Twin-Screw Extrusion Texturization of Extruded-Expelled Soybean Flour

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ABSTRACT: Texturized soy proteins (TSP) have been produced from hexane-extracted soy flours having a narrow range of characteristics. The objective of this study was to determine the influence of protein dispersibility index (PDI) and residual oil content on extrusion texturization of partially defatted soy flours produced by extruding-expelling (E-E). Ten E-E processed soy flours having residual oil contents and PDI values of 5.5–12.7% and 35.3–69.1%, respectively, were texturized using a twin-screw extruder. Water-holding capacities were greater for TSP prepared from E-E processed soy flours with lower residual oil contents. Bulk densities were significantly lower for TSP prepared from E-E processed soy flours compared with a commercial product made from hexane-extracted soy flour. The texture characteristics of extended ground beef patties containing texturized E-E processed soy flour were similar to that of 19% fat ground beef. Flavor acceptability was directly correlated (R = 0.761) with residual oil content of the E-E processed soy flours. However, lower residual oil and higher PDI flours exhibited better texturization and extrudate qualities.

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KEY WORDS: Extended meat, extruding-expelling, extrusion, soy flour, soy protein, texturized protein.

Defatted soybean flours and flakes are valuable materials for extrusion-texturized vegetable proteins (1), a product used in ground meat products and meat analogs (2). Small-scale extruder-expeller (E-E) operations, or mini-mills, have been increasing in popularity because of their low capital investment, local feed demand for high-energy protein supplements, and their ability to process identity-preserved and organic products. Partially defatted soybean flours are important coproducts of this process, particularly because these flours can be used for human as well as animal consumption. To compete in highly competitive oil and meal markets, E-E operations must explore potential value-added markets for these partially defatted soy flours, such as the production of texturized soy protein (TSP).

Hexane-extracted and flash-desolventized soybean flours and flakes are widely used to produce TSP. These flours typically contain less than 1% fat and have protein dispersibility index (PDI) values >80. It is uncertain whether E-E processed soy flour can be texturized, and the conditions necessary for extrusion-texturization of E-E processed partially defatted soy flour are unknown. Excess oil may reduce shear during extrusion, and proteins denatured prior to extrusion may resist alignment. Both may prevent meat-like texture from forming. However, Lusas and Riaz (1) have recently claimed that E-E processed soy flour can be texturized but have offered few data to support the claim or to document sensory and other performance characteristics.

Crowe *et al.* (3) have shown that by selecting proper screw configuration, moisture content, and feed material, a wide variety of residual oil contents and protein dispersibility index (PDI) values is possible. Soy meal with relatively low oil content (6%) can be achieved by E-E processing while maintaining relatively high PDI (>55). The objectives of this study were to extrude-texturize E-E produced partially defatted soy flours having wide ranges of PDI and residual oil contents to determine the roles of these variables in texturization. The hypothesis of this study was that E-E processed partially defatted soy flours with higher PDI values and lower residual oil contents can be extruded to produce better quality TSP compared with partially defatted soy flours having lower PDI values and higher residual oil contents. Should low-PDI and high-residual oil flours produce acceptable TSP, then the E-E processing would not need to be so tightly controlled.

EXPERIMENTAL PROCEDURES

Materials. Whole soybeans (Latham 610) were obtained from Iowa Soy Specialties (Vinton, IA) and were stored at 9.5% moisture content on their premises until processing. The soybeans used to study the effect of low moisture content on oilseed processing were dried to 6.7% moisture content using ambient air grain driers. Dehulled samples were processed using traditional methods of first cracking the soybean into 6–8 pieces with a roller mill (Ferrell-Ross, Oklahoma City, OK) and then aspirating the hulls with a Multi-Aspirator (Kice, Wichita, KS). A commercial TSP, ADM 165-118, was provided by Archer Daniels Midland Co. (Decatur, IL).

Extruding and expelling. Extruding-expelling whole and dehulled soybeans was performed at Iowa Soy Specialties using an Insta-Pro 2500 dry extruder and an Insta-Pro 1500 screw press (Triple "F"; Insta-Pro, Des Moines, IA). Following E-E processing, the presscake was placed into plastic-lined paper bags and allowed to cool at ambient temperature

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and then sealed for transport. The soymeal cake was milled to <100 mesh (94.7%) by using a Fitzmill (The Fitzpatrick Company, Elmhurst, IL). The Fitzmill was operated at 7,000 rpm using the blunt hammermill configuration, fed at 30 rpm feed screw rate, and fitted with a 1536-0060 screen. Milled samples were stored at −20°C prior to texturizing.

Texturizing. A co-rotating lab-scale Leistritz Micro-18 (American Leistritz Corp., Somerville, NJ) twin-screw extruder with a screw diameter of 18 mm and an L/D ratio of 25 was used. The barrel was divided into six electrically heated sections including the die. The twin screws had segmental screw elements so that the amount of shear input could be varied. A high-shear screw design with six temperature zones (Fig. 1) operating at a screw speed of 300 rpm was used for all treatments. Feed rate, screw speed, die, screw design, temperature, and flour moisture content were constant for each treatment. All partially defatted soy flours were hydrated to 27% moisture, mixed, and allowed to stand overnight at 4°C for tempering. The flours were fed to the extruder at a uniform feed rate of 150 g/min using a metering feeder (Accurate Inc., Whitewater, WI). The extruder was brought to steady state for each treatment and held for at least 5 additional min prior to collecting each sample. The extrudate was collected and dried at 50°C for 24 h.

Extruder torque and pressure. Screw torque and die pressure during extrusion were monitored by a digital control panel readout and were recorded after steady state had been reached and held for an additional 2 min.

Extrudate milling and sizing. The dried extrudates (TSP), including a commercial sample (ADM 165-118; Archer Daniels Midland Co.), were milled and sized using a set of corrugated cracking rolls (Witt Corrugating Inc., Wichita, KS) to pass through a 6-mesh screen and be contained on a 12-mesh screen. Milled TSP was stored in sealed polyethylene bags at 25°C until analyzed.

Soy flour composition. Moisture contents of soy flours were determined according to the 2-h oven-drying method (4). Crude fat contents were determined by Goldfisch extraction (5). Crude protein was measured using a PerkinElmer Series II Nitrogen Analyzer 2410 (PerkinElmer Corp., Norwalk, CT). Nitrogen contents were multiplied by a factor of 6.25 to estimate crude protein content.

Water-holding capacity. Water-holding capacity was determined by weighing 30 g TSP into a 400-mL beaker and adding 150 mL of 4°C water. The sample was held in a refrigerator for 1 h. The beaker was emptied onto a preweighed 20-mesh screen tilted at a 25° angle and allowed to drain for 3 min. The screen was blotted with a paper towel to remove excess water and weighed. Water-holding capacity was calculated as (hydrated weight − dry weight)/dry weight.

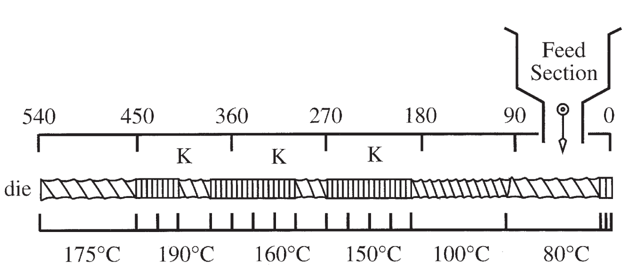

FIG. 1. Extruder screw configuration. K denotes kneading blocks; top scale denotes distance along barrel (mm) from end of screw; lower scale denotes sectional divisions with Leistritz high-shear screws and typical internal temperatures.

Bulk density. TSP was added to a 100-mL graduated cylinder in 20-mL intervals. At each interval, the cylinder was lightly tapped against a bench surface 20 times. The filled cylinder was emptied into a tared beaker to determine the weight of TSP. Bulk density was calculated as weight of TSP per 100 cc volume.

Texture analysis of TSP. Texture analysis was performed with a TA-XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) using the texture profile analysis measurement. About 10.0 g hydrated TSP (2.6 parts H_2O/1 part TSP, wt basis) were placed in an aluminum cylinder (internal diameter = 27 mm, depth = 27 mm) and pressed to make a smooth surface. A smooth 13-mm plastic probe was used to determine 70% compression at a rate of 5 mm/s. Samples were evaluated for hardness, springiness, cohesiveness, and chewiness as described by Breene and Baker (6). Six texture analyses were performed for each sample.

Preparation of TSP-extended ground beef patties. Based on the residual oil content of TSP, coarse ground beef with different fat levels (~7 and ~19%) was blended with the appropriate amount of hydrated TSP to give a final product with 7% fat content and 25% TSP. The mixture of ground beef and TSP was then ground by passing through a meat grinder fitted with a 0.32-cm die plate, and ground mixture was held at 4°C until used to make patties.

TSP-extended ground beef patties were formed by placing 48 g 25% TSP ground beef into a cylindrical mold and hand patting to a uniform thickness of 1.3 cm. The patties were held at −20°C until cooked.

Frozen patties were thawed at 4°C for 24 h and then were cooked at 185°C for 3.5 min, flipped, and allowed to cook for an additional 2.5 min to an internal temperature of 70°C. The patties were allowed to cool to room temperature, and a 25-mm core sample was taken from the center of each patty for sensory and textural analyses.

Texture analysis of cooked TSP-extended ground beef patties. Texture profile analysis was performed using a TA-XT2 Texture Analyzer (Texture Technologies Corp.). A 38-mm anvil was used to determine 70% compression at a rate of 5 mm/s. Samples were evaluated for hardness, springiness, cohesiveness, and chewiness. Six texture analyses were performed on each sample.

Cooking loss. Cooking loss was the gravimetric difference in weight between uncooked and cooked patties. Cooked patties were cooled to room temperature and blotted with a paper towel to remove excess surface fat and water. Weight differences were based on the sum of four patties. The percentage cooking loss was calculated as 100 × (uncooked weight − cooked weight)/uncooked weight.

Sensory evaluation. Frozen patties were thawed at 4°C for 24 h, and then were cooked at 185°C for 3.5 min, flipped, and allowed to cook for an additional 2.5 min to an internal temperature of 70°C. Patties were held at 60°C and were served within 15 min following cooking. Ten students of the Department of Food Science and Human Nutrition were trained to evaluate hardness, cohesiveness, chewiness, soy flavor, and overall flavor during two 1-h training sessions with samples similar to those they were to evaluate. In addition, texture and flavor references were provided. Panelists were asked to evaluate seven different samples presented in duplicate. Samples were evaluated under red light on two separate sittings.

Experimental design. Sample 45/8/1 (PDI/residual oil/times expelled) roughly represents the midpoint of samples with regard to PDI value and residual oil content. On using this sample, the extrusion conditions for texturizing were optimized based on instrumental textural comparison to the commercial TSP. All other samples were texturized under identical conditions with respect to moisture, temperature, screw speed, etc.

Statistical analysis. A randomized complete block design was used with each block replicated three times. In the third block, however, only eight of the ten treatments were measured because of insufficient sample. Statistical analyses were performed using the General Linear Model procedures of SAS 6.06 (7). Significance was established at $P < 0.05$.

RESULTS AND DISCUSSION

Partially defatted soy flour characteristics. The properties of the E-E processed soy flours are summarized in Table 1. By design, the E-E processed soy flours chosen represented a wide range of PDI values (35.4–69.1) and residual oil contents (5.4–12.7%) with little variability in crude protein contents (49.3–52.4%). The pH of the E-E processed soy flours used in this study ranged from 6.5 to 6.7. The pH of the feed material affects the fluidity of the dough in the extruder and thus influences shaping, density, chewiness, and rehydration properties of the TSP (8,9). Characteristics of raw materials, including source, previous handling or milling history, extraction conditions and extrusion parameters, also influence the functional properties of extrudates. These E-E processed soy flours were produced at maximum temperatures ranging from 86 to 162°C. Three samples (35/6/2, 67/10/2, and 58/6/2) were twice-expelled and therefore were subjected to longer periods of thermal processing. Dahl and Villota (10) suggested that physicochemical properties may be modified by excessively heated flour because of nonuniform melting of carbohydrate fractions and intermolecular peptide cross-linking.

Water-holding capacity and bulk density. Water-holding capacities and bulk densities of TSP produced from E-E processed soy flours are reported in Table 2. Residual oil was negatively correlated with water-holding capacity ($R = -0.473$, $P < 0.05$; Fig. 2). There were no significant differences in water-holding capacity for extrudates produced from low PDI (<55) vs. high PDI (>55) partially defatted soy flour. These results are similar to those reported by Bhattacharya and Hanna (11), who observed water-holding capacity to decrease as lipid content increased, and Kearns *et al.* (12), who found no significant difference in the water-holding capacity of extrudates produced from flours with PDI levels ranging from 20–70. Heating disrupts the quaternary structure of soy proteins and subsequently dissociates the subunits (13). These

TABLE 1
Compositional and Chemical Analyses of Extruded-Expelled Soybean Flour

Sample code[a]	PDI	Residual oil (% mfb)	Crude protein (% mfb)
38/8/1	37.7	7.7	51.3
35/6/2	35.3	5.5	52.4
45/8/1	45.4	7.7	50.9
67/10/2	67.2	9.5	50.5
71/13/1	70.7	12.7	49.1
55/13/1	55.3	12.6	50.0
58/6/2	58.4	5.5	52.0
57/8/1	57.3	7.6	50.6
40/12/1	39.8	11.5	49.3
70/11/1	70.4	10.5	49.5

[a]Denotes protein dispersibility index (PDI)/residual oil content.

TABLE 2
Water-Holding Capacities and Bulk Densities of Texturized Soy Protein from Extruded-Expelled Soybean Flour[a]

Sample code[b]	Water-holding capacity(%)	Bulk density (g/cc)
38/8/1	364[c]	0.231[a,b]
35/6/2	335[b,c]	0.254[b]
45/8/1	367[c]	0.229[a]
67/10/2	312[a,b]	0.264[b]
71/13/1	293[a]	0.264[b]
55/13/1	324[b]	0.245[a,b]
58/6/2	323[b]	0.264[b]
57/8/1	365[c]	0.223[a]
40/12/1	309[a,b]	0.255[b]
70/11/1	339[b,c]	0.236[a,b]
ADM118[c]	319[a,b]	0.382[c]

[a]Means within each column with different nonitalic superscripts are significantly different at $P<0.05$.
[b]Denotes PDI/residual oil content/times expelled. See Table 1 for abbreviation.
[c]Archer Daniels Midland (Decatur, IL).

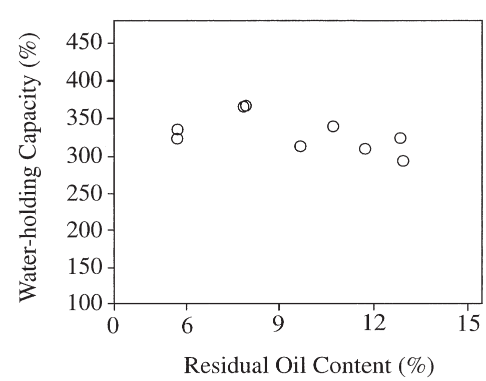

FIG. 2. Relationship between water-holding capacity and residual oil content of texturized soy protein.

fractions initially form soluble aggregates that are converted to insoluble aggregates with continued heat treatment as evidenced by increased water-holding capacity with increasing PDI. This may be indicative of protein unfolding, which allows active amino acid R-groups to become exposed for binding water. With extended thermal processing (lower PDI), the production of insoluble aggregates is favored as noted by decreased water-holding capacity.

Water-holding capacity was negatively correlated with bulk density ($R = -0.474$, $P < 0.05$; Fig. 3). Similarly, Rhee *et al.* (14) reported an inverse relationship between water-holding capacity and bulk density in extrudates produced from flours with a wide range of nitrogen solubilities. The lack of available water-binding sites makes these low-solubility or insoluble protein aggregates unable to incorporate sufficient water to develop proper dough consistency within the extruder barrel. On release from the die, the extrudate does not properly expand due to insufficient entrapped moisture as evidenced by decreased bulk density. The range of bulk densities for partially defatted soy flour extrudates was narrow, 0.22–0.26 g/cm^3, despite the relatively wide ranges of PDI values and residual oil contents.

Extruder conditions. The extrusion of proteins is associated with dissipation of mechanical energy caused by increased dough viscosity and frictional effects. Extruder torque and pressure are indirect measurements of these effects (Table 3). The relatively high residual oil content of the partially defatted soy flour may have had protein plasticizing and lubricating effects, reducing protein interactions and attenuating extruder torque and pressure. Texturizing sample 35/6/2 resulted in the highest extruder torque and pressure levels. This sample, which was twice-expelled, was exposed to excessive thermal processing, as evidenced by a low PDI value (35.4). However, sample 57/8/1 showed no significant change in torque or pressure with single vs. twice expelling. These samples (57/8/1 and 58/6/2) had higher PDI values (55.3 and 58.0, respectively), indicating less thermal treatment. In general, lower PDI samples (38/8/1, 35/6/2, and 45/8/1) were associated with increased torque. Kearns *et al.* (12) also reported increased energy requirements for PDI values <50. Mitchell and Areas (15) suggested that the presence of insoluble protein aggregates negatively affects flow behavior. However, Alcocer and Areas (16) found that increasing flour lipid content resulted in decreased protein aggregation, resulting in less energy input in comparison to low lipid-containing flours. Indeed, higher residual oil samples (71/13/1, 55/13/1, 40/12/1, and 70/11/1) had significantly lower torque and pressure compared with other partially defatted soy flours.

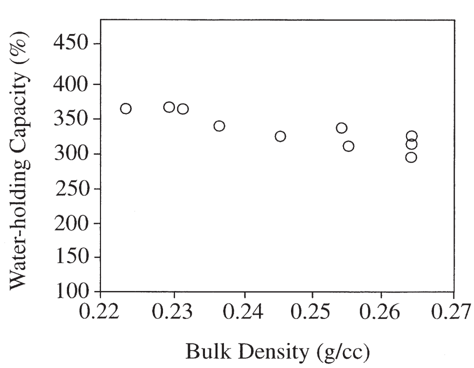

FIG. 3. Relationship between water-holding capacity and bulk density of texturized soy protein.

TABLE 3
Extruder Conditions During Texturization of Extruded-Expelled Soybean Flour[a]

Sample code[b]	Torque[c] (%)	Pressure (psi)
38/8/1	30.0^{b,c}	470^{b}
35/6/2	33.0^{c}	517^{c}
45/8/1	30.7^{b,c}	477^{b}
67/10/2	26.7^{a,b}	467^{b}
71/13/1	25.0^{a}	433^{a}
55/13/1	26.0^{a,b}	437^{a}
58/6/2	29.0^{b}	463^{b}
57/8/1	29.0^{b}	470^{b}
40/12/1	26.0^{a,b}	447^{a,b}
70/11/1	25.3^{a,b}	437^{a}

[a]Means within each column with different roman superscripts are significantly different at $P < 0.05$.
[b]Denotes PDI/residual oil content/times expelled.
[c]Torque is given as percentage of maximum load of extruder drive motor. See Table 1 for abbreviation.

Textural and sensory characteristics. TSP hardness was significantly reduced in high residual oil samples (71/13/1, 55/13/1, 40/12/1, 70/11/1) and in the twice-expelled sample 67/10/2 (Table 4). The negative correlation between residual oil and all instrumental texture measurements (except cohesiveness) indicates that the higher lipid contents of these samples may have inhibited protein interactions responsible for desirable extrudate textural attributes. Both Faubion and Hoseney (17) and Bhattacharya and Hanna (11) found that removing lipids from flours favorably influenced TSP textural qualities, and Kearns *et al.* (12) reported a maximum recommended fat level of 6.5% in raw materials.

Neither PDI value nor residual oil content affected textural attributes measured in the TSP-extended ground beef system (Table 5). In addition, no relationship was noted between texture measurements in the TSP-extended ground beef system vs. the TSP alone. All hydrated TSP samples had decreased hardness compared with the commercial sample; however, this decrease was not significant in samples 38/8/1 (PDI 37.7) and 58/6/21 (twice-expelled) (Table 4). Texture attributes in nearly all samples in the TSP-extended ground beef system were comparable to the commercial sample (Table 5). In addition, despite the lower fat content (7%), texture measurements of samples in the TSP-extended ground beef system were similar to those measured in the 19% fat ground beef control (Table 5).

Results from human sensory evaluation of TSP-extended ground beef patties are presented in Table 6. Few significant differences in hardness or chewiness were observed in the TSP-extended ground beef compared with the 19% fat control. As expected, soy flavor was significantly higher

TABLE 4
Texture Properties of Hydrated Texturized Soy Protein[a]

Sample code[b]	Hardness[c] (N)	Springiness[c]	Cohesiveness[c]	Chewiness[c] (N)
38/8/1	10.5[b,c]	0.870[a,b]	0.563[a]	5.1[b,c]
35/6/2	10.0[b]	0.870[a,b]	0.602[b]	5.2[b,c]
45/8/1	9.8[b]	0.903[b]	0.595[b]	5.2[b,c]
67/10/2	7.6[a]	0.854[a,b]	0.610[b]	3.9[a]
71/13/1	7.0[a]	0.863[a,b]	0.577[a,b]	3.5[a]
55/13/1	8.0[a,b]	0.837[a]	0.573[a,b]	3.9[a]
58/6/2	10.6[b,c]	0.884[a,b]	0.643[c]	6.0[c]
57/8/1	9.4[b]	0.884[a,b]	0.592[b]	4.9[b]
40/12/1	7.5[a]	0.866[a,b]	0.598[b]	4.0[a,b]
70/11/1	7.9[a]	0.859[a,b]	0.568[a,b]	3.9[a]
ADM118	11.4[c]	0.844[a]	0.566[a]	5.9[c]

[a]Means within each column with different superscripts are significantly different at $P < 0.05$.
[b]Denotes PDI/residual oil content/times expelled.
[c]Hardness and chewiness values are given in newtons; springiness and cohesiveness are unitless. See Table 1 for abbreviation and Table 2 for company address.

($P < 0.05$) in the TSP-extended ground beef vs. the 19% fat control. However, panelists judged overall flavor (like vs. dislike) in most of the TSP-extended ground beef samples to be similar to the 19% fat control and the commercial sample. Sample 71/13/1, produced from high residual lipoxygenase activity, partially defatted soy flour (data not shown) was judged to have the least desirable overall flavor. Overall flavor score was negatively correlated with residual oil content of partially defatted soy flour ($R = -0.761$, $P < 0.05$; Fig. 4). In general, TSP from low-fat, partially defatted soy flour had

TABLE 5
Texture Properties of Texturized Soy Protein-Extended Hamburger Patties[a]

Sample code[b]	Hardness[c] (N)	Springiness[c]	Cohesiveness[c]	Chewiness[c] (N)
38/8/1	112.9[a,b]	0.780[a,b]	0.539[a]	47.4[a,b]
35/6/2	105.3[a,b]	0.779[a,b]	0.543[a]	43.9[a,b]
45/8/1	123.7[b]	0.763[a,b]	0.539[a]	50.9[b]
67/10/2	96.1[a]	0.763[a,b]	0.558[a]	40.7[a]
71/13/1	110.4[a,b]	0.772[a,b]	0.571[a]	48.6[b]
55/13/1	131.8[b]	0.773[a,b]	0.529[a]	52.2[b]
58/6/2	105.8[a,b]	0.776[a,b]	0.561[a]	45.7[a,b]
57/8/1	119.8[b]	0.792[b]	0.554[a]	52.5[b]
40/12/1	100.9[a]	0.744[a]	0.560[a]	42.1[a]
70/11/1	111.1[a,b]	0.795[b]	0.532[a]	46.6[a,b]
ADM118	105.5[a,b]	0.800[b]	0.537[a]	45.3[a,b]
Control 7%	127.7[b]	0.772[a,b]	0.499[a]	50.0[b]
Control 19%	98.8[a]	0.802[b]	0.566[a]	44.1[a]

[a]Means within each column with different superscripts are significantly different at $P < 0.05$.
[b]Denotes PDI/residual oil content/times expelled.
[c]Hardness and chewiness values are given in newtons; springiness and cohesiveness are unitless. See Table 1 for abbreviation and Table 2 for company source.

TABLE 6
Sensory Properties of Texturized Soy Protein-Extended Ground Beef Patties[a]

Sample code[b]	Hardness[c]	Cohesiveness[d]	Chewiness[e]	Soy flavor[f]	Overall flavor[g]
35/6/2	7.3[b]	7.4[b]	7.6[b]	2.0[a,b]	11.1[a,b]
45/8/1	8.0[b]	7.2[b]	8.2[b]	5.0[d]	7.9[b]
71/13/1	7.2[b]	5.8[a]	7.7[b]	8.7[e]	3.3[c]
58/6/2	7.9[b]	6.8[b]	8.1[b]	3.1[b,c]	9.8[a,b]
40/12/1	7.9[b]	7.3[b]	8.6[b]	4.7[c,d]	8.3[b]
ADM118	4.5[a]	5.5[a]	4.8[a]	4.4[c,d]	9.1[a,b]
19% Control	6.6[a,b]	7.0[b]	8.7[b]	0.7[a]	11.7[a]

[a]Means within each column with different superscripts are significantly different at $P < 0.05$.
[b]Denotes PDI/residual oil content/times expelled.
[c]Score of 0 is soft; score of 15 is hard.
[d]Score of 0 is crumbly; score of 15 is deforming.
[e]Score of 0 is not chewy; score of 15 is very chewy.
[f]Score of 0 is no soy flavor; score of 15 is intense soy flavor.
[g]Score of 0 is dislike intensely; score of 15 is like very much. See Table 1 for abbreviation and Table 2 for company source.

less soy flavor and better overall flavor compared with TSP from high-fat partially defatted soy flour.

Cooking loss. All TSP samples produced from the E-E processed soy flours had cooking losses that were between the values for the 7% fat control and the 19% fat control (Table 7). Two samples, 45/8/1 and 57/8/1, did not have cooking losses significantly different from the 19% fat control. The cooking losses of most of the TSP-extended patties were less than reported by others for low-fat hamburger patties (18). Cooking losses for all samples were similar to those of the commercial TSP.

All E-E processed soy flours produced acceptable TSP, despite the relatively wide range of PDI and residual oil contents. It is clear from these results that partially defatted soy flours produced by E-E have the functional characteristics necessary for extrusion-texturization of value-added products suitable for food applications.

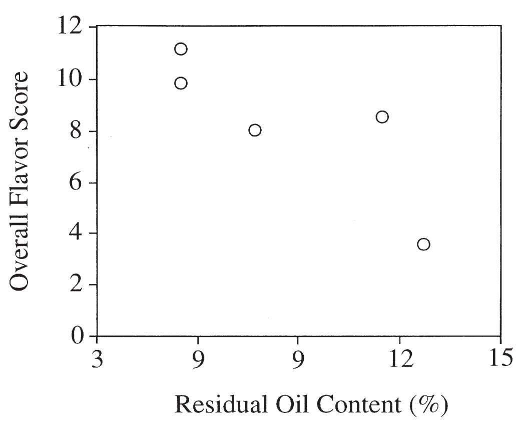

FIG. 4. Relationship between overall flavor score and residual oil content of texturized soy protein.

TABLE 7
Cooking Losses of Texturized Soy Protein-Extended Hamburger Patties[a]

Sample code[b]	Cooking loss (%)
38/8/1	21.2^{b}
35/6/2	$22.3^{b,c}$
45/8/1	$25.3^{c,d}$
67/10/2	21.7^{b}
71/13/1	$22.8^{b,c}$
55/13/1	$24.9^{c,d}$
58/6/2	21.7^{b}
57/8/1	$24.1^{b,c,d}$
40/12/1	21.9^{b}
70/11/1	$22.7^{b,c}$
ADM118	$24.3^{b,c}$
Control 7%	19.3^{a}
Control 19%	28.2^{d}

[a]Means within the column with different superscripts are significantly different at $P < 0.05$.
[b]Denotes PDI/residual oil content/times expelled. See Table 1 for abbreviation and Table 2 for company source.

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