Water Retention of Two Types of Hexane-Defatted Corn Germ Proteins and Soy Protein Flour[1]

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ABSTRACT

Water retention properties of two hexane-defatted corn germ protein (CGP) preparations processed by a modified and a conventional procedure and soy protein flour were studied in model systems and analyzed using response surface methodology. The protein preparations had different fat and protein contents. The defatted CGP obtained by the modified process was whiter, less red, and less yellow than defatted CGP processed conventionally and was similar in color to soy protein flour. Increased temperature of incubation in the range 5–80°C enhanced the water retention of both CGP preparations. Time of incubation (10–30 min) and pH of solution (pH 6–7) did not affect water retention. Defatted CGP obtained by the modified process had higher water retention (2.04) at low incubation temperatures than that processed by conventional procedure (1.49). Time and temperature of incubation and pH had no significant effect on the water retention of soy protein flour. Soy flour had higher water retention than defatted CGP at temperatures lower than 55°C due to its higher protein content.

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Water retention is a basic functional property of food components such as proteins and carbohydrates. Water retention of plant proteins has been studied by Karmas (1973), Fleming et al (1974), Lucisano et al (1984), Luallen (1985), Jones and Tung (1983), Lin and Zayas (1987) and others.

Even though it may have all prerequisites to be nutritionally superior, a protein will have no effect on human nutrition unless it can be successfully incorporated into food systems (Ryan 1977). Food ingredients of plant origin with a high content of carbohydrates were reported to neither participate in the water-binding property nor improve the emulsifying capacity of meat emulsions (Mittal and Usborne 1985). However, it was found that carbohydrate-rich corn protein had high water retention (Lucisano et al 1984, Bhattacharya and Hanna 1985, Luallen 1985). The functional properties of protein ingredients from cereal sources, such as water retention and fat binding, justify the use of these relatively low-cost raw materials.

Soy products provide a variety of protein ingredients: flour, concentrate, isolate, and their modified products. However, the uses of soybean proteins have been limited because of the strong beany, grassy, and bitter flavors associated with these proteins (Kinsella 1979).

Defatted corn germ protein (DCGP) has considerable potential for use as a supplement in a variety of foods as a new protein source. A good corn germ protein source can be obtained by drying corn germ meal at low temperatures and extracting the oil by solvent extraction (Lucisano et al 1984). At present, the conventional oil-extraction process with hexane as a solvent leaves residual lipids in the flour that reduce its quality (Phillips and Sternberg 1979). Oxidation of this residual oil in DCGP produces an unpleasant off flavor in the product, and sufficient storage stability cannot be obtained because of incomplete fat extraction.

In the production of DCGP, particularly during fat extraction, removal of hexane residues using the conventional desolventization procedure can damage the finished product due to changes in

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flavor and color resulting from protein denaturation and a browning reaction. Recently, Christianson et al (1984) studied a supercritical CO_2 method for extracting oil from corn germ meal and obtained a food-grade quality DCGP safe and palatable for human consumption. However, currently the corn milling industry is using a hexane-extraction process.

Functional properties of DCGP preparations reflect the composition of the sample; the nature and reactivity of the proteins; their native structure; and interactions with nonprotein components of DCGP preparations, carbohydrates, and lipids. They are affected also by environmental and processing conditions such as temperature of incubation and pH.

There is a little information related to water retention of DCGP (Lin and Zayas 1987). Although the individual functional properties of several kinds of corn proteins and DCGP have been studied (Peri et al 1983, Lucisano et al 1984, Lin and Zayas 1987), little work has been done to evaluate water retention properties of hexane-defatted CGP.

The objective of this study was to investigate the water retention of two hexane-defatted CGPs and soy protein preparations in order to obtain information related to their water retention capacity in the range of pH and temperature experienced during sausage manufacturing. Two DCGP obtained by conventional and modified fat-extraction methods were tested.

MATERIALS AND METHODS

Two hexane-defatted CGP preparations were used in the experiments. DCGP was obtained after hexane fat extraction in dry milling operations. One hexane-defatted CGP was processed by the conventional method and the other by the modified technique. Soy flour (Soya fluff 200W) used as a control was obtained from the Central Soya, Inc. (Chemurgy Division, Fort Wayne, IN).

Color Measurements

Color of DCGP and soy protein flour was measured by the illuminate A (ILLA), *L*, *a*, and *b* values with a Hunterlab spectrophotometer (Hunterlab D54, Hunter Associates Laboratory, Fairfax, VA). The reflected light source (tungsten lamp) was used in the instrument, which was standardized with a white and gray tile. Samples were measured in a 7-cm diameter sample cup. An optical unit with reflectance speculum included was used, and samples were measured through a 3-cm viewing area.

Composition Analyses

Moisture (method 14.081), fat (method 14.085), and protein of crude DCGP and soy protein flour nitrogen (N × 6.25, method 2.055) were analyzed by AOAC methods (1984).

Water Retention

The methods of Janicki and Walczak (1954) modified by Aoki et al (1980), were used for water retention determination. For slurry preparation, 5 g of DCGP or soy protein flour was dispersed in 95 ml of distilled water. The suspension (adjusted pH 6.0–7.0) was mixed using a magnetic stirrer at temperatures ranging from 10 to 80°C for 10–30 min. Two 50-ml centrifuge tubes were filled with the suspension and placed in a water bath for 30 min for temperature equilibration. Then the tubes were centrifuged at 1,000 × g for 30 min at room temperature (Safeguard centrifuge, Clay-Adams, Inc., New York, NY). The water retention or binding values were calculated as the difference between hydrated weight (pellet) and original weight and expressed in grams of water retained by 1 g of DCGP or soy flour.

Statistical Analyses

The ranges and intervals of experimental parameters for response surface methodology (RSM) followed the designs of Box and Behnken (1960) and Box and Wilson (1951). Each experiment was replicated once for each treatment. Data analysis was conducted using SAS programs (SAS 1982). Quadratic models were used to create three-dimensional response surfaces. In RSM, the independent variables are located along the x- and y-axes, and the dependent variable is on the z-axis. One-way analysis of variance and least significant difference were conducted by the methods of Steel and Torrie (1980).

RESULTS AND DISCUSSION

Difficulties in determining the functionality of proteins in foods are related to the diversity of their properties and functions as well as the interactions between different protein and nonprotein components. The model systems used in our experiments for testing the functionality of DCGP provided valuable information about the use of those products.

Composition Analyses

Different hexane-defatting processes influenced the composition of the DCGP preparations. Proximate analysis indicated that DCGP processed by the modified procedure was 5.09% higher in protein and 1.96% lower in fat content than DCGP processed by the conventional procedure (Table I). Carbohydrates became a major component in DCGP (Wall et al 1971). The improved defatting process had a significant effect on the composition of DCGP. Protein content of soy protein flour was two times higher than that in DCGP on a wet weight basis. Decreased fat residue and increased protein content of the modified product may improve the functional properties of DCGP in food systems. The greater amount of fat extracted by the modified hexane-defatting method should significantly increase the shelf life of the defatted corn germ products.

Color

The color measurements of two types of hexane-defatted CGP and soy flour are shown in Table I. Samples were visually different. The conventional hexane-defatted CGP was a light yellowish color. Soy protein flour was white, and the modified CGP was a very faint yellowish color. The processing technology influenced the color of the preparations. DCGP processed by the modified procedure was whiter (*L*), less red (*a*), and less yellow (*b*) than that processed by the conventional method. The higher percentage of fat and fat-soluble pigments may contribute to the yellow color of conventionally defatted CGP. The DCGP processed by the modified defatting process had improved color and composition.

TABLE I
Composition and Color Measurements of Defatted Corn Germ Proteins (DCGP) Processed by Modified and Conventional Procedures and Soy Protein Flour

Protein	Moisture[a] (%)	Fat[a] (%)	Protein[a] (%)	ILLA[b]		
				L	*a*	*b*
Corn germ proteins						
Modified DCGP	3.20 a	0.35 a	23.85 a	81.89 a	2.82 a	6.50 a
Conventional DCGP	4.62 b	2.31 b	18.76 b	78.36 b	5.33 b	9.57 b
Soy flour protein	5.91 c	5.83 c	51.71 c	90.65 c	1.52 c	5.90 a
MSE[c]	0.015	0.142	0.55	0.093	0.005	0.035

[a] Expressed on a percentage wet weight basis. Means in the same column followed by different letters are different ($P < 0.05$).
[b] Illuminate A.
[c] Mean square error, df = 3, $n = 2$.

Soy flour had more white, and less red and yellow compared with corn germ proteins.

Water Retention

Water-retention capacity is an important factor for protein additives used in food systems. Water retention of DCGP can be used to define how this protein can be added to formulated foods and how it can replace animal proteins traditionally used. The amount of water present in processed DCGP will depend on the extent to which the dry DCGP absorbs or adsorbs water under various environmental conditions. Phillips and Sternberg (1979) reported that corn protein concentrate has a water-binding capacity similar to that of a commercial soy protein concentrate. Because DCGP can be utilized as a food ingredient in sausage production, the water retention of DCGP processed by modified and conventional methods was determined over a range of temperatures corresponding to various sausage-processing conditions.

Water retention of DCGP obtained by the modified process significantly increased as the temperature of incubation increased from 30 to 80° C (Figs. 1 and 2). Times of incubation ranging from 10 to 30 min had no significant effects on water retention of modified DCGP (Fig. 1). However, the highest water retention was reached at 80° C and 30 min of incubation (Fig. 1). Swelling of carbohydrates, possibly due to starch gelatinization as they take up water from the solution, may also contribute to the increase of water retention. Changing the pH of the solution in the range from 6 to 7 did not have any effect on water retention of modified DCGP after 30 min of incubation (Fig. 2).

Similar surface responses were obtained for DCGP processed by the conventional method. Temperature of incubation also was an important factor in water retention of conventionally processed DCGP. Water retention of this DCGP increased as the temperature of incubation increased from 35 to 80° C (Figs. 3 and 4). At incubation temperatures of 40 to 80° C, DCGP processed by the conventional procedure retained 15–20% more water (4.43 vs. 3.83 g of water/g of protein flour) than DCGP processed by the modified procedure. However, water retention of DCGP processed by the conventional procedure at low incubation temperatures of 5–35° C was lower (1.49 vs. 2.04 g of water/g of protein flour) than for DCGP processed by the modified method. Surface responses for water retention at temperatures from 5 to 30° C are of particular importance because temperatures from 5 to 18° C are used during sausage batter processing.

Water absorption by corn germ preparations, attributed to the protein content, also is affected by starch content and a number of other factors. A pH between 6 and 7 during incubation did not have a significant effect on water retention of DCGP processed by the conventional procedure (Fig. 4). In fact, DCGP preparations showed a particularly low response to pH. The pH (6–7) did not alter the water retention properties of DCGP processed by either the modified or the conventional method.

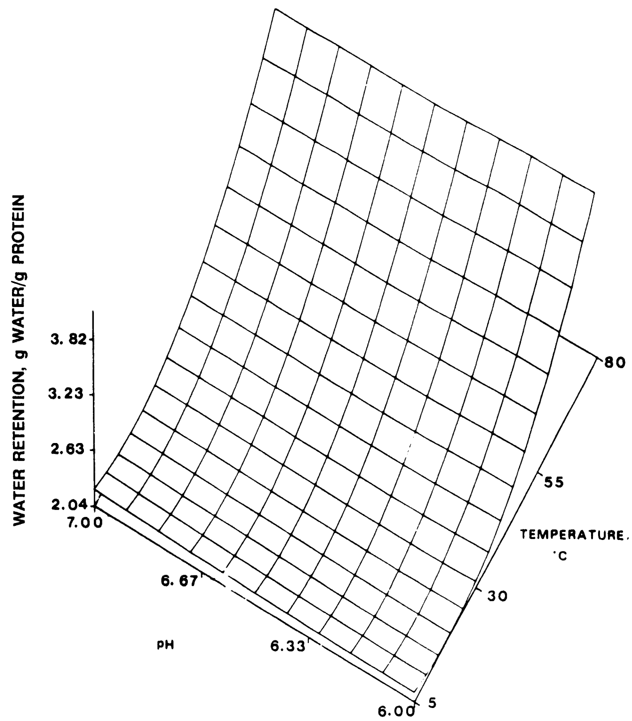

Fig. 2. Water retention of hexane-defatted corn germ protein processed by a modified procedure as a function of pH and temperature of incubation.

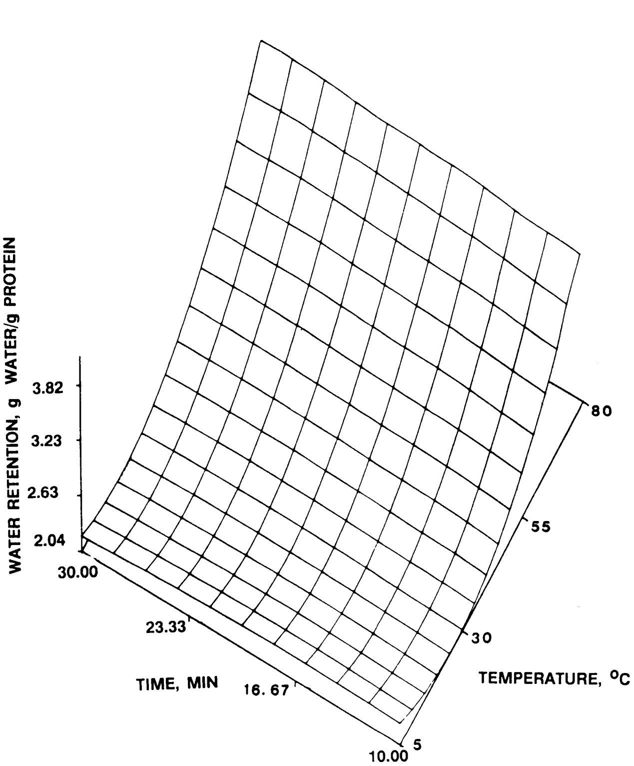

Fig. 1. Water retention of hexane-defatted corn germ protein processed by a modified procedure as a function of incubation time and temperature.

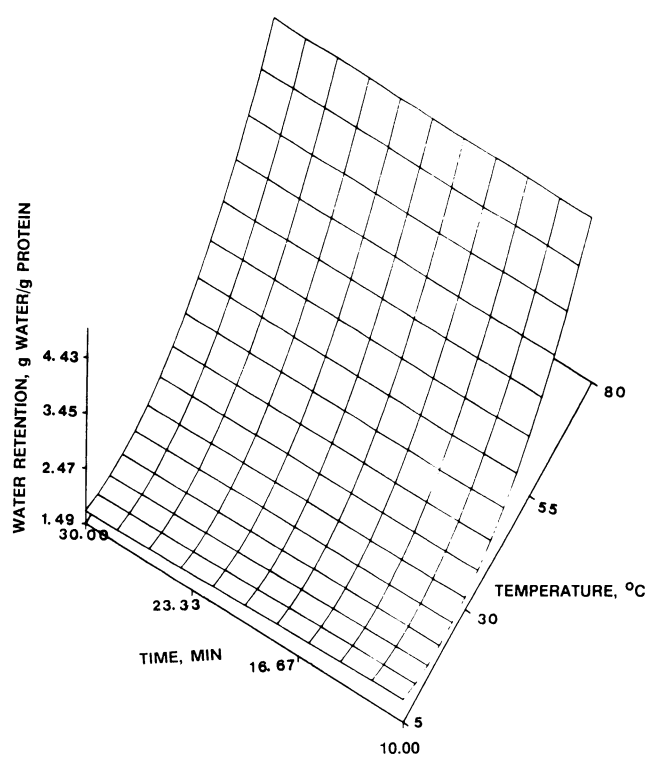

Fig. 3. Water retention of hexane-defatted corn germ protein processed by a conventional procedure as a function of incubation time and temperature.

The overall surface responses for soy protein flour were not significantly different with the defined conditions of pH, time, and temperature of incubation. Soy flour had significantly lower water retention as a percentage of protein weight than the DCGPs. The ratio of water retention was 3:1 (water/flour). The highest water retention was obtained at an incubation temperature from 5 to 15°C and an incubation time of from 10 to 15 min (Fig. 5). Higher temperatures and longer incubation times had a negative effect on water absorption because of soy protein denaturation and resulted in a lower water-retention capacity (Figs. 5 and 6). A pH between 6 and 7 had no significant effect on water retention of soy flour protein (Fig. 6). A nonsignificant decrease in water retention occurred when the protein solution was incubated at 80°C with high pH (pH 7) for 30 min.

The quadratic models for water retention of hexane-defatted CGP processed by modified and conventional procedures and soy protein flour were:

$$Y_1 = 4.1589 + 1.5252T - 0.695P - 4.0093\text{ E}{-3}\ M - 3.9583\text{ E}{-4}\ T^2 - 5.0\ E{-4}\ PT + 6.1667\ E{-2}\ P^2 + 1.5833\ E{-4}\ TM - 3.1667\text{ E}{-3}\ PM + 4.7824\text{ E}{-4}\ M^2 \quad (P < 0.0001,\ R^2 = 0.994)$$

$$Y_2 = 9.8136 + 0.1461\ T - 2.7\ P - 5.4223\text{ E}{-2}\ M + 1.334\text{ E}{-5}\ T^2 - 2.2307\text{ E}{-2}\ TP + 0.2889\ P^2 + 8.6411\text{ E}{-5}\ TM + 2.6\text{ E}{-3}\ PM + 7.9286\text{ E}{-4}\ M^2 \quad (P < 0.001,\ R^2 = 0.9785)$$

$$Y_3 = -17.9217 + 0.31\ T + 4.9725\ P + 2.021\text{ E}{-2}\ M + 1.563\text{ E}{-3}\ T^2 - 5.9\text{ E}{-2}\ TP - 0.265\ P^2 - 0.0045\ PM + 2.08\text{ E}{-5}\ M^2 \quad (P > 0.05,\ R^2 = 0.6458)$$

where Y_1, Y_2, and Y_3 were water retention of DCGP processed by modified (Y_1) or conventional (Y_2) procedures and soy protein flour (Y_3), M = incubation temperature, T = time of incubation, and P = pH.

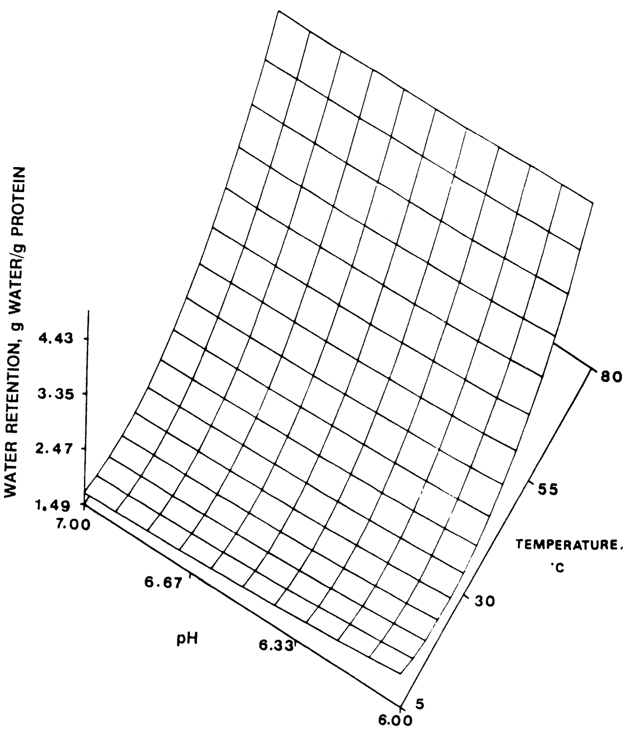

Fig. 4. Water retention of hexane-defatted corn germ protein processed by a conventional procedure as a function of pH and temperature of incubation.

CONCLUSION

In model systems, DCGP processed by a modified procedure at low incubation temperatures had better functional properties than DCGP processed by the conventional method. Higher water retention at low incubation temperatures (5–35°C) is of particular importance because these temperatures are applied during sausage batter processing. DCGP processed by the conventional procedure had more yellow color and more fat residue. Because of the better functional properties, particularly color, higher water retention, lower fat, and higher protein contents, DCGP processed by the modified procedure is recommended for utilization as an ingredient in comminuted and other meat products.

Higher water retention in relation to the percentage of protein in flour was obtained for DCGP preparations than for soy protein flour. The carbohydrates in the DCGP preparations absorbed more water at high temperatures. At low temperature ranges (5–35°C), the soy protein flour and modified hexane-defatted CGP had similar water retention levels. However, the soy protein flour had lower water retention (less temperature effect) than the two types of DCGP proteins in a model system. The pH change of the protein suspension from 6 to 7 did not have a significant effect on the water retention capacity of DCGP preparations or soy protein flour. Studies of other functional properties of DCGP processed by modified and conventional methods are necessary, particularly the role of the protein component alone in water.

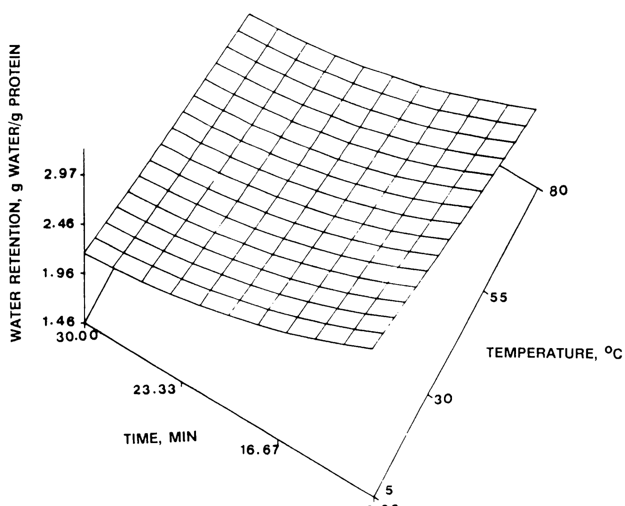

Fig. 5. Water retention of soy protein as a function of incubation time and temperature.

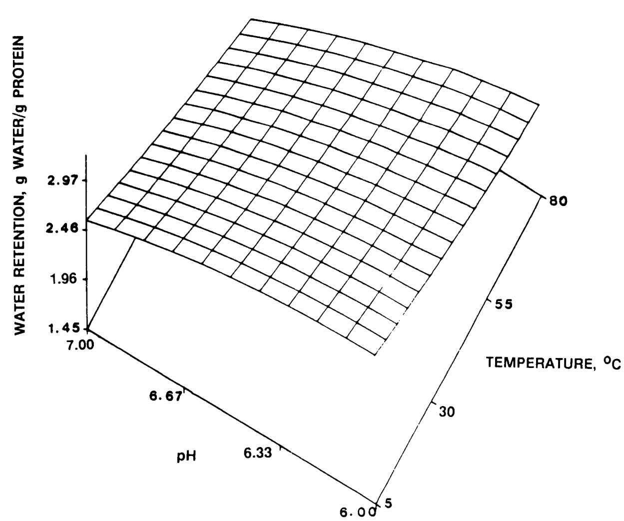

Fig. 6. Water retention of soy protein as a function of pH and temperature of incubation.

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