Solubilized Wheat Protein Isolate: Functional Properties and Potential Food Applications[†]

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Solubility, foaming capacity/stability, water holding and fat absorption capacities, and emulsifying capacity/stability of a solubilized wheat protein isolate (SWPI) were compared with those of commercial protein, that is, sodium caseinate (NaCAS), dried egg white (DEW), nonfat dry milk (NFDM), and soy protein isolate (SPI). SWPI was highly soluble at pH 6.5−8.5. Foaming capacity of SWPI was superior to those of SPI, NFDM, and DEW, and its foaming stability was similar to those of the commercial proteins. Foaming properties of SWPI were greatly improved in the presence of 0.5% (w/v) $CaCl_2$. Water holding capacity of SWPI was greater than that of NaCAS, NFDM, and DEW, whereas its fat absorption capacity was comparable to that of SPI, NaCAS, and DEW. SWPI exhibited emulsifying properties similar to those of SPI. SWPI was incorporated at 5, 10, 15, or 20% into ice cream, chocolate chip cookies, banana nut muffins, and hamburger patties. Products containing <5% SWPI were acceptable to consumers.

Keywords: *Functional properties; wheat protein isolate; consumer acceptability; food applications*

INTRODUCTION

Functionality has been defined as any property of a food ingredient, except its nutritional value, that affects its utilization (Kinsella, 1976). Functional properties are, however, often used to denote any property of proteins that affects their use, either as a processing aid or as a direct contributor of product attributes (Wilding et al., 1984). Most functional properties affect the sensory characteristics of food and can play a major role in the physical behavior of foods or food ingredients during their preparation, processing, and storage. Various forms of protein additives are added to foods to achieve functional, nutritional, or economic goals (Rakosky, 1989). Potential functional benefits include emulsification, foam formation, gelation, increased viscosity, and improved appearance, flavor, texture, and binding of fat or water. The selection of a specific protein depends on the function to be achieved in a finished product.

Gluten, the wheat protein, has attracted the attention of food processors for new product development or for use in existing food products. Gluten is sought after as a protein additive because of its desirable viscoelastic properties (Sarkki, 1979). Wheat gluten is in abundant supply as a byproduct of the wheat starch industry, but its utilization is limited by its insolubility (Mimouni et al., 1994). Researchers have been focusing on chemical and enzymatic modifications of wheat gluten protein to enhance its water binding capacity and solubility (Wu et al., 1976; Sarkki, 1979; Matsudomi et al., 1982; Kato et al., 1987; Popineau and Thebaudin, 1990; Bollecker et al., 1990; Mimouni et al., 1994). Such modifications are critical for the commercial use of wheat gluten in

food formulations, because protein hydration is related to other properties of proteins, such as solubility, emulsification, foamability, viscosity, and gelation (Vani and Zayas 1995; Asghar and Henrickson, 1982).

Wheat protein's unique functional and nutritional properties (although low in lysine) may offer enormous possibilities for use not only in existing food applications but also in new food product formulations. Although literature reports attempt to produce protein isolate from wheat germ (Hettiarachchy et al., 1996), very limited information is available on possible production and characterization of protein isolate prepared from wheat. A commercial production of wheat protein isolate may offer an inexpensive protein source for use in various food products and for nutritional supplementation. This investigation was undertaken to determine the functional properties of a modified solubilized wheat protein isolate (SWPI), to develop various food products containing SWPI, and to evaluate consumer acceptability of the sensory qualities of the products. Specific objectives were to (1) compare the functional properties of SWPI with those of sodium caseinate (NaCAS), nonfat dry milk (NFDM), soy protein isolate (SPI), and dried egg white (DEW) [functional properties included foaming capacity and stability (with and without $CaCl_2$), emulsifying capacity and stability, water holding capacity, fat absorption capacity, solubility profile, and gelling properties] and (2) prepare ice cream, chocolate chip cookies, banana nut muffins, and hamburger patties containing various %SWPIs and evaluate their consumer sensory acceptability.

MATERIALS AND METHODS

Experimental Materials. The SWPI, a noncommercial experimental product having a composition of 90% protein, 6% moisture, and 4% other components, was furnished by Midwest Grain Products Inc., Atchison, KS. DEW (94% protein) and NaCAS (83% protein) were purchased from Sigma Chemical

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Co., St. Louis, MO, and NFDM (35% protein) was obtained from a local grocery store. SPI (90% protein) was provided by Ralston Purina Co., St. Louis, MO. Note that the abbreviations for wheat protein isolate and commercial proteins mentioned above will be used throughout this paper.

Functional Property Analyses. *Solubility.* Protein solubility was determined using the method described by Vani and Zayas (1995) with modifications. Protein solution (5% w/v in deionized water) was prepared at room temperature (~25 °C) from each protein source, divided into six portions, and subsequently adjusted to pH 3.5, 4.5, 5.5, 6.5, 7.5, and/or 8.5 using 1.0 N NaOH or HCl. Samples were then centrifuged (model Sorvall RC-5B, DuPont Instruments, Newtown, CT) at $12000g$ for 15 min at ~25 °C. Supernatant liquid was analyzed in duplicate for nitrogen content using an FP-428 LECO nitrogen determinator (LECO Corp., St. Joseph, MI).

Foaming Capacity and Stability. Foaming capacity (FC) and foaming stability (FS) were determined in quadruplicate using the method described by Mitchell (1986). Seventy-five milliliters (V_I) of the solutions (3% w/v in deionized water) of SWPI (with or without 0.5% CaCl$_2$; Zhu and Damodaran, 1994) or commercial proteins was blended for 3 min using a high-speed blender, poured into a graduated cylinder, and immediately recorded for the volume of foam (V_F). Protein foams were left undisturbed at ~25 °C for 30 min, and the volume of liquid (V_0) generated beneath the foam was measured. FC (milliliters of foam per milliliter of liquid) and FS (milliliters of liquid remaining in foam per milliliter of initial volume) were calculated using the following equations: $FC = V_F/V_I$ and $FS = (V_I - V_0)/V_I$.

Water Holding and Fat Absorption Capacities. Water holding capacity was determined using the method outlined by the American Association of Cereal Chemists (AACC, 1981). Five grams of proteins was weighed into preweighed 50-mL centrifuge tubes. For each protein source, distilled water was added in small increments to a series of tubes under continuous stirring with a glass rod on the sides of the tube after each addition. After the mixture was thoroughly wetted, the stirring rod was wiped on the side of the centrifuge tube to minimize losses of protein materials and samples were centrifuged (model Sorvall RC-5B, DuPont Instruments) at $2000g$ for 10 min. The amount of added water resulting in the supernatant liquid in the test tube after centrifugation was recorded. Water holding capacity (grams of water per gram of protein) was calculated as $WHC = (W_2 - W_1)/W_0$, where W_0 is the weight of the dry sample (g), W_1 is the weight of the tube plus the dry sample (g), and W_2 is the weight of the tube plus the sediment (g). Quadruplicate samples were analyzed for each protein.

Fat absorption capacity was determined using the method of Chakraborty (1986). One gram of protein was weighed into preweighed 50-mL centrifuge tubes and thoroughly mixed with 10 mL of corn oil. The protein−oil mixture was centrifuged at $1600g$ (model Sorvall RC-5B, DuPont Instruments) for 10 min. Immediately after centrifugation, the supernatant was carefully removed and the tubes were weighed. Fat absorption capacity (grams of oil per gram of protein) was calculated as $FAC = (W_2 - W_1)/W_0$, where W_0 is the weight of the dry sample (g), W_1 is the weight of the tube plus the dry sample (g), and W_2 is the weight of the tube plus the sediment (g). Quadruplicate samples were analyzed for each protein.

Emulsifying Capacity and Stability. Emulsifying capacity (EC) and emsulifying stability (ES) were determined in quadruplicate according to the method described by Yasumatsu et al. (1972). Eight grams of each protein was weighed, transferred into a blender, and mixed with 100 mL of distilled water and 100 mL of corn oil at high speed for 1 min to form an emulsion. For each protein, a fixed quantity (40 mL, V_T) of emulsion was poured into a 50-mL centrifuge tube and centrifuged (model Sorvall RC-5B, DuPont Instruments) at $1475g$ for 5 min, and the volume of emulsified fraction (V_{F1}) was recorded. The tubes containing the oil-in-water emulsified fraction were heated in a water bath at 80 °C for 30 min and cooled to room temperature (~25 °C). Upon cooling, these tubes were centrifuged at $1475g$ for 5 min, and

the volume of the remaining emulsified fraction (V_{F2}) was recorded. EC and ES were, respectively, reported as EC (%) $= (V_{F1}/V_T) \times 100$ and ES (%) $= (V_{F2}/V_T) \times 100$.

Gel Strength. Gel strength was determined in duplicate according to the procedure described by Chakraborty (1986). On the basis of the preliminary study, the known protein concentration (10, 15, 15, and 20% for DEW, SPI, NaCAS, and SWPI, respectively) that induces gelation was used to determine the effect of temperature on gel strength. Each solution was divided into five portions and separately heated at 60, 70, 80, 90, or 100 °C for 25 min and cooled overnight at 4 °C in a refrigerator. Gel viscosity was measured in centipoise using a digital Brookfield viscometer (model DV II, Brookfield Engineering Laboratory, Stoughtown, MA), which was mounted on a helipath stand (model D, Brookfield Engineering Laboratory), equipped with a T-D spindlee and operated at a speed of 10 rpm.

Formulation and Preparation of Food Products. Four products [(1) ice cream (20% sugar, 10% whole egg, 30% whole milk, 24% evaporated milk, 14% water), (2) chocolate chip cookies (14% sugar, 12% brown sugar, 15% butter, 7% whole egg, 28% wheat flour, 23% chocolate chip), (3) banana nut muffins (20% butter, 17% sugar, 9.5% whole egg, 23% banana, 24% wheat flour, 5.8% pecan), and (4) hamburger patties (ground beef)], each respectively representing a dairy product, a snack product, a bakery product, and a meat product, were prepared with different percentages of SWPI. Preliminary sensory evaluation (overall acceptability) of these four products was done by three experts to establish the maximum level of SWPI to be incorporated into the formulations. Up to 10% SWPI can be incorporated into the ice cream product without noticeable changes in taste, color, or texture. For chocolate chip cookies, banana nut muffins, and hamburger patties, 20, 20, and 15% SWPI can be added to the formulations, respectively.

Consumer Sensory Evaluation. The newly formulated foods along with the corresponding controls were coded and presented to a panel of 20 judges. They were asked to evaluate acceptability of these products for appearance, color, flavor, texture, and overall liking using a 9-point hedonic scale (Peryam and Pilgrim,1957) with a rating of 9 indicating "like extremely" and 1 indicating "dislike extremely." Overall acceptability of each product was assessed using a 2-point (yes/no) scale (Ahmedna et al., 1998) in which "yes" indicates "acceptable" and "no" indicates "not acceptable."

Statistical Analysis. All experimental data were analyzed using the generalized linear model procedure of the Statistical Analysis System (SAS, 1988). The data obtained on the functional properties of various proteins including SWPI were analyzed by one-way analysis of variance (ANOVA). Tukey's post-ANOVA test was used to determine differences in mean attributes among the various proteins. Data obtained from consumer sensory evaluation were analyzed by ANOVA, and Dunnett's post-ANOVA test was subsequently used to compare differences in acceptability of the formulated foods containing SWPI to the controls (without SWPI). To eliminate variation of sensory scores due to variation from consumers as opposed to formulations, consumers were treated as random blocks.

RESULTS AND DISCUSSION

Functional Properties. *Solubility.* Among the functional properties of proteins, solubility is probably the most critical because it affects other properties such as emulsification, foaming, and gelation (Kinsella, 1976; Hettiarachchy et al., 1996). Solubility of SWPI and NaCAS was much greater at alkaline pH values than at acidic pH values (Figure 1). Increasing pH from 4.5 to 8.5 did not cause a drastic change in solubility of DEW, NFDM, and SPI, but it did sharply increase the solubility of SWPI and NaCAS. The solubility of SWPI increased (16 times) from 4.2% at pH 4.5 to 67.2% at pH 7.5. At pH 7.5, the protein solubility of SWPI was similar to that of NaCAS and DEW but greater than that of SPI and NFDM.
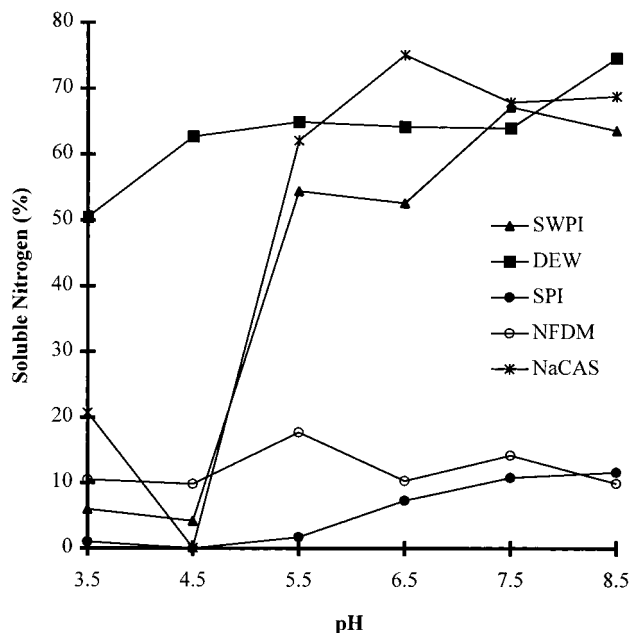
Figure 1. Effects of pH on protein solubility of SWPI, DEW, SPI, NFDM, and NaCAS.

SWPI exhibited a solubility profile (Figure 1) similar to that of deamidated wheat gluten (Mimouni et al., 1994) and wheat germ protein (Hettiarachchy et al., 1996). SWPI solubility was lowest at pH 4.5 (close to its isoelectric pH, pI, where proteins precipitate) and highest at pH 7.5. This is in agreement with the findings of Vani and Zayas (1995), who reported that most plant proteins have isolelectric points at pH 4−5. Mimouni et al. (1994) reported the least solubility of deamidated wheat gluten at pH 4−4.5. These authors also reported a sharp increase in solubility of deamidated wheat gluten between pH 4.5 and 6, similar to the profile presented in Figure 1. Solubility, which is affected by a wide range of pH, temperature, and ionic strength conditions (Wagner and Anon, 1990; Zayas, 1997), is the main characteristic of proteins selected for use in liquid or reconstituted foods and beverages. The enhanced solubility exhibited by SWPI at pH near neutrality (6−7.5) makes it a good candidate for use in high-protein beverages and for products requiring emulsifying and foaming properties.

Foaming Capacity and Stability. The ability of protein to form and stabilize foams depends on several parameters such as types of protein and degree of denaturation, other compositions, the presence or absence of calcium ions, pH, temperature, and whipping methods (Fennema, 1996; Townsend and Nakai, 1983). Foaming capacity and stability of SWPI and other proteins are shown in Figure 2. Foaming capacity of SWPI (1.67 mL of foam/mL of liquid) was higher than that of SPI (1.35), NFDM (1.49), and DEW (1.35) but lower than that of NaCAS (2.0). However, in the presence of 0.5% (w/v) CaCl$_2$, foaming capacity of SWPI increased significantly ($p < 0.05$) from 1.67 to 2.47 and consequently was higher than that of NaCAS. The ability of SWPI to form foams around neutral pH in this experiment can be attributed to its high solubility (Figure 1). Because protein solubility requires high net charges, which influence the adsorption of proteins at the air−water interface (Cherry and McWatters, 1981), high protein solubility is believed to improve foaming capacity. Wang and Kinsella (1976) found foaming capacity of alfalfa leaf protein to parallel
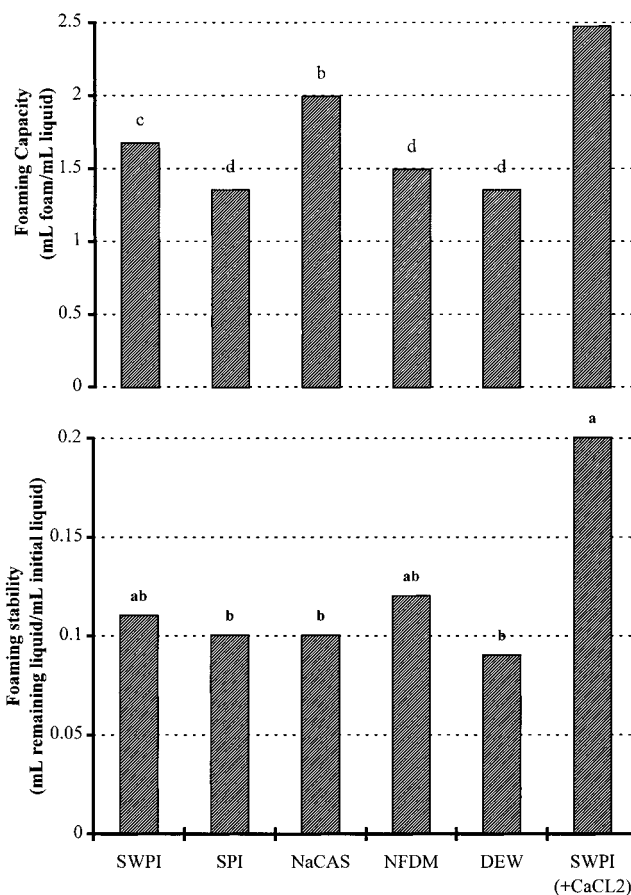

Figure 2. Foaming capacity and stability of SWPI and commercial proteins. For each panel, bars with different letters are significantly different at $p < 0.05$.

its solubility profile. In this study, the ability of proteins to form foam around neutral pH (Figure 2) followed the solubility pattern (i.e., NaCAS > DEW > SWPI > NFDM > SPI; Figure 1), except for that of DEW. Other factors such as size and flexibility of DEW protein may have affected its foaming capacity.

The foam stability of SWPI was comparable to that of other proteins (Figure 2). Although solubility of proteins is often required for foam formation, it may not always help stabilize the foam, as is the case of NaCAS in this study. For example, the solubility and foaming capacities of NaCAS were greater than those of SWPI, but its foaming stability was slightly lower than that of SWPI (Figure 2). As with the foaming capacity, addition of 0.5% (w/v) CaCl$_2$ to SWPI increased foaming stability nearly twice as much as that of SWPI without CaCl$_2$ (Figure 2). The ability of calcium chloride to enhance both foaming capacity and stability is due to its stabilizing effect through ionic bridging between protein molecules (Fennema, 1996).

Foams contribute to smoothness, lightness, flavor dispersions, and palatability of foods. Foaming of protein solutions can be desirable in many food applications. The similarity in foaming stability of SWPI and four other commonly used proteins indicates that SWPI may serve as a potential replacement of these proteins in food applications requiring high foamability and foam stability, such as in cakes, breads, marshmallow, whipped toppings, ice cream, cakes, and desserts.

Water Holding and Fat Absorption Capacities. Comparison of the water holding capacity of SWPI to that of other proteins is shown in Figure 3. The water
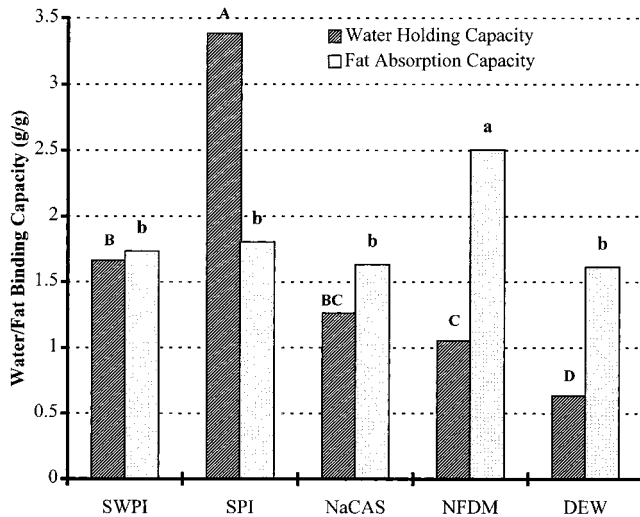
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Figure 3. Water holding and fat absorption capacities of SWPI and commercial proteins. Bars with different letters (upper case for water holding capacity and lower case for fat absorption capacity) are significantly different at $p < 0.05$.

Figure 4. Emulsifying capacity and stability of SWPI and commercial proteins. Bars with different letters (upper case for emulsifying capacity and lower case for emulsifying stability) are significantly different at $p < 0.05$.

holding capacity of SWPI (1.66 g/g) was significantly ($p < 0.05$) higher than that of NFDM (1.05) and DEW (0.63). SPI had superior water holding capacity (3.38 g/g) compared with that of SWPI and other proteins investigated. This may have been due to partial denaturation, dissociation, and unfolding of protein due to heat treatment during preparation. Results indicated that there was no direct relationship between solubility at pH 6.5–7.5 (Figure 1) and water holding capacity of proteins (Figure 3); that is, high protein solubility did not necessarily yield high water holding capacity as observed for NaCAS. Hermansson (1979) and Prinyawiwatkul et al. (1997) noted that solubility data give no information about the extent to which protein can bind water.

Fat absorption capacity is the binding of fat by nonpolar side chains of proteins (Sathe, 1982). Fat absorption capacity of SWPI and other proteins is presented in Figure 3. SWPI had a fat adsorption capacity (1.73 g/g) similar to other proteins except for NFDM, the fat absorption (2.5 g/g) of which was highest among the protein sources investigated. SWPI can bind slightly more fat (1.73 g/g) than water (1.66 g/g). The ability of SWPI, like other proteins, to bind fat is likely due to nonpolar side chains that bind hydrocarbon chains, thereby contributing to increased oil absorption (Lin and Zayas, 1987). The majority of reports on water and fat retention of plant protein additives in food systems have involved their incorporation into comminuted meat systems (Lin and Zayas, 1987; Zayas, 1997). The ability of SWPI to absorb and retain water and fat may help improve binding of the structure and reduce yield losses of extended meat products. On the basis of its water and fat binding capacities (Figure 3), SWPI would perform well in foods such as low-fat bakery products and doughnuts, as well as in emulsion-type foods.

Emulsifying Capacity and Stability. Emulsifying capacity of SWPI and various proteins is presented in Figure 4. The emulsifying capacity of SWPI (87%) was similar to that of SPI (87.5%) but was superior to that of NaCAS (79%), NFDM (58%), and DEW (53%). The ability of SWPI to emulsify oil and protein suspension into a mixture of fine fat globule dispersions is mainly attributed to soluble proteins. Soluble proteins are
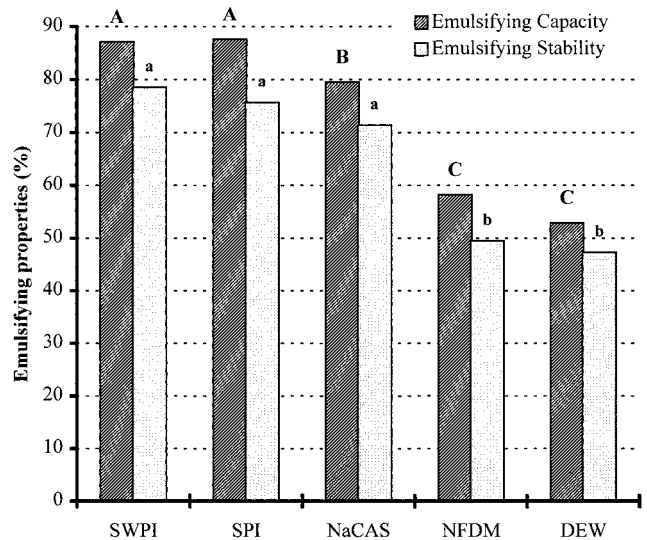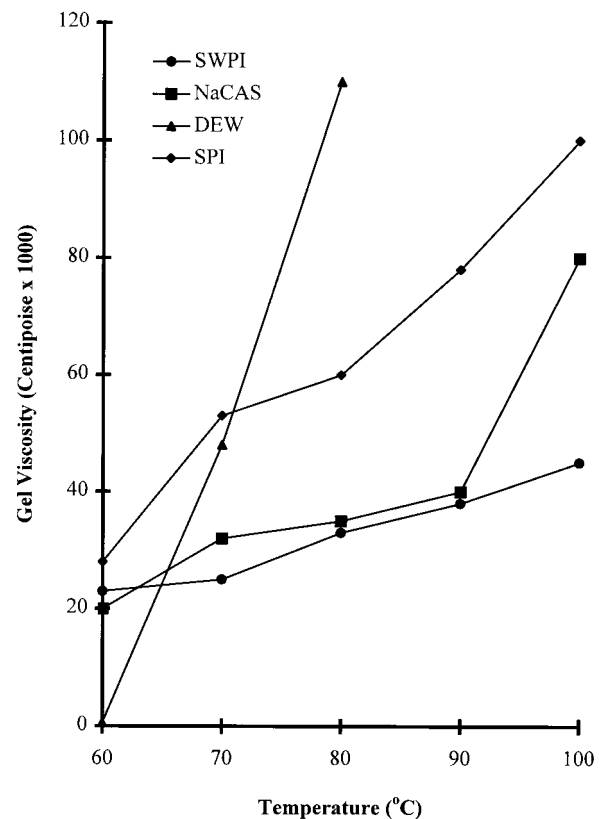

Figure 5. Effects of temperature on gel strength of SWPI and commercial proteins.

inherently surface active due to their amphiphilic nature and tendency to adsorb at oil–water interfaces. Although the solubility of SWPI was much greater than that of SPI around neutral pH (Figure 1), the emulsifying capacities of SWPI and SPI were similar (Figure 4). This may have been due to the fact that emulsifying capacity is influenced more by quality than quantity of soluble proteins (Prinyawiwatkul et al., 1993). Another example that substantiates this hypothesis is the much lower emulsifying capacity of DEW compared with that of SWPI (Figure 4) despite their nearly equal amounts of soluble proteins around neutral pH (Figure 1).

Table 1. Mean Consumer Sensory Acceptability Ratings of Banana Nut Muffins and Chocolate Chip Cookies[a]

sensory attribute	banana nut muffin formulation			chocolate chip cookie formulation		
	control	10% SWPI	20% SWPI	control	10% SWPI	20% SWPI
appearance	6.80 ± 1.4	7.45 ± 0.69	6.70 ± 1.34	6.95 ± 1.05	7.40 ± 0.60	6.65 ± 0.93
color	6.65 ± 1.46	7.45 ± 0.69	6.70 ± 1.30	6.90 ± 1.07	7.50 ± 0.61	6.70 ± 1.08
flavor	7.40 ± 0.88	7.50 ± 0.76	4.90 ± 1.52*	6.85 ± 1.35	6.15 ± 1.46	5.75 ± 1.68*
overall texture	7.35 ± 1.04	7.50 ± 0.61	5.85 ± 1.27*	6.15 ± 2.00	5.75 ± 1.41	5.40 ± 1.39
overall liking	7.25 ± 0.85	7.40 ± 0.75	5.25 ± 1.37*	6.80 ± 1.28	6.50 ± 1.24	5.65 ± 1.35*
acceptability (% yes)	95	100	65	90	90	65

[a] Mean values of 20 consumer responses. *, mean value significantly different from control ($p < 0.05$).

Table 2. Mean Consumer Sensory Acceptability Ratings of Hamburger Patties[a]

sensory attribute	formulation			
	control	5% SWPI	10% SWPI	15% SWPI
appearance	5.74 ± 1.59	6.32 ± 1.20	5.47 ± 1.5	5.11 ± 1.85
color	5.58 ± 1.61	6.47 ± 1.07	5.79 ± 1.40	5.53 ± 1.71
flavor	6.37 ± 1.34	5.47 ± 1.31	3.63 ± 1.64*	3.58 ± 1.89*
overall texture	6.21 ± 1.08	5.32 ± 1.77	4.32 ± 1.57*	3.95 ± 2.22*
overall liking	6.11 ± 1.20	5.32 ± 1.60	3.79 ± 1.65*	3.37 ± 2.17*
acceptability (% yes)	79	68	21	32

[a] Mean values of 19 consumer responses. *, mean value significantly different from control ($p < 0.05$).

Table 3. Mean Consumer Sensory Acceptability Ratings for Ice Cream[a]

sensory attribute	formulation				
	A = control (with starch)	5% SWPI	10% SWPI	10% SWPI with chocolate	B = control (without starch)
appearance	6.85 ± 1.23	5.10 ± 1.55[AB]	5.50 ± 1.70[AB]	5.45 ± 1.57[AB]	6.65 ± 1.84
color	6.90 ± 1.25	6.05 ± 1.57	5.70 ± 1.66[A]	5.80 ± 1.47[A]	6.50 ± 1.82
flavor	6.35 ± 2.08	4.25 ± 1.92[AB]	3.90 ± 1.83[AB]	5.20 ± 1.76[AB]	6.89 ± 1.49
overall texture	6.20 ± 1.47	4.65 ± 1.46[AB]	5.10 ± 1.7[AB]	5.60 ± 1.76[B]	6.75 ± 1.62
overall liking	6.30 ± 1.75	4.25 ± 1.77[AB]	4.05 ± 1.6[AB]	5.05 ± 2.0[AB]	6.65 ± 1.46
acceptability (% yes)	80	35	30	60	85

[a] Mean values of 20 consumer responses. Mean values significantly different from control are indicated by superscript A and/or B.

Any emulsion is potentially unstable, and stable emulsions will remain unchanged without creaming, flocculation, coalescence, and/or phase inversion upon heating and/or shaking (Zayas, 1997). The emulsifying stability pattern of the protein investigated is similar to that of emulsifying capacity (Figure 4). SWPI, SPI, and NaCAS exhibited similar emulsion stabilities (79, 76, and 71%, respectively), and their emulsions were significantly more stable than that of NFDM (49%) and DEW (47%) after heating at 80 °C for 30 min and centrifugation. The comparable, and in some cases superior, emulsifying capacity and stability of SWPI compared to those of other proteins investigated make it a potential ingredient in many food formulations such as salad dressing, sausages, comminuted meats, ice cream, cake batters, bologna, and mayonnaise.

Gel Strength. Solutions of most globular proteins in foods (e.g., egg white, soybean, and whey protein) form aggregates and heat-set gels as temperature increases. The effect of temperature on the gel strengths of various proteins are shown in Figure 5. Gel viscosity increased with increased temperature used for heating the protein solutions for all proteins investigated. DEW formed a rigid gel around 80 °C. Kato et al. (1990) reported that the strengthening of gel formed from egg white is mainly attributed to hydrogen bonding and hydrophobic interactions and partially to the formation of intermolecular disulfide bonds. SWPI showed a gradual increase in viscosity over the 60–100 °C range. This may be an indication that the gelling point of SWPI is >100 °C. Gels formed by SWPI were generally less viscous than those formed by other proteins. To exploit the gelation properties of SWPI, increased protein concentration (>20% w/v) and temperature may be required.

Consumer Sensory Evaluation. *Banana Nut Muffins and Chocolate Chip Cookies.* Muffins containing 10% SWPI received higher acceptability scores for appearance, color, flavor, texture, and overall liking compared to the control and muffins containing 20% SWPI (Table 1). All consumers found muffins with 10% SWPI to be acceptable, and 95% of them found the control sample to be acceptable. Visual observation indicated that muffins containing 10% SWPI had more product volume and were lighter in color and moister compared to the control sample. The moistness of muffins containing SWPI was likely due to the water holding capacity of SWPI. Addition of up to 20% SWPI to muffin formulation caused the flavor to be unacceptable. This was probably due to the perceived off-flavor. Cookies formulated with 10% SWPI were rated as acceptable as the control by 90% of the consumers (Table 1). As with the muffin samples, SWPI at 10% addition improved the appearance (more product volume) and color (lighter) of cookies. However, the addition of 10% SWPI caused the texture to be softer compared to the control, resulting in the lower acceptability score for texture. Cookies containing 20% SWPI were least acceptable as a result of less desirable texture and flavor.

Hamburger Patties. The hamburger patty containing 5% SWPI was similar to the control in terms of flavor, texture, and overall liking (Table 2). Addition of 5% SWPI to the formulation improved the appearance (smoother surface) and color of patties. Addition of up to 15% SWPI yielded patties with appearance and color comparable to those of the control; however, the product was not acceptable. Patties containing 15% SWPI had a fibrous texture typical of those meat products extended with extruded vegetable proteins.

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Ice Cream. Increases in appearance and overall texture acceptability scores were observed when SWPI was increased from 5 to 10% in the formulations (Table 3). Addition of chocolate flavor to the ice cream product containing 10% SWPI increased color, flavor, overall texture, and overall liking acceptability. Flavor was likely to be the sensory attribute most influencing overall sensory acceptability. Modification of SWPI to attain more desirable flavor may open new marketing opportunities for this product.

In summary, SWPI exhibited functional properties similar or superior to those of commonly used commercial proteins. Because of its high protein content (>90%) and good functionality, SWPI has potential applications in new product formulations and fortification. Solubilized wheat protein isolate (SWPI) may offer an alternative protein source for use in various food products.

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