Effect of Value-Enhanced Texturized Soy Protein on the Sensory and Cooking Properties of Beef Patties

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ABSTRACT: Texturized soy protein (TSP) originating from varieties of value-enhanced soybeans and commodity soybeans, which were processed by extrusion-expelling, were incorporated into ground-beef patties. The soybean varieties included high-cysteine, low-linolenic, lipoxygenase-null, high-sucrose, low-saturated-fat, and high-oleic. The lower the bulk density was, the better the water-holding capacity of TSP. Neither property was affected by the protein dispersibility index or residual oil of the low-fat soy flours from which the TSP was prepared. All extruded-expelled processed flours from value-enhanced soybeans made acceptable TSP. The high-sucrose soybeans produced TSP with higher expansion and improved water-holding capacity. There were no differences in cooking properties or proximate compositions of patties for all treatments. Inside and outside colors were darker for the TSP-extended patties than for the all-beef control, and there was little difference among soybean varieties. The patties containing TSP had significantly more soy flavor and were harder than the all-beef control patties. Some TSP treatments produced more tender and less cohesive cooked patties than did the all-beef control.

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KEY WORDS: Extended meat patties, extrusion-expelling, genetically enhanced soybeans, low-fat soy flour, soy flour, soy protein, soybeans.

Adding soy protein to meat products, particularly ground-beef patties (hamburger), has been practiced since the early 1900s (1). Today, soy protein is added to ground-meat products mostly in the form of texturized soy protein (TSP), in order to maintain meatlike texture (2). Adding TSP to meat products reduces manufacturing costs (3) and consumer dietary fat intake. Consumers want these less-expensive, healthier alternatives, yet desire a product that is similar in flavor and texture to the all-animal-protein products. Bowers and Engler (4) and Drake *et al*. (5) found that adding TSP did not impart negative quality or sensory attributes to meat products except for soy flavor. However, there is debate on the effects of added TSP in ground beef on decreased meat flavor and added soy flavor (6). Twigg *et al.* (7) and Liu *et al*. (8) found that adding TSP to ground beef neither added soy flavor nor decreased meat flavor. Recently, Crowe and Johnson (9) found that texturized low-fat soy flour from commodity soybeans produced extended ground-beef patties with equivalent sensory properties and improved cooking properties compared with 19% fat ground beef.

Value-enhanced soybeans are those that have altered traits either through genetic modification or through traditional plant breeding. Value-enhanced soybeans include soybeans with altered FA compositions, soybeans with altered protein compositions, or soybeans with deleterious enzymes removed. Although value-enhanced soybeans are not new, few studies have been published on the characterization of functional properties or utilization of these value-enhanced soybeans and their processed ingredients (i.e., flour, protein, and oil) in food products.

Extrusion-expelling (EE) is gaining in popularity due to reduced capital investment, ease of using equipment, and the economic feasibility of processing value-enhanced soybeans in an identity-preserved system. Low-fat soybean meal, or flour if soybeans are dehulled and the press cake is ground, (6–11% residual oil) and crude soybean oil are products obtained by using EE processing. There is little literature focused on using the low-fat meal in any form (i.e., grits, flour, TSP) in food products. We hypothesized that the altered FA composition of the residual oil, the absence of the enzyme lipoxygenase, and increased sucrose content may affect cooked hamburger flavor, and the modified protein composition may affect texture. In a companion paper (10), we have already reported on the functional properties of the low-fat flours produced from these genetically enhanced soybeans. The objective of the present research was to determine if the TSP produced from the value-enhanced soybeans affected cooking and sensory characteristics of the ground-beef hamburger patties compared with TSP from nongenetically enhanced soybeans and ground beef without TSP.

EXPERIMENTAL PROCEDURES

Soybeans. The value-enhanced varieties included high-sucrose (Hs), low-linolenic (LLL), lipoxygenase (Lox)-null, high-oleic (Ho), low-saturated-fat (Ls), and high-cysteine (Hc). Hs soybeans have increased amounts of sucrose (6.7% sucrose compared with 5.7% for normal soybeans) and decreased amounts of stachyose (0.3% stachyose compared with 4.6% for normal soybeans). LLL soybeans have decreased amounts of the unsaturated FA linolenic acid (3.1% linolenic acid compared with 7.5% for normal soybeans). Lox-null soybeans have all three Lox isozymes removed. Ho

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soybeans have increased amounts of the FA oleic acid (79.2% oleic acid compared with 25.2% for normal soybeans). Ls soybeans have decreased amounts of all saturated FA(8.4% total saturated FA compared with 15.7% for normal soybeans) (2). Hc soybeans have increased amounts of the amino acid cysteine in the 7S protein fraction. This increase is equivalent to five residues of cysteine per mole of 7S protein. For controls, two lots of nongenetically enhanced soybeans were obtained: Wc, mixed bulk soybeans, West Central Cooperative (Ralston, IA); and St, variety 3690-0, Stine Seed Company (Adel, IA).

Soy flour preparation. Low-fat soybean meal was produced at Iowa Soy Specialties (Vinton, IA) from the six different value-enhanced soybean varieties and two commodity soybean varieties using methods previously reported (9). The meals were ground into low-fat soy flour (100 mesh) using a pin mill (Bauermeister, Inc., Memphis, TN). Two replicates were produced for each of the eight treatments.

Texturization. The flours were texturized using a co-rotating lab-scale Leistritz Micro-18 twin-screw extruder (American Leistritz Corp., Somerville, NJ) following methods outlined by Crowe and Johnson (9).

Preparation of ground-beef patties. Coarse ground beef (mixture of fat and beef trimmings) was obtained from the Iowa State University Meat Laboratory (Ames, IA). The meat was mixed with 30% rehydrated TSP (1:2.6 TSP to water) to produce a typical fast-food-style ground-beef patty. Fat levels were determined using an Anyl Ray Fat Analyzer (model 316-4A; Kartridge Pak Co., Davenport, IA) standardized for low (20%) and high (50%) fat. Coarse ground-beef was first ground with a meat grinder fitted with a 0.93-cm (3/8 in.) plate and then combined with rehydrated TSP. The mixture was blended in a ribbon mixer for 3 min and then ground with the meat grinder fitted with a 0.32-cm (1/8 in.) plate. Patties with a target weight of 113 g each were formed by using a mechanical patty maker (Hollymatic Supermodel 54, Countryside, IL). Patties were interwoven with waxed patty paper, blast frozen at −30°C, and stored at −18°C until needed.

Cooking protocol. Patties were cooked on a household griddle at 162°C, 3.5 min on one side and 2 min on the other, to an internal temperature of 71°C. For sensory evaluation, patties were cooked, covered with aluminum foil, and placed in a prewarmed oven set at 93°C for no more than 10 min before serving. For all other determinations, patties were cooked and allowed to cool to room temperature. Two replications of TSP-extended patties were produced for each treatment.

Proximate analysis. Proximate analyses (moisture, protein, and fat) of cooked patties were determined by using standard AOAC methods (39.1.02, 39.1.16, 39.1.08, respectively) (11). Moisture and fat analyses were carried out in triplicate for each replication. Protein was measured in duplicate for each replication.

Water-holding capacity (WHC) and bulk density (BD). WHC and BD were measured on the TSP according to methods of Crowe and Johnson (9).

Cooking properties. Cooking yields, fat retention, and moisture retention were calculated using the following formulas (12):

$$\text{cooking yield (\%)} = \frac{\text{cooked weight (g)}}{\text{raw weight (g)}} \times 100 \quad [1]$$

$$\text{fat retention (\%)} = \frac{\text{cooked weight (g)} \times \text{fat in cooked patty (\%)}}{\text{raw weight (g)} \times \text{fat in raw patty (\%)}} \times 100 \quad [2]$$

$$\text{moisture retention (\%)} = \frac{\text{cooking yield (\%)} \times \text{moisture in cooked patties (\%)}}{100} \quad [3]$$

Cooking yields, fat retention, and moisture retention were determined in triplicate for each replication.

Texture profile analysis (TPA). TPA was carried out using a texture analyzer (model TA-XT2; Texture Technologies Corp., Scarsdale, NY). A 40-mm aluminum anvil was used at a compression rate of 80% and a test speed of 3.3 mm/s. The attributes of hardness, springiness, and cohesiveness were determined. Hardness is defined as the peak force at the first compression and is the force necessary to attain a given deformation. Springiness is calculated as the proportion of compression distance recovered between the first and second compressions and is the rate at which a deformed material returns to its undeformed condition following removal of the deforming force. Cohesiveness is the area under the first curve divided by the area under the second curve and is a measure of the strength of the internal bonds (13,14). Samples were prepared by cutting 2 × 2 × 2-cm cubes from the center of the patty and placing them in the middle of the platform. Two samples were taken from each of three patties per replication of each treatment.

Color measurements. A Hunter Lab Spectrocolorimeter (model LS5100, Reston, VA) was used to determine the color of patties. The spectrocolorimeter was standardized using a white tile (No. LS 14318, $L = 92.32$, $a = -0.74$, $b = -0.40$) and a black tile. The standard observer was set at 10°, the light source was set at D65, and a 5.08-cm port size was used with a 4.45-cm view. Transparent plastic wrap was placed over the viewing port for protection, and patties were placed directly on the plastic wrap. For exterior color, each whole patty was placed on the port, and color was measured at three areas per side. For interior color, each patty was cut longitudinally, and color was measured in three areas. Two patties per replication were measured.

A split-plot design was used for assessing color. Soybean variety was used as the whole plot treatment, and either inside or outside color measurement was used as the subplot treatment.

Sensory evaluation. A 12-member trained panel was used for sensory evaluation. Panel members were recruited from students and staff in the Food Sciences Building at Iowa State University. Panelists were age 20–42, and six males and six females participated. Panelists were trained in two 1-h sessions to evaluate soy flavor, tenderness, cohesiveness, chewiness, and juiciness. A descriptive analysis test was used, with panelists evaluating five attributes for which they were trained. Panelists were informed of the origin of the TSP and allowed to withdraw without penalty.

Sensory evaluations were conducted in individual booths of the Sensory Evaluation Facility, Center for Crops Utilization Research. Panel sessions were conducted on six days, three times per week for two weeks. At each session, panelists were presented with three samples. Red light was used to mask any color differences that might bias the results.

Servings were two pieces of one-fourth of the patty presented warm in glass petri dishes. Warmed samples did not remain in the warm oven for more than 10 min. Each sample was assigned a random three-digit number. Presentation of samples was randomized between panelists, following a randomized incomplete block design.

Statistical analysis. Chemical and physical determinations were made following a randomized complete block design. Sensory evaluation analysis followed a randomized complete block design to maintain consistency between the production of raw material and sensory evaluation. All data were tested by General Linear Modeling (GLM) using SAS statistical software (SAS Institute, Inc., Cary, NC, 1999). A Tukey test was used for multiple comparisons, and P-values were determined using least square means. Significance was determined at the $P < 0.05$ level for all data analyses. Dunnett's t-test (a comparison between each treatment vs. the control) was run on all analyses, and significance was determined at the $P < 0.05$ level.

RESULTS AND DISCUSSION

Relationships between soy flour properties and TVP properties. PDI and RO values of the soy flour treatments ranged from 32.0 to 49.5 and from 7.0 to 11.7% for RO, respectively (Table 1) (10). Protein contents ranged from 47.4 to 52.6%. All soy flours had acceptable PDI and RO to make satisfactory TSP following guidelines defined by Crowe and Johnson (9).

The BD and WHC of the TSP made with different value-enhanced soybeans are shown in Table 1. BD and WHC of the TSP were negatively correlated ($R = -0.68$) with each other but were not correlated with PDI or RO of the soy flour. The only soybeans that were significantly different for BD were Wc, which were significantly more dense, and the only soybeans significantly different for WHC were Wc and Hs. Wc had the highest BD and the lowest WHC, which may be a result of its low protein content. Hs had the lowest BD and the highest WHC. The increased sucrose content of Hs soy flour may have bound more water compared with normal soy flour, thereby increasing expansion during texturization and leading to improved WHC.

Properties of cooked patties. There were no significant differences in proximate compositions of cooked patties among all treatments (Table 2). The moisture levels of cooked patties ranged from 51.6 to 55.0%; these moisture levels fall within the range of other published cooked moisture values (8,12,15,16). Cooked fat levels of all patties ranged from 16.5 to 17.9% and protein contents from 20.0 to 21.8%.

Cooking and texture properties. Although there were no statistical differences, moisture retentions, fat retentions, and cooking yields were generally higher in TSP-extended patties compared with the all-beef control (Table 3). TSP has the capacity to bind excess water and fat. Moisture retention ranged from 34.7 to 37.4%; fat retention, from 58.3 to 67.2%; and cooking yield, from 65.5 to 69.7%.

The addition of TSP increased hardness of the cooked ground-beef patties. TSP made from Hc and Hs soybeans gave the highest hardness values. There were no significant differences in cohesiveness values. Cooked TSP-extended beef patties were significantly less springy than the all-beef control, which was also observed by Crowe and Johnson (9). TSP made from Hs soybeans had the lowest springiness values.

Outside and inside colors. Surface colors of cooked TSP-extended patties were lighter than those of the all-beef control as indicated by higher L values, but there were no differences among soybean varieties (Table 4). There were no significant differences in a and b values.

The inside colors of the TSP-extended patties were also lighter than those of the all-beef control. Only the St soybeans

TABLE 1
Properties of EE-Processed Soy Flours from Value-Enhanced Soybeans and Their TSP[a]

	Soy flour			TSP	
Treatment[b]	PDI (%)	RO (%)	Protein (%)	BD[c] (g/cc)	WHC[c] (g water/g protein)
LLL	32.2	7.7	52.1	0.32[a]	2.96[a,b]
Hs	35.5	7.0	52.4	0.29[a]	3.29[b]
Ls	32.0	7.1	51.8	0.31[a]	2.94[a,b]
Ho	45.2	7.5	51.8	0.34[a,b]	2.73[a,b]
Hc	42.7	9.0	51.2	0.30[a]	2.96[a,b]
Lox-null	49.5	11.7	52.6	0.30[a]	2.96[a,b]
Wc	41.2	11.0	47.4	0.41[b]	2.41[a]
St	48.7	10.5	50.1	0.30[a]	2.97[a,b]

[a]EE, extruded-expelled; PDI, protein dispersibility index; RO, residual oil; BD, bulk density; WHC, water-holding capacity; TSP, texturized soy protein.
[b]Treatment names: LLL, low-linolenic; Hs, high-sucrose; Ls, low-saturated-fat; Ho, high-oleic; Hc, high-cysteine; Lox-null, lipoxygenase-null; Wc and St, commodity soybeans.
[c]Values in same vertical column followed by the same roman letter are not significantly different at the $P < 0.05$ level.

TABLE 2
Proximate Compositions of Cooked, TSP-Extended Ground-Beef Patties[a]

Treatment[b]	Moisture (%)	Fat (%)	Protein (%)
Control	54.2	17.5	21.8
LLL	52.8	17.2	20.9
Hs	53.4	17.4	21.4
Ls	55.0	16.5	21.7
Ho	53.9	17.4	21.6
Hc	53.4	17.0	20.0
Lox-null	53.9	17.4	21.8
Wc	51.6	17.1	20.9
St	54.2	17.9	20.8
	NS	NS	NS

[a]All measurements on as-is basis. NS denotes no significant difference among any values in column at $P < 0.05$.
[b]See Table 1 for treatment names and abbreviation.

TABLE 3
Properties of Cooked, TSP-Extended Ground-Beef Patties[a,b]

	Cooking parameters			TPA		
Treatment[c]	MR (%)	FR (%)	Cooking yield (%)	Hardness (g)	Cohesiveness (g)	Springiness (cm)
Control	34.7	60.7	65.9	50.0	31.5	0.94
LLL	36.1	60.7	68.3	54.0[a]	31.2	0.90[a]
Hs	37.0	64.0	67.9	67.1[a,z]	37.2	0.86[a,z]
Ls	36.0	58.3	66.1	60.7[a]	35.3	0.89[a]
Ho	36.7	61.6	68.7	54.5[a]	29.4	0.88[a,z]
Hc	37.4	67.2	69.7	68.3[a,z]	38.0	0.87[a,z]
Lox-null	35.4	60.9	65.5	66.4[a,z]	36.8	0.87[a,z]
Wc	34.9	59.1	65.6	52.8[a]	30.3	0.87[a,z]
St	36.4	64.7	68.0	67.7[a,z]	40.2	0.87[a,z]
	NS	NS	NS		NS	

[a]Values in same vertical column followed by same superscript roman letter are not significantly different at $P < 0.05$. NS denotes no significant difference among any values in column. Superscript z denotes a significant difference between this sample and all-beef control patty.
[b]MR, moisture retention; FR, fat retention; TPA, texture profile analysis.
[c]See Table 1 for treatment names and other abbreviation.

produced significantly lighter colors than the other TSP treatments (Table 4).

Sensory properties of cooked patties. Panelists detected soy flavor in all TSP-extended patties (Table 5), but none of the soybean treatments were significantly different from each other. Patties made with TSP from LLL, Ls, Ho, and St soybeans were judged to be more tender compared with the control all-beef patties. Patties made with TSP from LLL and Ho soybeans were significantly less cohesive compared with the control. There were no significant differences in chewiness and juiciness between TSP-extended patties and the control.

In general, no significant differences were found in the physical and chemical measurements among all the samples. Sensory evaluation results showed no significant differences between the 100% all-beef control and the 30% TSP-extended patties except for tenderness values, for which TSP-extended patties showed more tenderness than the 100% beef controls. More research is required to investigate why some significant differences were found in the sensory attributes between some of the TSP-extended patties.

TABLE 4
Outside and Inside Colors of Cooked, TSP-Extended Ground-Beef Patties[a]

	Outside			Inside		
Treatment[b]	*L*	*a*	*b*	*L*	*a*	*b*
Control	32.4	5.6	9.4	52.0	4.7	11.0
LLL	40.8[a,z]	5.2	8.6	53.9[a]	4.7	11.4
Hs	42.8[a,z]	5.2	9.4	53.0[a]	4.8	11.2
Ls	40.1[a,z]	5.0	8.3	53.0[a]	4.8	11.2
Ho	41.5[a,z]	5.0	8.7	54.3[a]	4.3	11.3
Hc	39.2[a,z]	5.2	8.4	53.1[a]	4.4	10.9
Lox-null	41.3[a,z]	5.2	8.5	52.9[a]	4.7	11.2
Wc	41.2[a,z]	4.9	9.7	51.7[a]	4.5	11.5
St	44.7[a,z]	4.9	8.1	55.2[a,z]	4.7	11.1
		NS	NS		NS	NS

[a]Values in same vertical column followed by same superscript roman letter are not significantly different at $P < 0.05$. NS denotes no significant difference among any values in column. Superscript z denotes a significant difference between this sample and all-beef control.
[b]See Table 1 for treatment names and other abbreviation.

TABLE 5
Sensory Analysis of Cooked, TSP-Extended Ground-Beef Patties[a]

Treatment[b]	Soy flavor	Chewiness	Tenderness	Cohesiveness	Juiciness
Control	2.4	7.9	6.6	8.0	6.2
LLL	4.4[a,z]	7.2	8.0[a,z]	6.7[a,z]	6.2
Hs	4.9[a,z]	7.6	8.1[a,z]	7.7[a]	7.2
Ls	5.1[a,z]	8.1	7.8[a,z]	7.7[a]	6.6
Ho	4.7[a,z]	8.2	8.6[a,z]	6.4[a,z]	7.0
Hc	5.0[a,z]	7.4	7.6[a]	8.1[a]	7.4
Lox-null	5.6[a,z]	7.6	7.9[a]	7.2[a]	6.1
Wc	5.8[a,z]	7.7	7.6[a]	7.7[a]	6.2
St	5.6[a,z]	7.3	8.0[a,z]	6.9[a]	6.5
		NS			NS

[a]Values followed by the same superscript roman letter are not significantly different at $P < 0.05$. NS denotes no significant difference among any values in column. Superscript z denotes a significant difference between this sample and all-beef control patty.
[c]See Table 1 for treatment names and abbreviation.

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