Utilization of Soybeans and Their Components through the Development of Textured Soy Protein Foods

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ABSTRACT: Textured soy protein (TSP), an extruded and fibrous-structured product, is mainly used as meat analog or extender. Meat alternatives are third in sales in the U.S. soy food marketplace. A primary problem that limits the incorporation of more TSP into products is the undesirable "beany" flavor. The objective of this study was to develop the best formulation of TSP and vegetable-based flavors to produce consumer acceptable "chicken" or "shrimp" flavored TSP using heat application processes. Four different types of commercial TSP (containing an average of 51% protein) strip-shaped extruded with a narrow die (STRIP-N) or with a wider die (STRIP-W), shred-shaped (SHRED) strips, and 1-cm crouton-shaped bits (BITs) were used. The TSPs were baked or deep-fat fried after soaking in 5 different commercial vegetable-based powered, liquid, or oil-based flavors ranged from 0% to 22.3% concentrations. Four descriptive analyses with a minimum of 14 trained panelists were utilized to evaluate the attributes of the finished TSP. Proximate, color, and texture analyses were performed on each TSP product. All treatments were statistically analyzed. Both instrumental and sensory tests demonstrated that BIT had a significantly higher crispness than other TSP. The powder type of chicken flavor used for a consumer panel had a more intense flavor than others with the optimum hydration time, 15 min. A consumer test with 125 people was performed with the highest chicken flavored (22.3%) fried and baked BIT. Overall, 66% of the total consumers preferred the fried BIT to the baked BIT, and 31% preferred the baked BIT.

Keywords: consumer, flavor, meat alternative, sensory study, textured soy protein

Introduction

Soy protein foods have long been a major product in natural foods market as health-promoting foods. Meat alternatives are the third in sales, next to soymilk, in soy food product sales in the United States (The Soyfoods Assn. of North America 2005). Textured soy protein (TSP), which is an extruded and fibrous-structured product, is mainly used as a meat analog or extender. TSPs are usually made from defatted soybeans or flour, and isolated soybean protein concentrates (Berk 1992). TSP has a long-term shelf life, at least 1 y, if stored in a dry and airtight container (The Soyfoods Assn. of North America 2005).

The primary problem that limits the incorporation of a large amount of TSP into meat-alternative products is an undesirable flavor or odor, called "beany." The undesirable beany flavor or odor is a result of the oxidation of unsaturated fatty acids by lipoxygenase enzymes during processing of soy protein products (Wilson 1995). After the hydration process, the TSP has a sponge-like structure. This fibrous structure is the other challenge in this study, because it makes the products too chewy compared with real poultry or meat products.

The objective of this study was to develop the best formulation of TSP and vegetable-based flavors to produce consumer-acceptable flavored TSP using heat application processes.

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Materials and Methods

Preparation of flavored TSP

Four different shapes of commercial unflavored TSP (Heartland Fields LLC., West Des Moines, Iowa, U.S.A.) were used to develop "chicken" or "shrimp" flavored TSP products in this study. The TSPs were made from partially defatted soy flour (approximately 8% fat as dry basis) from lipoxygenase-present soybeans using a twin-screw extruder. Those 4 different types of commercial TSP (containing an average of 51% protein) were strip-shaped TSP extruded with a narrow die (STRIP-N), strip-shaped TSP extruded with a wider die (STRIP-W), strip- and shred-shaped TSP (SHRED), and 1-cm crouton-shaped bits-type TSP (BIT). The composition data of the TSP by chemical analysis are shown Table 1.

Based on the recommended starting usage level of flavors by the flavor companies, all types of flavor were tested at flavor concentration levels of 0% (control), 2%, 3%, and 4% at the 1st setout. Twenty and 30 g of unflavored TSP were weighted and soaked in each flavor concentration. The amount of time to fully hydrate the TSP was also determined for water temperatures at 5, 60, 80, and 93 °C before flavoring was added.

During the preparation of the last descriptive analysis, only the powder type of chicken and shrimp flavors was tested. For shrimp flavors, flavor concentrations from 1.0% to 22.2% were tested to find an optimum concentration of flavor solutions. For chicken flavor, flavor concentrations from 16.7% to 22.3% were tested. Thirty and 50 g of unflavored TSP were weighed and marinated with each flavor concentration. The optimum condition that minimizes hydration time and maximizes flavor was chosen.

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Treatments for the 1st and 2nd chicken-flavored TSP sensory studies

The 1st chicken-flavored TSP study used a powder type of chicken flavor and 2 types of strip-shaped TSP (STRIPT-N and STRIPT-W). Two different flavor concentrations, 3% as low and 4% as high concentration, were chosen based on the results from the preparation test. Thirty grams of unflavored TSP were soaked in 100 g of flavor solutions at 80 °C for 3 h for each batch. The extra flavor solution was drained off. The flavored TSP was then fried at 191 °C for 4 min in a deep-fryer (Presto Frydaddy electric deep fryer, stock nr 05420, Eau Claire, Wis., U.S.A.) with 500 mL of commercial low saturated soybean oil. A total of 4 treatments were provided to the panelists, flavored STRPT-N with 3% and 4% concentrations (3% + STRIP-N and 4% + STRIP-N) and flavored STRIP-W with 3% and 4% concentrations (3% + STRIP-W and 4% + STRIP-W).

The 2nd chicken-flavored TSP study used a liquid type of chicken flavor and the same 2 types of TSP (STRIP-N and STRIP-W) as used in the 1st chicken-flavored TSP study. The concentrations were also the same as that of the 1st study, 3% and 4%. The preparation procedure and treatments were followed and provided to the panelists by the same method as in the 1st study.

Treatments for the shrimp-flavored TSP sensory study

Two powder types of shrimp flavors made from nonmeat derivatives (Bell Flavors and Fragrances Inc., Northbrook, Ill., U.S.A.) were used in the shrimp-flavored TSP study. One had a crab-like characteristic flavor, and the other had an oyster-like characteristic flavor. According to the specifications of the flavors, the oyster-like shrimp flavor was typical of standard. Two different formulations of shrimp flavor were studied. Single (S) used only this oyster-like shrimp flavor, and combination (C) was the mixture of both types of shrimp flavors (the ratio of mixture was 1:1 as dry basis). Thirty grams of unflavored strip- and shred-shaped TSP (SHRED) were marinated with 18 g of 16.7% and 22.2% of flavor solutions at 80 °C for 15 min, and stored in a freezer for 30 min. The frozen SHRED was then baked in an oven (Caloric Prestige Series, Raytheon Co., Waltham, Mass., U.S.A.) at 160 °C for 8 min. A total of 4 treatments were provided to the panelists, SL, SH, CL, and CH. “S” or “C” stands for single or combination of flavor, and “L” or “H” stands for low (16.7%) or high (22.2%) concentration of flavor solution.

Treatments for the 3rd chicken-flavored TSP sensory study

The 3rd chicken-flavored TSP study used the same powder type of chicken flavor as used in the 1st study. The smallest size of TSP (BIT) was used. Fifty grams of unflavored BIT were weighed and marinated with 30 g of 16.7% and 22.3% flavor solutions at 80 °C for 15 min, and stored in a freezer for 30 min. Two types of cooking processes were applied, baked and fried. The frozen BIT was either baked in an oven (Caloric Prestige Series, Raytheon Co.,) at 160 °C for 12 min, or fried with 500 mL of commercial low saturated soybean oil at 191 °C for 2 min and 30 s in a deep-fryer (Presto Frydaddy electric deep fryer, stock nr 05420). A total of 4 treatments were provided to this sensory study, LB-BIT, HB-BIT, LF-BIT, and HF-BIT. “L” or “H” stands for low (16.7%) or high (22.3%) concentration, and “B” or “F” stands for baked or fried application.

Treatments for the consumer preference test

Only the highest concentration of chicken flavor (powder type) solution (22.3%) and the smallest size of TSP (BIT) were chosen to use in the consumer preference test. Both baked (B) and fried (F) cooking processes were applied. Therefore, a total of 2 treatments (HB-BIT and HF-BIT) were provided to the consumer preference test.

The materials, preparation, and cooking processes followed the same methods as in the 3rd chicken-flavored TSP study.

Sensory analysis

After being approved by the Human Subjects Research Office at Iowa State Univ., sensory evaluations were performed in the Center of Crops Utilization Research (CCUR) sensory facilities at Iowa State Univ. The panelists were asked to sign a letter of informed consent. The panelists participated voluntarily in the descriptive analysis and were instructed and screened during the training sessions. The participants were trained in two 30-min sessions on 2 different days. During the training sessions, a minimum of 14 volunteers were selected to be panelists based on their ability to detect the important attributes of all food samples by providing the reference standards. The attributes to describe samples were discussed and agreed upon by the participants. The sensory attributes for the 1st chicken-flavored TSP sensory study were beany flavor/aroma, oily flavor/aroma, chicken-flavor/aroma, saltiness, crispiness, and color. For the 2nd and 3rd chicken-flavored TSP sensory studies, chewiness was added to the attributes based on the discussion and agreement by the participants. The attributes for the shrimp-flavored TSP sensory study were beany flavor/aroma, fishy flavor/aroma, shrimp-flavor/aroma, saltiness, crispiness, and color. After the training sessions, a descriptive analysis with 15-cm line scales was then performed with the trained panelists. The scale was measured with 0 as a minimum and 150 as a maximum intensity from left to right with increasing intensity for each attribute (for color attribute, 0 as light color and 150 as dark color) (Stone and Sidel 1993; Lawless and Heymann 1999). Each product was given a 3-digit random code before being presented to the panelists. For the 1st and 2nd chicken-flavored, and also shrimp-flavored TSP sensory studies, the sample size was two of the processed TSP for each treatment. For the 3rd chicken-flavored TSP sensory study, the sample size was four of the processed TSP (BIT) for each treatment. The panelists evaluated each treatment individually on the individual score sheets. The samples were also presented in random order under controlled

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Table 1 — Composition data of unflavored raw TSP from chemical analysis.

	TSP			
Tests (units)	STRIP-N	STRIP-W	SHRED	BIT
Moisture by vacuum oven (%)	6.5	6.0	6.3	8.0
Protein combustion (%)	49.4	51.4	50.8	53.4
Crude fat by acid hydrolysis (%)	12.2	12.9	9.8	8.3
Trypsin inhibitor (TIU/g)	< 2050	< 2100	< 2000	< 2000
Peroxide value (meq/kg)	15.0	< 5.4	8.5	7.1

STRIP-N = strip-shaped TSP extruded with a narrow die; STRIP-W = strip-shaped TSP extruded with a wider die; SHRED = strip- and shred-shaped TSP; BIT = 1-cm crouton-like-shaped TSP.

environmental conditions. Each panelist evaluated all treatments at each session. Four replications of the descriptive analysis were conducted in each sensory study.

Consumer preference test

Preference testing with a 9-point hedonic scale (Resurreccion 1998; Lawless and Heymann 1999) based upon the trained panelist results was performed in a local grocery store in Ames, Iowa. A total of 125 consumers voluntarily participated in the in-store test. The panelists were provided an approved (ISU Human Subjects Research Office) consent form, questionnaire sheet, and 2 pages with 9-point hedonic scales. Each of the 2 pages with 9-point hedonic scales had a random 3-digit code for the baked and fried chicken-flavored products (HB-BIT and HF-BIT). The evaluation order of the sample was randomized when the samples were provided to the panelists. The panelists evaluated each treatment individually on the individual score sheet, and indicated their liking on the hedonic scale. The scale was balanced on a ballot with a score ranging from 9 (like extremely) to 1 (dislike extremely). The score from the 9-point hedonic scale was individually calculated for each treatment. The questionnaire sheet asked the demographics of the panelists. The demographics were gender, age, and frequency of soy consumption. At the end of the questionnaire sheet, they were asked to choose the sample they preferred overall. Their overall preference was calculated by percentage based on the answers from all participated consumers.

Instrumental analyses

A LabScan XE spectrophotometer (Hunter Associate Laboratory Inc., Va., U.S.A.) with the Hunter Lab system was used for the color analysis. The Hunter system had 3 values to explain the color of samples, L (0 as black/darkness and 100 as white/lightness), a (a negative value as greenness and a positive value as redness), and b (a negative value as blueness and a positive value as yellowness). The parameters of the Hunter scales used were D65 (daylight 65), 10° standard observer, 0.70 inch port size, and 0.50 inch area view. During the same time as the sensory session was performed, the finished TSP samples from each treatment were randomly selected at every sensory session. The selected TSP samples were put in a plastic bag and crushed into small particles using a roller to have an even color of samples. Three of 12 g of the crushed TSP samples were weighed, placed in a plastic clear petri dish, and 3 spots from each dish were analyzed for color analysis. A total of 9 spots for each treatment were calculated to have an average at every session. The analysis was repeated during 4 replications of sensory study.

A TA.XT2i texture analyzer (Texture Technologies Corp., N.Y., U.S.A.) with a TA-45 incisor knife blade was used for the texture analysis. The hardness of samples was measured as grams of force with the program set in "compression return to start." The parameters of the program were 2.0 mm/s pretest speed, 1.0 mm/s test speed, 10.0 mm/s post speed, 75% strain distance, and 25-mm calibration distance. A 25-kilo load cell was calibrated with a 5 kg weight. During the 1st and 2nd chicken-flavored sensory studies, 10 pieces of finished TSP from each treatment were selected based on the same weight. Three spots on each piece were chosen to analyze the texture. A total of 30 spots for each treatment were calculated to have an average at every session. The baked TSPs in the shrimp-flavored TSP study were breakable compared with the fried products in the previous studies. Only 2 spots on each piece were selected to analyze for each treatment. Five pieces of finished TSP from each treatment were selected based on the same weight. A total of 10 spots for each treatment were calculated to have an average at every session. In the 3rd chicken-flavored TSP study, 10 pieces of finished BIT from each treatment were selected based on the same weight. One spot on each piece was analyzed for texture. A total of 10 spots for each treatment were calculated to have an average at every session. All texture analysis methods were repeated during the 4 replications of sensory study.

Chemical analysis

All raw ingredients and finished products were chemically analyzed by following the AOAC official methods (AOAC 2000) procedures (934.01 for moisture by vacuum oven, 990.03 for crude protein by combustion method, and 954.02 for crude fat by acid hydrolysis) and the AOCS official methods (AOCS 1997 revised 2004) procedures (Ba 12-75 for trypsin inhibitor activity and Cd 8-53 for peroxide value). The analysis was duplicated.

Statistical analysis

A random effect model was used to compare groups, while removing effect of correlation among the observations. For the sensory and instrumental data, the averages were used to summarize correlated data. The summarized data were then statistically analyzed using JMP 5.1.2, the Statistical Discovery Software (SAS Inst. Inc., Cary, N.C., U.S.A.). A matched pair t-test was set at a P value of 0.05. The variables analyzed for each attribute were panelist ID, treatments, applications, and flavor concentrations.

Also a Tukey–Kramer HSD adjustment was used for the sensory results to minimize type I error inflation (Ramsey and Schafer 2002).

Results and Discussion

During the preparation of the 1st chicken-flavored TSP study, the oil type of chicken flavor was not mixed evenly with hot water and did not hold enough chicken flavor after fried. The powder type of chicken flavor was then tested next. The powder type of chicken flavor was mixed well with hot water and stable at the high frying temperature 191 °C. The optimum conditions of this flavor to process 30 g of raw STRIP-N and STRIP-W were 3% and 4% flavor concentrations, 80 °C for water temperature, and 3 h for full but minimum hydration time.

In the 1st chicken-flavored TSP sensory study using this powder type of chicken flavor, low (3%) and high (4%) flavor concentrations resulted in no significant difference in beany flavor/aroma, oily aroma/flavor, and chicken aroma. The panelists found a significant difference in chicken flavor, saltiness, and crispness due to the concentration difference (Table 2). STRIP-W had a more fine-network structure than STRIP-N. STRIP-N had more rough air pockets in the structure after hydration. A strong difference in texture was not seen in the statistical results (Table 2); however, color (Table 2 and 3) and oily flavor (Table 2) were significantly different between the 2 TSP types.

The liquid type of chicken flavor was also mixed well and stable at the high frying temperature 191 °C after processing. In the 2nd chicken-flavored TSP sensory study using this liquid type of chicken flavor, the structure difference between the 2 TSP samples (STRIP-N and STRIP-W) was shown clearly in the results from both sensory and instrumental analyses (Table 4). STRIP-N had a significantly higher crispiness and lower chewiness in sensory analysis (raw data are not shown). This result agreed with the results from the texture analysis (Table 4). The results from a TA.XT2i texture analyzer showed that STRIP-N had a significantly harder texture (more force required to break) than STRIP-W. This crispiness of STRIP-N could be related to less moisture content than STRIP-W

(Table 5). Originally, both of the raw TSP had almost same chemical compositions (Table 1); however, the structure difference made the finished STRIP-W samples almost 2 times higher in moisture content than the STRIP-N samples. There was also a color difference between the 2 TSP types (Table 4). Differences due to flavor concentration were found in oily flavor, chicken flavor, color, and saltiness.

The next objective flavor in this study was shrimp flavor. When the finished fried products from both the 1st and 2nd chicken-flavored TSP studies were stored at room temperature for 1 night,

Table 2 — Matched pairs *t*-test for the 1st chicken-flavored (powder) TSP sensory analysis.

Attributes	Matched pairs	*P* value	*t*-test
Beany flavor	4% to 3% (concentration)	0.1692	Not significant
	STRIP-N–STRIP-W (TSP)	0.5814	Not significant
Oily flavor	4% to 3% (concentration)	0.3406	Not significant
	STRIP-N–STRIP-W (TSP)	0.0033	Significant
Chicken flavor	4% to 3% (concentration)	0.0290	Significant
	STRIP-N–STRIP-W (TSP)	0.1963	Not significant
Color	4% to 3% (concentration)	0.4252	Not significant
	STRIP-N–STRIP-W (TSP)	$<$0.0001	Significant
Saltiness	4% to 3% (concentration)	0.0037	Significant
	STRIP-N–STRIP-W (TSP)	0.4799	Not significant
Chicken aroma	4% to 3% (concentration)	0.1120	Not significant
	STRIP-N–STRIP-W (TSP)	0.8941	Not significant
Oily aroma	4% to 3% (concentration)	0.1323	Not significant
	STRIP-N–STRIP-W (TSP)	0.5595	Not significant
Beany aroma	4% to 3% (concentration)	0.3506	Not significant
	STRIP-N–STRIP-W (TSP)	0.7226	Not significant
Crispiness	4% to 3% (concentration)	0.0117	Significant
	STRIP-N–STRIP-W (TSP)	0.0931	Not significant

STRIP-N = strip-shaped TSP extruded with a narrow die; STRIP-W = strip-shaped TSP extruded with a wider die.

Table 3 — Four means comparisons by Tukey–Kramer HSD test for the 1st chicken-flavored (powder) TSP sensory study.

	Attributes								
Treatments	Beany flavor	Oily flavor	Chicken flavor	Color	Saltiness	Beany aroma	Oily aroma	Chicken aroma	Crispiness
3% + STRIP-N	55.35^A	66.02^A	66.01^A	84.08^A	63.00^A	48.17^A	66.44^A	66.93^A	98.11^A
4% + STRIP-N	56.26^A	64.97^A	71.29^A	90.06^A	73.68^A	52.26^A	57.23^A	71.32^A	87.75^A
3% + STRIP-W	61.85^A	61.14^A	66.43^A	63.81^B	61.08^A	50.50^A	61.02^A	67.19^A	87.43^A
4% + STRIP-W	52.55^A	57.67^A	76.79^A	62.07^B	71.77^A	52.55^A	57.67^A	72.21^A	81.01^A

Means within a column with different letters are significantly different ($P < 0.05$).
0 = minimum intensity, 150 = maximum intensity score (for color attribute, 0 = light, 150 = dark).
3% + STRIP-N = flavored STRIP-N with 3% flavor concentration.
4% + STRIP-N = flavored STRIP-N with 4% flavor concentration.
3% + STRIP-W = flavored STRIP-W with 3% flavor concentration.
4% + STRIP-W = flavored STRIP-W with 4% concentration.

Table 4 — Matched pairs *t*-test for the 2nd chicken-flavored (liquid) TSP sensory analysis and TA.XT2 texture analysis.

Attributes	Matched pairs	*P* value	*t*-test
Beany flavor	4% to 3% (concentration)	0.2119	Not significant
	STRIP-N–STRIP-W (TSP)	0.4921	Not significant
Oily flavor	4% to 3% (concentration)	0.0483	Significant
	STRIP-N–STRIP-W (TSP)	0.0811	Not significant
Chicken-flavor	4% to 3% (concentration)	0.0427	Significant
	STRIP-N–STRIP-W (TSP)	0.9753	Not significant
Color	4% to 3% (concentration)	0.0016	Significant
	STRIP-N–STRIP-W (TSP)	$<$0.0001	Significant
Saltiness	4% to 3% (concentration)	0.0171	Significant
	STRIP-N–STRIP-W (TSP)	0.1216	Not significant
Beany-aroma	4% to 3% (concentration)	0.5019	Not significant
	STRIP-N–STRIP-W (TSP)	0.6874	Not significant
Oily aroma	4% to 3% (concentration)	0.1299	Not significant
	STRIP-N–STRIP-W (TSP)	0.1446	Not significant
Chicken aroma	4% to 3% (concentration)	0.5741	Not significant
	STRIP-N–STRIP-W (TSP)	0.2206	Not significant
Crispiness	4% to 3% (concentration)	0.5151	Not significant
	STRIP-N–STRIP-W (TSP)	0.0155	Significant
Chewiness	4% to 3% (concentration)	0.1292	Not significant
	STRIP-N–STRIP-W (TSP)	0.0344	Significant
TA.XT2 analysis	4% to 3% (concentration)	0.0055	Significant
	STRIP-N–STRIP-W (TSP)	0.0003	Significant

STRIP-N = strip-shaped TSP extruded with a narrow die; STRIP-W = strip-shaped TSP extruded with a wider die.

the texture of those products became soft with a soggy "finger feeling." Oily flavor and aroma could be the major problems for the fried TSP samples. Also, those fried products were not appropriate for a long shelf life. To look for more crispiness and less oil problem of finished products, strip- and shred-shaped TSP (SHRED) and a baked application were also tested for comparing with the previous products to prepare for the shrimp-flavored sensory study. The raw SHRED was similar in structure to STRIP-N, and had more rough air pockets after hydration. Therefore, SHRED was chosen to use for the shrimp-flavored TSP study. During the preparation of the shrimp-flavored TSP sensory study, both shrimp flavors (oyster-like and crab-like characteristic flavors) were found to be not suitable for a fried application. The preparation test was performed with either each flavor alone or a combination of both flavors at different levels of flavor concentrations. For the combination flavor solutions, different ratios of mixture were also tested. However, after fried processing, all finished flavored products did not have any shrimp flavor and aroma characteristic but more fishy like characteristic. When a baked application was tested with shrimp-flavored TSP, unique shrimp flavor and aroma were found in the finished samples. Also, using either the oyster-like shrimp flavor alone (S) or combination (C) of both types of shrimp flavors (the ratio of mixture was 1:1 as dry basis) had the most intense shrimp flavor and aroma in the finished baked products. In the shrimp-flavored sensory study using this formulation of flavors and SHRED, there were significant differences in fishy, shrimp flavors, and saltiness between high and low concentrations of flavor (Table 6). The difference in flavor formulation (single or combination) did not make any significant difference in most of attributes, except crispiness (Table 6). During the training sessions, the oiliness of the baked product was not perceived by the trained panelists. Therefore, oiliness was excluded from the attributes. However, during the sensory evaluations, they noted that chewiness became a major problem when eating the baked SHRED products. The same amount of heat was applied to the structure, taking out moisture and giving crispness to the thin parts, but not to the thick parts due to the irregular shapes of SHRED. The finished SHRED which was thicker than the others TSP became chewy due to having more moisture content in its structure. To solve the 2 major problems, oiliness with the fried application and chewiness with the baked application, the smallest size and more regular-shaped TSP, BIT (1-cm crouton-shaped bits-type), was chosen to use for the next sensory study. Also, both heat applications (baked and fried) were tested with this BIT to find the solutions to the problems. When the finished shrimp-flavored baked products were stored at room temperature for several days, the flavor and aroma from all treatments had less shrimp flavor characteristics. The smell of products became more fishy-like characteristic day by day. The shrimp-flavored products were not appropriate for a long shelf life. The 2 shrimp flavors were the only vegetable-based flavors that were available in this study. The powder type of chicken flavor was chosen to use again with BIT. This chicken flavor was the most stable at the high frying temperature at 191 °C. The flavor was also able to be held longer in the finished products than the liquid and oil type even after several days.

In the 3rd chicken-flavored TSP sensory study, it was clear that the fried samples had a significantly higher oiliness of flavor and aroma than the baked samples (Table 7). The chemical analysis showed that the fried BIT samples had more than 3 times higher

Table 5 — Chemical analysis data for the finished flavored TSP samples in the 2nd chicken-flavored (liquid) TSP study.

	TSP treatments			
Tests (units)	3% + STRIP-N	4% + STRIP-N	3% + STRIP-W	4% + STRIP-W
Moisture by vacuum oven (%)	4.1	5.0	8.1	7.9
Protein combustion (%)	29.5	31.1	30.8	30.8
Crude fat by acid hydrolysis (%)	50.2	48.9	46.3	49.4
Trypsin Inhibitor (TIU/g)	<2000	<2000	<2000	<2000
Peroxide value (meq/kg)	2.8	2.7	1.8	1.9

3% + STRIP-N = flavored STRIP-N with 3% flavor concentration; 4% + STRIP-N = flavored STRIP-N with 4% flavor concentration; 3% + STRIP-W = flavored STRIP-W with 3% flavor concentration; 4% + STRIP-W = flavored STRIP-W with 4% concentration.

Table 6 — Matched pairs *t*-test for the shrimp-flavored TSP (SHRED) sensory analysis and TA.XT2 texture analysis.

Attributes	Matched pairs	*P* value	*t*-test
Beany flavor	H–L	0.0573	Not significant
	S–C	0.6253	Not significant
Fishy flavor	H–L	0.0071	Significant
	S–C	0.7492	Not significant
Shrimp flavor	H–L	0.0087	Significant
	S–C	0.0984	Not significant
Color	H–L	0.2394	Not significant
	S–C	0.5343	Not significant
Saltiness	H–L	<0.0001	Significant
	S–C	0.7294	Not significant
Beany aroma	H–L	0.2493	Not significant
	S–C	0.4590	Not significant
Fishy aroma	H–L	0.0515	Not significant
	S–C	−2.0000	Not significant
Shrimp aroma	H–L	0.4794	Not significant
	S–C	0.8191	Not significant
Crispiness	H–L	0.7533	Not significant
	S–C	0.0383	Significant
TA.XT2 analysis	H–L	0.5124	Not significant
	S–C	0.0077	Significant

H = high concentration (22.2%) of flavor solution; L = low concentration (16.7%) of flavor solution; S = single flavor; C = combination flavor.

Table 7 — Four means comparisons by Tukey–Kramer HSD test for the 3rd chicken-flavored (powder) TSP (BIT) sensory study.

	Attributes									
Treatments	Beany flavor	Oily flavor	Chicken flavor	Color	Saltiness	Beany aroma	Oily aroma	Chicken aroma	Crispiness	Chewiness
LB-BIT	35.88^{A}	13.64^{B}	52.35^{B}	40.36^{B}	60.00^{B}	24.20^{A}	13.55^{B}	47.32^{B}	106.29^{AB}	50.63^{A}
HB-BIT	35.39^{A}	14.44^{B}	64.95^{AB}	44.46^{B}	79.41^{AB}	23.35^{A}	15.43^{B}	52.72^{AB}	101.74^{B}	52.08^{A}
LF-BIT	24.72^{A}	49.14^{A}	78.10^{AB}	105.17^{A}	79.35^{AB}	19.58^{A}	50.11^{A}	72.67^{AB}	121.40^{A}	26.98^{A}
HF-BIT	15.30^{A}	53.84^{A}	83.37^{A}	110.38^{A}	90.18^{A}	18.42^{A}	53.73^{A}	79.98^{A}	121.07^{A}	31.72^{A}

Means within a column with different letters are significantly different ($P < 0.05$).
0 = minimum intensity, 150 = maximum intensity score (for color attribute, 0 = light, 150 = dark).
LB-BIT = low concentration (16.7%) flavored and baked BIT.
HB-BIT = high concentration (22.3%) flavored and baked BIT.
LF-BIT = low concentration (16.7%) flavored and fried BIT.
HF-BIT = high concentration (22.3%) flavored and fried BIT.

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fat content than the baked BIT samples (Table 8). The application difference resulted in a significant difference in both sensory and instrumental color analyses (Table 7 and 9). The sensory panelists scored a darker color for the fried BIT samples than the baked samples (Table 7). This result strongly agreed with the Hunter color analysis results (raw data are not shown). The fried samples had a lower *L* value (darker color/more black), a higher *a* value (more redness), and a lower *b* value (less yellowness) than the baked samples. The flavor concentration difference also contributed significant differences in chicken-flavor/aroma and saltiness in sensory analysis. The major significant difference due to flavor concentrations was in saltiness with $P < 0.0001$ (raw data are not shown). The trained panelist perceived a higher intensity in saltiness with the higher concentration of chicken flavor. The crispiness between the fried STRIP-N (3% and 4%-STRIP-N) and fried BIT (L and HF-BIT) was also compared to see how the final formulation could improve and solve the application problems. The crispiness of fried BIT was significantly improved, with a higher score than that of the fried STRIP-N from the 1st chicken-flavor study (Table 10). Oily flavor was also significantly improved with the fried BIT compared with the fried STRIP-N in the 1st study. At the end of the 3rd chicken-flavored TSP study, the previous 2 major problems had solved. Also, the finished fried BIT maintained the crispiness even after 7 days at room temperature. All the data and results were carefully reviewed, and both heat applications were chosen to perform a consumer preference test with the highest concentration of chicken flavors (22.3%). When the flavored baked and fried BIT were prepared for the consumer test, a strong beany flavor was perceived from the low concentration (16.7%) chicken-flavored finished TSP. This problem had not been seen during the sensory study. The strong beany flavor came from an oxidation of raw materials during the storage. The BITs were stored for 1 mo while 2 training sessions and 4 replications of the 3rd chicken-flavored TSP sensory study were performed. When the consumer preference test was prepared, the BIT was already stored for 6 mo. It assumed that the storage condition was not airtight enough to store the BIT for 6 mo. Therefore, only the high concentration chicken-flavored BIT products (22.3% concentration flavored fried BIT and baked BIT) were chosen to use for the consumer test.

The consumer preference test was performed with 125 consumers at a local grocery store in Ames, Iowa, using the chicken-flavored BIT products. Figure 1 shows the summary of the demographic and preference results. Of the total consumers who voluntarily participated, 68% were female, 30% were male, and 2% gave no answer (Figure 1A). The ages of 125 consumers varied from 18 to more than 64 y. The major age range was between 25 and 34 y (Figure 1B). The majority (59%) of the panelists had higher soy consumption level. Of the total participating consumers, 31% consumed soy products several times per week (Figure 1C). On a 9-point hedonic scale, when the score from the people who preferred one to the other was calculated, the fried product was given an average 7.1, and the baked products were given an average of 6.7 score. Overall, 66% of the total consumers answered that they preferred the fried products to the baked products, and 31% preferred the baked products. Of the total consumers, 2% answered that they preferred neither of them, while 1% preferred both of the BIT products (Figure 1D).

Table 8—Chemical analysis data for the finished flavored TSP samples in the 3rd chicken-flavored (powder) TSP (BIT) study.

	TSP treatments			
Tests (units)	LB-BIT	HB-BIT	LF-BIT	HF-BIT
Moisture by vacuum oven (%)	4.7	2.7	4.0	4.0
Protein combustion (%)	53.9	54.5	41.6	41.3
Crude fat by acid hydrolysis (%)	7.8	8.0	28.6	26.4
Trypsin Inhibitor (TIU/g)	< 2000	< 2000	< 2000	< 2000
Peroxide value (meq/kg)	2.3	2.6	2.6	2.4

LB-BIT = low concentration (16.7%) flavored and baked BIT.
HB-BIT = high concentration (22.3%) flavored and baked BIT.
LF-BIT = low concentration (16.7%) flavored and fried BIT.
HF-BIT = high concentration (22.3%) flavored and fried BIT.

Table 9—*P* values from color analysis results in the 3rd chicken-flavored (powder) TSP (BIT) study.

	Hunter color values		
Matched Pairs	*L*	*a*	*b*
H–L (concentration)	0.6582	0.0026*	0.2501
F–B (application)	< 0.0001*	< 0.0001*	< 0.0001*

*Indicates a statistically significant difference ($P < 0.05$) between matched pairs.
L: 0 = black/darkness; 100 = white/lightness.
a: –*a* = green; +*a* = red.
b: –b = blue; +*b* = yellow.
H = high concentration (16.7%) of flavor solution; L = low concentration (22.3%) of flavor solution; F = Fried BIT; B = Baked BIT.

Conclusions

This study succeeded in the utilization of the soybean components through the development of chicken-flavored fried TSP that was accepted by the consumers. The process of the flavored BIT had simply 3 steps—hydration with flavor solution, chilling a short time, and frying or baking. The ingredients were also only TSP (BIT), vegetable-based chicken flavor, and low saturated soybean oil. The plant-based ingredient formulation developed in this study allows easy incorporation of the TSP products into the diet as stand-alone products or ingredients. It can be marketed inside and outside of the United States.

The disadvantage that limited the incorporation of a large amount of TSP into meat-alternative products for human consumption, beany flavor, had been overcome in this study by the use of all plant-based ingredients. Future studies of soybean utilization will be seen as more economical and functional. It will provide benefits that can contribute to consumers as per the results of this study.

Table 10—Comparison with matched pairs *t*-test between fried STRIP-N and fried BIT in sensory analysis.

Attributes	Treatments	Means	Mean difference	SE	*P* values	*t*-test
Crispiness	BIT	121.60	27.19	4.81	< 0.001	Significant
	STRIP-N	94.41				
Oily flavor	BIT	49.77	−17.09	7.71	0.036	Significant
	STRIP-N	66.86				
Oily aroma	BIT	50.67	−12.64	6.89	0.079	Not significant
	STRIP-N	63.33				

0 = minimum intensity, 150 = maximum intensity score.
BIT = Fried 1-cm crouton-like-shaped TSP.
STRIP-N = Fried strip-shaped TSP extruded with a narrow die.
SE = standard error.

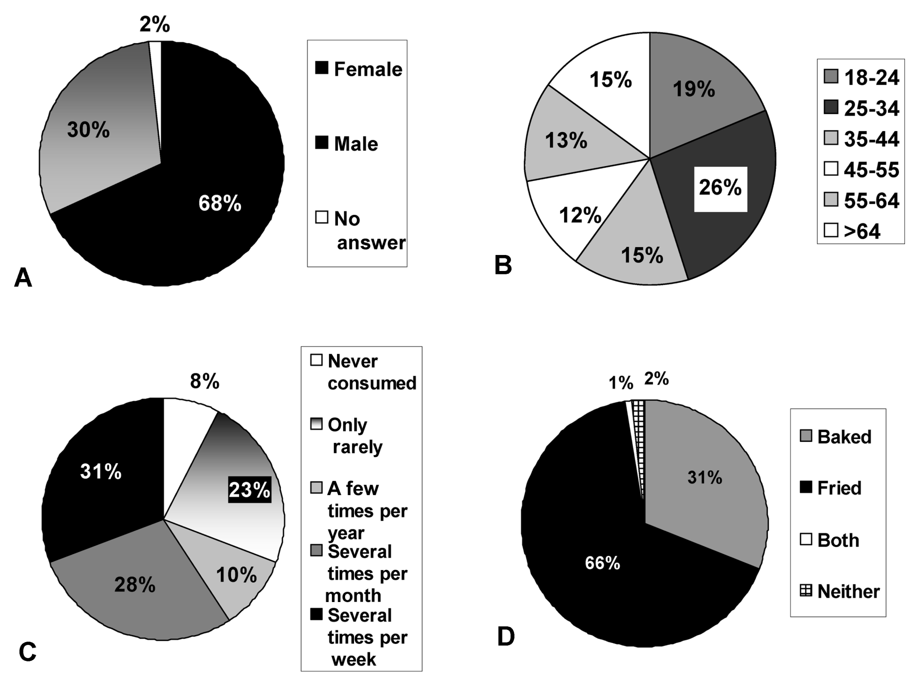

Figure 1 — Summary of consumer preference test in (A) gender, (B) age, (C) soy consumption, and (D) preference.

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