWLEDGMENTS

The work was supported by the Dairy Farmers of Ontario (Mississauga, Ontario, Canada) and the Ministry of Agriculture, Food and Rural Affairs (Guelph, Ontario, Canada).

### Table 2. Effect of dairy proteins (2% protein content added) on texture profile analysis parameters of cooked lean chicken meat batters

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fracturability (N)</th>
<th>Fracture distance (mm)</th>
<th>Hardness (N)</th>
<th>Springiness (mm)</th>
<th>Cohesiveness (ratio)</th>
<th>Chewiness (N)</th>
<th>Gumminess (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>7.12 ± 0.4a</td>
<td>3.85 ± 0.09c</td>
<td>31.3 ± 1.2e</td>
<td>0.52 ± 0.02c</td>
<td>0.43 ± 0.01d</td>
<td>6.04 ± 0.4c</td>
<td>11.2 ± 0.6c</td>
</tr>
<tr>
<td>Milk powder</td>
<td>19.9 ± 0.3b</td>
<td>5.36 ± 0.07a</td>
<td>40.1 ± 1.7ab</td>
<td>0.72 ± 0.01a</td>
<td>0.38 ± 0.01ab</td>
<td>11.46 ± 0.3a</td>
<td>15.3 ± 0.3ab</td>
</tr>
<tr>
<td>Skim milk-I</td>
<td>20.7 ± 0.5b</td>
<td>5.26 ± 0.09a</td>
<td>43.1 ± 1.5ab</td>
<td>0.74 ± 0.01a</td>
<td>0.38 ± 0.01ab</td>
<td>11.95 ± 0.5a</td>
<td>15.9 ± 0.4a</td>
</tr>
<tr>
<td>Skim milk-II</td>
<td>21.9 ± 0.4a</td>
<td>5.36 ± 0.10a</td>
<td>44.0 ± 1.5ab</td>
<td>0.73 ± 0.02a</td>
<td>0.37 ± 0.02ab</td>
<td>12.35 ± 0.3a</td>
<td>16.5 ± 0.4a</td>
</tr>
<tr>
<td>Caseinate</td>
<td>15.3 ± 0.6d</td>
<td>4.45 ± 0.03b</td>
<td>41.2 ± 1.4ab</td>
<td>0.65 ± 0.03b</td>
<td>0.36 ± 0.01bc</td>
<td>9.55 ± 0.7a</td>
<td>15.2 ± 0.3bc</td>
</tr>
<tr>
<td>Modified whey-I</td>
<td>19.6 ± 0.5b</td>
<td>5.35 ± 0.08a</td>
<td>44.7 ± 1.6c</td>
<td>0.73 ± 0.01a</td>
<td>0.39 ± 0.01a</td>
<td>12.36 ± 0.5a</td>
<td>16.9 ± 0.5a</td>
</tr>
<tr>
<td>Modified whey-II</td>
<td>11.3 ± 0.5d</td>
<td>4.14 ± 0.10abc</td>
<td>39.8 ± 1.1b</td>
<td>0.55 ± 0.02c</td>
<td>0.33 ± 0.03d</td>
<td>7.31 ± 0.5c</td>
<td>13.0 ± 0.5bc</td>
</tr>
<tr>
<td>Lactose</td>
<td>7.17 ± 0.3e</td>
<td>3.89 ± 0.7c</td>
<td>30.4 ± 1.7e</td>
<td>0.52 ± 0.02c</td>
<td>0.35 ± 0.02cd</td>
<td>5.69 ± 0.6d</td>
<td>11.0 ± 0.7c</td>
</tr>
</tbody>
</table>

a–eMeans (n = 18) ± SE in the same column followed by different superscripts are significantly different (\(P < 0.05\)).
REFERENCES


