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I am submitting herewith a thesis written by Kim Anderson entitled "Evaluation of Defatted Soy Flour in Tapioca Starch Pastes and in a Tapioca Based Snack Food." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

S. L. Melton

S. L. Melton, Major Professor

We have read this thesis
and recommend its acceptance:

John R. Mount

Mayou P. Penfield

Accepted for the Council:

C. W. Minkel

Vice Provost
and Dean of the Graduate School

EVALUATION OF DEFATTED SOY FLOUR IN TAPIOCA
STARCH PASTES AND IN A TAPIOCA
BASED SNACK FOOD

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ABSTRACT

The effect of 4 levels (0, 10, 20 and 30 g) of each type of defatted soy flour (SF), protein dispersibility indexes (PDI) 20 and 70, at pH values of 5.5, 6.3, 7.1 and 7.9 on gelatinization were determined. Gelatinization variables studied included time to onset of gelatinization, time to maximum viscosity, maximum viscosity (MV) and viscosity at 60 min (V60), for tapioca starch dispersions (30 g/420 ml phosphate buffer) heated in an amylograph. The experimental design was an incomplete randomized block with 3 randomly selected combinations of SF level and pH for each SF being the partial second replication. Surface response methodology was used to show the significant SF level and pH effects on the variables. Level and pH did not affect any of the time variables ($P < .05$), but did affect MV and V60 in different ways for each SF. In general, MV and V60 increased with increasing SF level at any pH, and pH had the most effect on V60 in dispersions containing PDI 20 SF.

The effect of 4 substitution levels (0, 33.33, 66.67 and 100%) of each SF, PDI 20 and 70, for shrimp was determined on the chemical composition, color, and texture (force required to break a single chip) of a tapioca-based shrimp chip. A single rep consisted on the 4 levels of the 2 types of SF in the chip, and 2 reps were run. As SF increased from 0 to 100% substitution, the following changes ($P < .05$) in the chip were found: the protein increased linearly from 1.84 to 11.18%; the fat decreased linearly from 42.75 to 25.50% and the force increased linearly from 286 to 585 g. The chips tended to become darker, redder

and more yellow with increasing level of SF, but a significant PDI x SF level interaction was found for the Hunter color "L" and "a" values of the chip. The 100% SF chip was selected for sensory evaluation because its texture was closest to that (723 g) of a commercially produced pork rind which was similar in appearance to the shrimp chip.

Chips containing 100% SF flavored by a commercial shrimp flavor at low and high levels (50 g and 25 g chips/g flavor, respectively) were evaluated by a 57-member panel on an 8-point hedonic scale where 1 = dislike extremely and 8 = like extremely and on a 9-point Food Action Rating Scale. The panel liked the chips with the low flavor level (5.4) better than those with the high flavor level (4.9). Twenty-three of the panel members who said that they would buy the chip liked the chip moderately and would eat it now and then. The hedonic rating of the chip was not affected by age or gender of the judges nor by their attitude towards shrimp flavor ($P < .05$). However, judges who ate chips several times a week liked the chip significantly less than those who ate chips several times a month or year.

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CHAPTER I

INTRODUCTION

During recent years, the snack food industry has developed into a multi-billion dollar business. Sales for fabricated chips increased from 128 to 203 million dollars during this period (Anon., 1986).

Since 1940, defatted soy meal has primarily been used as a protein supplement in animal feed. Conversion of this meal to edible soy protein for man adds to its value; however, it still remains the most economical and abundant source of protein for man (Langsdorf, 1981). Currently, soy protein products are used in the commercial preparation of doughnuts and baked products in the United States. In these products, soy proteins are valued primarily for their functional properties rather than as a source of additional protein (Dubois and Hoover, 1981). Supplementation of any new or existing food with these soy protein products, particularly defatted soy flour, could increase their use, resulting in an increased market value for the soybean.

Although some patents were found in which soy protein products were used to produce high protein snacks (Duffy, 1981), no reports were found in the literature where defatted soy flour had been substituted for more expensive meat or fish products in a tapioca-based snack food. This substitution could markedly reduce ingredient costs to the snack food processor. In addition, the only report of research found concerning interactions of soy protein with tapioca starch was in a Japanese journal (Yagi and Okamoto, 1976). Research is needed to

determine the interactions of soy protein products with tapioca starch in a model system and to determine the effects of substituting defatted soy flour for meat or fish on the physical, chemical and sensory characteristics of a tapioca-based snack food. Therefore, the objectives of the present study were (1) to investigate the interactions of defatted soy flour with tapioca starch during gelatinization at different pH values, (2) to investigate the effects of different levels of defatted soy flour substituted for shrimp on the chemical composition and physical characteristics of a tapioca-based shrimp chip and (3) to determine the effect of added shrimp flavoring on the acceptability of the chip that contained the highest level of soy flour substitution and had a texture closest to that of a commercially produced chip with characteristics similar to the shrimp chip.

CHAPTER II

REVIEW OF LITERATURE

I. Snack Foods

At the present time, snack food sales are increasing rapidly. Total snack food sales in 1985 rose to \$23.1 billion in the United States which was a 9.77% increase over 1984 sales (Anon, 1986). This increase in sales can be attributed to changing demographics, increasingly diversified snack products and the advent of premium quality snack foods (Anon., 1986). The American obsession with current snack food and flavor trends may also contribute to the rise of snack food sales (Blades, 1986).

An increase in consumption of meat-based snack foods has occurred in the United States. During the last ten years, snack foods containing meat have more than doubled in sales from \$166 million in 1976 to \$375 million in 1985 (Anon, 1986). The main ingredient of meat snacks, excluding meat products, is some type of starch, usually tapioca or corn starch or flour.

In many parts of the world, fish chips or chips made from different seafoods provide a significant contribution to snack food consumption. The idea of mixing ground fish with other ingredients such as tapioca flour to form a completely new snack food is not new (Yu et al., 1981). This product is known as "keropok" and is popular in Indonesia, Malaysia, and other parts of southeast Asia.

Soy proteins also have been added to food systems because of their functional and nutritional properties. Desirable functional characteristics may include fat and water binding, increased viscosity and improved texture of some food formulations (Langsdorf, 1981). These characteristics may also improve the appearance and overall quality of the formulated food (Andres, 1981). Soy isolates, in particular, have been used in a variety of snack food items. However, very little research has been performed regarding the utilization of defatted soy flour in a tapioca or manioc starch-based snack food. At the present time, patents exist for production of high protein snack foods containing soy protein (Duffy, 1981). These patents, however, specify the use of expensive soy protein products such as isolates and may not appeal to cost-conscious snack food processors. In many cases, soy protein is employed to supplement, extend or replace more costly ingredients (Smith, 1980; Bressani, 1981). As processing costs continue to increase, it becomes more important to reduce ingredient costs. This can be achieved by substituting defatted soy flour for more expensive protein sources or ingredients. The possibility exists that defatted soy flour could be substituted for the more expensive meat or fish in a snack food without appreciable loss of protein quantity or quality, thus lowering the ingredient costs to the processor. The wholesale cost of a pound of defatted soy flour is approximately \$0.22-0.23 cents compared with the wholesale cost of shrimp at \$5.89 per pound (Cunningham, 1986). Flavor changes could be overcome by adding meat or fish flavorings, which are available commercially. However, the effects of the substitution of soy flour in such a snack food need to

be determined relative to the chemical, physical and sensory characteristics of the snack food.

II. Soy Flours in "Chip" Type Snack Foods

Soy flour as a snack food ingredient has received limited attention. The only reported research studies found in which defatted soy flour had been added in a chip type snack food include papers by Capansang et al. (1984), Siegel and Lineback (1976) and an anonymous report concerning work done by Dr. Johnsun in 1978 (Anon., 1978). The objective of all these studies was to increase the protein content of the snack foods. The study by Siegel and Lineback (1976) was undertaken by the food research division of The Food and Nutrition Research Institute to provide a nutritious and economically feasible snack normally made from cassava and rice for Philippine children. Four snack items were produced as dehydrated pieces, then deep-fat fried to produce crispy chips. Acceptability tests were then performed by elementary school children using a 5-point hedonic scale where 1 = really bad to 5 = great with a commercially produced cassava-rice chip as a control. Snacks containing added soy flour actually scored higher than the control chips. In addition, the snacks containing soy flour also absorbed less oil during frying when compared with those snacks prepared without soy. Addition of soy flour decreased caloric content while increasing protein quantity. The resulting snack food was of a higher nutritive value than the cassava-rice chip and required low production costs. It was concluded that the rice-soy chips could be adopted as a livelihood project.

Capansang and co-workers (1984) produced a snack food using rice and soybeans. The mixture was extruded for a short period at a pre-determined high temperature, thus modifying the starch structure and consequently forming an expanded product.

Another snack food containing soy flour was studied by Dr. Johnsun (Anon., 1978). This snack food called "snoiks" was formulated with 23% soy flour and 77% corn flour. The dough was extruded in a screw jacket extruder to form a cheese-curl type product. The resulting product was sprayed with vegetable oil and sprinkled with commercial flavorings.

III. Interaction of Soy Protein Products with Different Food Starches

The interaction of soy protein products with food starches has been studied, but has been limited to corn, rice and wheat starches. No reports of studies were found in which the interactions of soy protein with tapioca or cassava starch had been investigated.

Neumann and co-workers (1984) investigated coextrusion processing of wet-milled corn gluten and defatted soy flour. The physical, chemical and nutritional properties were also characterized. They found that the physical and chemical changes in the protein during coextrusion of corn gluten and defatted soy flour involved alteration of molecular conformation and formation of intermolecular disulfide bonds. These changes were the result of heat, shear forces and pressure encountered in the extruder. They concluded that corn gluten: defatted soy flour extrudates with blend ratios between 33:67

and 28:72 would have a protein quality superior to that of textured soy protein and of the other prepared blends.

Chauhan and Bains (1985) produced an extruded snack food by blending 15% and 30% defatted soy flour with rice flour. Brittleness of the extruded snack was markedly decreased with the addition of 15% soy flour; addition of 30% soy flour did not further effect brittleness.

The Water Solubility Index (WSI) of the rice-soy blends increased sharply after adding soy flour both before and after extrusion. Damaged starch content decreased as the addition of soy flour increased. Total protein content increased from 8.1 to 24.4% depending upon the level of incorporation of soy flour. The extruded rice snack with 15% defatted soy flour was found to be highly acceptable.

Circle and co-workers (1964) investigated the rheology of isolated soy protein dispersions in relation to heat and other food ingredients. In the absence of heat, they found that the viscosity rises exponentially with increased soy protein concentration. In concentrations above 7% by weight, heat caused thickening then gelation. Viscosities of both heated and unheated 10% dispersions were raised by the addition of soy oil, soy lecithin, wheat starch, carboxymethylcellulose or carrageenan.

IV. Tapioca Starch/Flour as a Component of Snack Products

Cassava, or more commonly, tapioca, (Manihot esculenta Crantz) belongs to the genus *Manihot* of the natural order Euphorbiaceae (Hudson and Ogunsua, 1976). It is widely grown for its edible tubers which

serve as a staple food for approximately 300 million people living close to subsistence level in tropical countries (Collins and Temalilwa, 1981).

Tapioca provides 38.6, 11.7, and 6.7% of the total caloric requirement in Africa, Latin America and the Far East respectively (Nartey, 1977). The incidence of malnutrition is frequent with respect to individuals subsisting on tapioca-based diets. The protein quantity of tapioca is very low 0.7-2.6%, with the sulfur amino acids being among the most limiting (Johnson and Raymond, 1965).

Tapioca flour differs from wheat and rice flours in that it becomes rubbery when it is steam cooked, which limits its use in cereal-based products (Abraham et al., 1982). However, tapioca flour has been successfully substituted for wheat in bread making (Ciacco and D'Appolonia, 1978). They suggested 10% tapioca as a replacement for wheat flour, thus possibly decreasing the amount of wheat required for import for many developing countries.

Another important property of tapioca flour is that it can replace up to 20% of cereal flours without greatly altering the final product (Pluncknett, 1979). Other characteristics of tapioca flour include desirable expansion properties and a bland flavor which make it particularly adaptable for use in snack products (Feldberg, 1979).

Tapioca flour has also been successfully formulated into a snack food using various meat products as a base. Wahid (1983) produced a snack food by incorporating different animal meats into a tapioca-based formulation.

Tapioca starch is manufactured from the root of cassava. Today, world production of tapioca starch is approximately 900,000 tons (Beynum and Roels, 1985). It is produced in Thailand, Brazil, the Philippines, Nigeria, Malaysia and Angola and is used in the production of food products and adhesives.

Tapioca starch characteristics have also been determined. Scanning electron microscopy has shown that tapioca starch granules are extremely smooth, spherical and semi-spherical in shape (Kawabata et al., 1981). The granules contain approximately 17.0% amylose and 83.03% amylopectin (Beynum and Roels, 1985).

Textural properties of finished products are greatly influenced by the ratio of amylose and amylopectin. The waxy type (high amylopectin) starches such as tapioca promote puffing and produce an extremely light, fragile product (Lachmann, 1969). It is this amylose:amylopectin ratio which also indirectly influences the oil absorption during deep fat frying. According to Feldberg (1979), as the degree of puffing increases, the percentage oil absorbed will generally increase.

V. Starch Chemistry

Starch granules are composed of an organized structure containing both a linear polymer, amylose, and a branched polymer of glucose termed amylopectin (Beynum and Roels, 1985). These two fractions differ in molecular weight and chemical structure. Amylose consists of 200-1000 glucopyranoses joined through alpha 1-4 glucosidic linkages. Enzyme studies indicate perhaps a trace amount of branching in the amylose molecules or in a portion thereof (Banks and Greenwood, 1975).

Amylopectin has a highly branched structure consisting of 1500 or more glucopyranose units linked at alpha 1-4 but branched at the alpha 1-6 linkage (Beynum and Roels, 1985).

When starch granules are heated in water to progressively higher temperatures, swelling occurs. The temperature at which progressive swelling occurs is between 60°C and 70°C and is termed "gelatinization" (Beynum and Roels, 1985). The initial swelling takes place in the amorphous regions of the starch granule, disrupting the weak bonding between the starch molecules and hydrating them. As the temperature of the aqueous starch mixture rises, more hydration occurs and the hydrogen bonds in the crystalline regions begin to be disrupted. This allows a portion of the amylose molecules to leach out into the aqueous medium (Banks and Greenwood, 1975).

Maximum viscosity is reached when all of the starch granules have hydrated fully. If heating and agitation of the starch mixture continues, the swollen starch granules begin to rupture and collapse, yielding a viscous colloidal dispersion of swollen granule fragments, hydrated starch aggregates and dissolved molecules (Beynum and Roels, 1985).

VI. The Amylograph and Starch Gelatinization

Apparent viscosity changes of starch pastes during cooking are best studied with the Brabender Visco/Amylograph (Beynum and Roels, 1985). This instrument measures the apparent viscosity of starch-water dispersions that are stirred and heated at a uniform rate and held at a desired temperature for a specific time. Generally, the sample

temperature is increased at a rate of 1.5°C/minute and the heating continues until the temperature reaches 95°C. The paste is then held at this temperature for up to 60 minutes with continuous stirring. This instrument can be used to determine the extent of starch paste interactions with different food substances during gelatinization.

The properties of a starch paste are determined by the type of starch, the concentration, cooking conditions (pH, temperatures, heating times, agitation, instrumentation, etc.) and the presence of other food materials (Beynum and Roels, 1985). Brabender viscosity curves are characteristic for each type of starch (Nartey, 1977). Initially, no viscosity effect is noted as the starch suspension is heated until the gelatinization temperature is reached (Beynum and Roels, 1985). The temperature at which the viscosity begins to rise is called the temperature of gelatinization and can be important to food processors and to the development of new food products (Beynum and Roels, 1985).

As the temperature of the starch suspension is increased, the granules swell, thus increasing viscosity. This process continues until maximum viscosity is reached which is the highest viscosity encountered during preparation of a starch paste.

Tuber and root starches typically show a sharper rise in viscosity during cooking and a higher peak viscosity than do the common cereal starches (Nartey, 1977). The root starches swell at lower temperatures and to a greater extent: thus demonstrating a lesser degree of association than cereal starches (Beynum and Roels, 1985).

Starch gelatinization and rheological properties are of great technological importance (Kawabata et al., 1981). Snack food processors can utilize these properties as guidelines for the development of new food products (Feldberg, 1979). Quantitative information regarding starch-protein interactions can also be helpful to food processors and product development. Few studies, however, have been conducted regarding starch-protein interactions.

Ofelt and co-workers (1955) studied the effects of raw soy flour, defatted soy flour and heat-modified soy flour on the viscosity of wheat starch pastes as measured by the amylograph. The viscosity effects of malt α -amylase and β -amylase were also studied in relation to the starch-soy pastes. They found that β -amylase has a small effect on the viscosity of wheat starch pastes, whereas α -amylase has a marked effect. They concluded that the lipoxidase responsible for liquefaction of starch was heat labile, and that commercial soy flours have received sufficient heat treatment to inactivate this enzyme. Raising the pH to 11.0 or lowering the pH to 2.0 also alleviated the liquefaction problem.

Moore and Carter (1972) investigated the molecular interactions of β -lactoglobulin, soy protein and egg albumin with selected starch hydrolysates at elevated temperatures. The extent of interaction was determined by gel filtration and solubility studies. Results indicated that covalent bonding, noncovalent aggregation and other factors can account for the extent of interaction. A model was proposed to study functional roles played by proteins and carbohydrates in food products.

No reports were found in which the effect of defatted soy flour on the gelatinization of tapioca starch was studied. Through such an investigation, some insight may be gained as to the behavior of a soy-starch paste at various concentrations, pH levels and temperatures. This knowledge may then be applicable toward the development of new snack food items.

CHAPTER III

MATERIALS AND METHODS

I. Source of Ingredients

Two types of soy flours which had been sifted through a No. 200 size mesh sieve and had Protein Dispersibility Indexes (PDI) of 20 or 70 were obtained from Cargill, Inc. (Cedar Rapids, IA). Tapioca starch and flour were manufactured in Thailand and packed for Summit Import Corporation (New York). Both tapioca products were obtained from a local retailer in Knoxville, Tennessee. The shrimp extract flavor used for sensory analysis was obtained from Accurate Ingredients (Syosset, NY).

II. Gelatinization Study

The Brabender Visco/Amylograph (C. W. Brabender, Inc., Hackensack, NJ), equipped with a 700 cmg cartridge, was used to study the gelatinization of tapioca starch and defatted soy flour dispersions. The statistical design for the gelatinization study was an incomplete randomized block approach, as shown in Table 1. The order in which each combination was tested was randomized across all combinations and types (PDI 20 or 70) of soy flour. Completions of all combinations for the two types of soy flour constituted one replication. A partial second replication consisting of three randomly selected combinations for each type of soy flour was also performed.

Table 1. Incomplete randomized block design for gelatinization study of tapioca starch

pH value	Defatted soy flour added to dispersion			
	g			
	0	10	20	30
5.5	11 ^a	--	13	14
6.3	--	22	23	24
7.1	31	32	33	--
7.9	41	42	--	44 ^a

^a Represents combinations of different pH value and defatted soy flour levels; 11 - pH of 5.5 with 0.0 g of soy flour, and 44 represents pH 7.9 with 30 g of soy flour.

For each dispersion, 30 g of tapioca starch was mixed with 200 ml of 0.1M phosphate buffer at 25°C. Next, soy flour was added at 0, 10, 20, or 30 g, and the pH of the dispersion was adjusted to 5.5, 6.3, 7.1, or 7.9 with 1.0 M HCl or NaOH. An additional 220 ml of phosphate buffer at 25°C, adjusted to the correct pH, was used to wash the dispersion into the mixing bowl. The starch/flour dispersion was heated from 25°C to 95°C at a rate of 1.5°C per min, then held at 95°C for 15 min.

The apparent viscosity of the starch paste in Brabender units was recorded as a function of time as the pastes were heated to 95°C (45 min) and held at that temperature for 15 min. From the amylogram for each dispersion, the following variables were determined:

- (1) the time to onset of gelatinization,
- (2) the time to reach maximum viscosity,
- (3) the maximum viscosity,
- (4) the viscosity at 60 min.

The dependent variables were analyzed statistically as a function of pH, soy flour level, and PDI of the soy flour. When significant pH and/or soy flour level effects were found for any dependent variable, orthogonal polynomials were used to partition their sums of squares into linear, quadratic and cubic representations, and to produce an equation containing both pH and level of soy flour. If significant pH X soy flour level interactions were found, these terms were also included in the equation. From these equations, a surface response model for each variable was developed.

III. Substitution of Defatted Soy Flour for Shrimp in Chips

A. Chip Formulation and Experimental Design

A tapioca-based snack formulation similar to that used for production of fish chips by Wahid (1983) was developed and is shown in Table 2. This formulation was used for production of the soy-extended chip. Four different levels of two types of defatted soy flours (PDI 20 or 70) were substituted for shrimp, as shown in Table 3, and represented a single replication. Two replications were performed. The order in which the chips containing different levels and type of soy flour were produced was randomized across soy flour type, level and replication.

B. Preparation of Chips

The ingredients for each formulation were weighed in the quantities specified in Table 2. Small, frozen, commercially available shrimp were thawed under cold running water, then processed in a blender to obtain a comminuted mass. Sugar, egg, yeast, and salt were added to the shrimp and mixed with a spatula until the ingredients were moist. The ingredients were then transferred to a 4.5-qt Kitchen Aid mixer bowl. Tapioca starch and hot water were then added and mixed with a paddle on medium speed. When a homogeneous emulsion was obtained, tapioca flour and soy flour were added to form a dough-like mixture. Mixing was continued for 5 additional min.

From this mass, sausage-like rolls weighing approximately 100 g each were formed by hand. The rolls were immersed in boiling water for 20 min to gelatinize the starch. The cooked rolls were then cooled on

Table. 2. Shrimp chip formulation

Ingredient	Level (g)
Tapioca starch	100.00
Water (60°C)	50.00
Shrimp meat	50.00
Sugar	20.00
Tapioca flour	20.00
Yeast	.20
Egg	8.00
Salt	2.48

Table 3. Substitution of defatted soy flour for shrimp in chip formulation

Constituent	Level (g)			
	1	2	3	4
Soy flour ^a	00.00	16.67	33.33	50.00
Shrimp meat	50.00	33.33	16.67	0.00

^aAn additional 10 g of water was added to the formulation for each 16.67 g of soy flour added.

wax paper at room temperature, and frozen at 5°C overnight until firm and ready for slicing.

The rolls were sliced mechanically using a Hobart deli slicer to a thickness of 0.60 mm. These thin slices were arranged in rows on wire mesh screens and dried in a Stewart Warner dehydrator oven at 50°C for 40 min. After drying, the slices were fried in vegetable oil for 10 sec at 190°C, and allowed to cool on paper towels to absorb any excess oil. The chips were then stored at ambient temperature under nitrogen in airtight containers until evaluation.

The chemical composition (moisture, fat and protein levels), color and texture of the fried chips from each treatment and soy flour level in each replication were determined as described in the sections below.

C. Methods of Chemical Analysis

Protein, fat, and moisture content were determined for each combination and replication. Protein, fat and moisture levels were analyzed according to the AOAC (1980) methods. Protein content was determined by the Kjeldahl method on 2-g samples (% nitrogen X 6.25). Moisture was determined by the vacuum oven method. Two-gram samples were dried to a constant weight at 100°C for 6 hr. Fat was determined by a modified Babcock method developed specifically for snacks by Hefnawy et al. (1978).

D. Methods of Physical Analysis

- (1) Texture analysis. The Instron Universal Testing Machine, Model 1132, connected to a Shimadzu Chromatopac C-R3A integrator was used to determine the force required to break

the chips (Anon., 1975). A blade 2.5 mm thick, operating against a 3.2 mm open groove 7 cm long, was used. A 50-kg load cell was used, and the texture was determined as g of force required to fracture a single chip. Ten chips were evaluated for each type and level of soy flour in each replication. The highest and lowest values were omitted, and the remaining values averaged for each measurement.

- (2) Color analysis. The chip color was measured on all formulations using the Hunter Color Difference Meter, Model D25M-2 (Anon., 1979). Samples were crushed and held in a cuvette with an optical glass bottom for the measurement. Values L, "a" and "b" were recorded for the chips. The meter was standardized against a white tile (No. C2-21125), with $L = 91.03$, $"a" = -1.3$, and $"b" = 1.6$.

E. Statistical Analysis

The dependent variables from chemical analyses (protein, moisture and fat levels), texture and Hunter Color Values (L, a, and b) were analyzed as a function of soy flour type, soy flour level and their interaction, as shown in Table 4. Significantly different means for level were separated by orthogonal polynomials across soy type in the absence of a significant type x soy level interaction and for each type in the presence of a significant interaction. Equations showing the significant level effects on all dependent variables were obtained.

Table 4. Analysis of variance for soy flour type and level

Source	Degrees of freedom
Treatment (T, soy flour type)	1
Level (SL)	3
T x SL	3
Error	8
Total	15

IV. Selection of Chips for Sensory Evaluation

Commercially produced pork rinds similar in appearance and texture to the laboratory produced shrimp chip were selected for texture measurement using the Instron Universal Testing Machine Model 1132 (Anon., 1975). Chips containing the highest levels of soy flour with textures closest to that of the pork rinds were selected for sensory evaluation using a commercial shrimp flavoring.

V. Sensory Evaluation

The chips formulated with PDI 70 defatted soy flour were prepared the day before evaluation as previously described, and held in airtight containers at ambient temperature until evaluation.

Shrimp extract powder was used to formulate the two flavor levels of the chips for sensory evaluation. The first formulation was prepared by mixing 100 g chips with 2.0 g extract powder; the second by mixing 50 g chips with 2.0 g powder. Chips prepared for sensory analysis were flavored by placing the fried chips in a polyethylene bag containing the powdered shrimp flavor, then sealing and shaking the bag until the chips were coated with the seasoning.

Chips were evaluated by an untrained sensory panel consisting of 57 students and faculty. Samples were coded with three-digit random numbers and were evaluated one sample at a time. The order of the sample presentation was balanced to reduce order bias. Panelists were seated in individual booths and testing was conducted under white lights between 9:30 a.m. and 11:30 a.m. and 1:30 p.m. and 3:30 p.m. An

8-point hedonic scale (Appendix A) was used to determine how well panelists liked the chips. A 9-point Food Action Rating Scale (FACT) developed by Schutz (1965) was used to estimate potential frequency of consumption if the chips were available in the market (Appendix A).

After evaluating the samples, panelists were asked to supply information (Appendix B) on age, frequency of snack chip consumption, types of chips they consume most frequently, potential purchase of the sample chips if available in the market, and how well they liked the shrimp flavor.

The hedonic and FACT scores were statistically analyzed as a function of flavor level, frequency of snack chip consumption, whether or not the consumer would buy the chip if available, age group, gender, and how well the panelists liked the flavor of the chip. Significantly different means were separated by Duncan's Multiple Range Test.

The statistical analysis was performed using the Statistical Analysis System (SAS, 1982) program available through the IBM-CMS mainframe computer at the University of Tennessee, Knoxville.

CHAPTER IV

RESULTS AND DISCUSSION

I. Gelatinization Study

As shown in Table 5, the analyses of variance for the variables in the gelatinization study, the time to onset of gelatinization was not significantly affected by pH, soy flour level or soy flour type. The average time to onset of gelatinization of tapioca starch with or without added soy flour was 30.06 min.

The time to reach maximum viscosity was not significantly affected by soy flour type, pH or soy flour level. Starch dispersions with a pH of 7.9 tended to require the longest time to reach maximum viscosity 37.65 min, and pH 6.3 dispersions the least time 36.60 min.

The maximum viscosity of the pastes was affected significantly by the type of soy flour, pH and soy flour level, and for each type, the manner in which the pH and level affected the maximum viscosity was different ($P < .05$) (Table 6). As shown in Table 7, addition of PDI 20 soy flour resulted in pastes with higher maximum viscosity than did PDI 70 soy flour. However, this difference may not be of any practical importance in view of the significant interactions of soy flour type with pH level or both pH and level. This may be the result of the heat treatment of the soy flour and the state of the soy proteins. PDI 20 soy flour proteins have largely been denatured by heating and only 10 to 20% remain water dispersible. On the other hand, 60 to 80% of the proteins in the PDI 70 soy flour remain water dispersible such that

Table 5. Sums of squares from the analysis of variance for variables of gelatinization of tapioca starch as a function of defatted soy flour levels and pH

Source	Degrees of freedom	Variable ^a			
		TimeG	TimeMV	Maxvis	Vis60
Soy flour type (T)	1	.5333	2.7000	7616 ^d	163
pH	3	1.1575	4.7816	69733 ^d	55693 ^d
Soy flour level (SL)	3	.1262	6.7070	365841 ^d	180040 ^d
T x pH	3	.3170	2.0598	367 ^b	2051
T x SL	5	.1538	.5760	8077 ^d	4986
pH x SL	3	1.2567	7.3857	2441 ^c	19553 ^b
T x pH x SL	5	1.3221	1.2566	1536 ^c	3731
Error	6	1.0000	10.5000	150	4600
Total	29	5.8667	35.9667	455763	270817

^aTimeG = time to onset of gelatinization; TimeMV = time to maximum viscosity; Maxvis = maximum viscosity; and Vis60 = viscosity at 60 min.

^bp < .05.

^cp < .01.

^dp < .001.

Table 6. Orthogonal polynomial separation of significant sums of squares of maximum viscosity and viscosity at 60 min for soy flour level and pH values and their interactions by soy flour type

Source	Degrees freedom	Variable ^a	
		Maxvis	Vis60
<u>Soy flour type PDI 20</u>			
Soy flour level (SL)	1	166920 ^d	71741 ^d
(SL) ²	1	18237 ^d	47
(SL) ³	1	1956 ^d	173
(pH)	1	8536 ^d	2851
(pH) ²	1	1080 ^d	62
(pH) ³	1	15848 ^d	19314 ^c
(SL) x (pH)	1	157 ^b	1806
(SL) x (pH) ²	1	72	8652 ^b
(SL) ² x (pH)	1	39	3208
(SL) ² x (pH) ²	1	75	254
(SL) x (pH) ³	1	21	3585
<u>Soy flour type PDI 70</u>			
(SL)	1	169468 ^d	96886 ^d
(SL) ²	1	1633 ^d	1057
(SL) ³	1	11152 ^d	7045 ^b
(pH)	1	27431 ^d	15218 ^c
(pH) ²	1	10975 ^d	18770 ^c
(pH) ³	1	10783 ^d	9604 ^b
(SL) x (pH)	1	733 ^c	1372
(SL) x (pH) ²	1	341 ^c	1091
(SL) ² x (pH)	1	2128 ^d	3096
(SL) ² x (pH) ²	1	407 ^c	176
(SL) x (pH) ³	1	5	44

^aMaxvis = maximum viscosity and Vis60 = viscosity at 60 min.

^bP < .05.

^cP < .01.

^dP < .001.

Table 7. Maximum viscosity of tapioca starch pastes containing defatted soy flour averaged across pH and soy flour level for each type of soy flour

Type soy flour	Maximum viscosity (BU) ^a
PDI 20	872 ^b
PDI 70	840 ^c

^aBU = Brabender units.

^{bc}Means in a column bearing different superscripts are significantly different at the $P < .05$ level.

enzymes may still be active (Dubois and Hoover, 1981). The possibility exists that these enzymes caused hydrolysis of the starch or of the protein during the gelatinization of the starch resulting in a lower maximum viscosity than did the PDI 70 soy flour.

The maximum viscosity of the tapioca starch pastes is shown as a function of pH and soy flour level for PDI 20 soy flour in Figure 1. The equation for this figure is shown in Appendix C. At any pH, as soy flour level in the pastes increased from 0 to approximately 25 g, the maximum viscosity increased from 652 to approximately 940 BU before decreasing slightly with addition of 25 to 30 g of soy flour. The pH had little affect on the maximum viscosity at any soy flour level.

For pastes containing PDI 70 soy flour, the maximum viscosity is shown as a function of pH and soy flour level in Figure 2 and the equation for the figure in Appendix C. At any pH, there was a cubic relationship between maximum viscosity and soy flour level. The maximum viscosity was at a minimum of 626 BU after addition of 5 g soy flour and at a maximum of approximately 1030 BU after addition of 27 to 28 g soy flour. The pH level had only a slight effect on the maximum viscosity. Pastes containing any level of soy flour had the highest maximum viscosity at pH 6.2 and lowest at pH 7.9.

The surface response graph of viscosity at 60 min in tapioca starch pastes containing PDI 20 soy flour is shown in Figure 3 as a function of pH and soy flour level with the equation for the figure given in Appendix C. As can be seen, a significant pH X soy flour level interaction (Table 5) was also found. In pastes containing no soy flour, the highest viscosity at 60 min was found at pH 6.3, but in

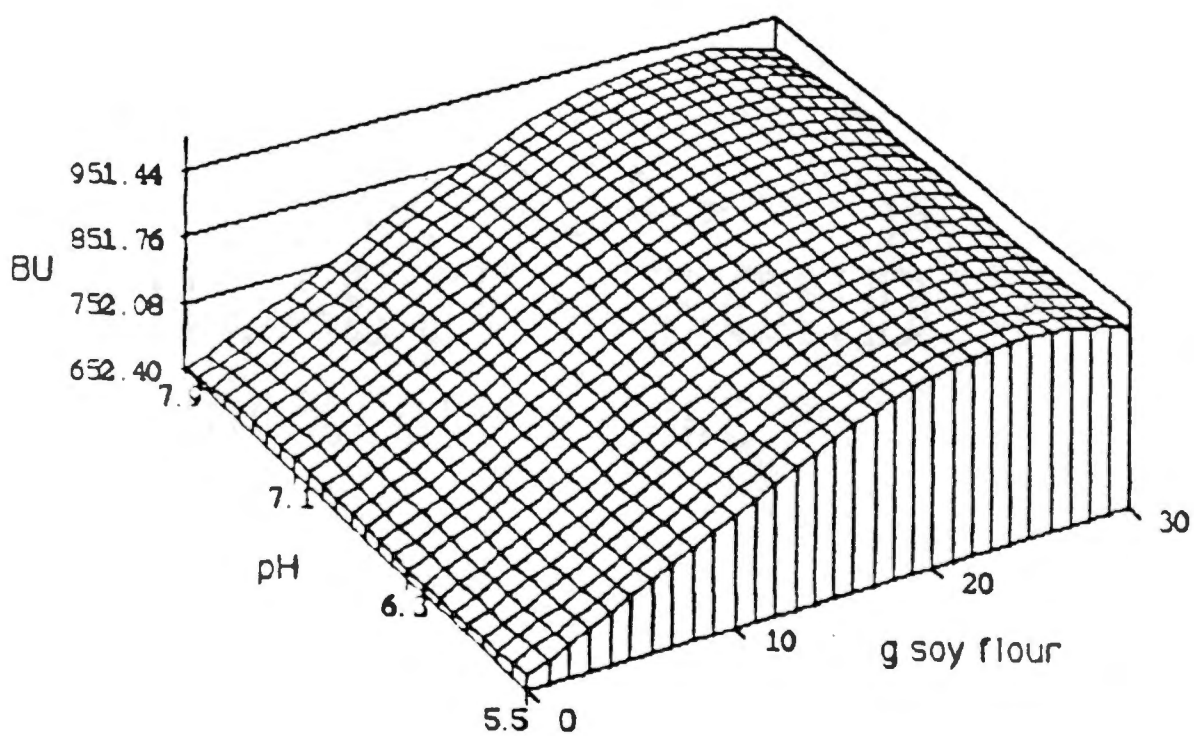


Figure 1. Maximum viscosity (BU) of tapioca starch pastes containing defatted soy flour (PDI 20) as a function of pH and soy flour level.

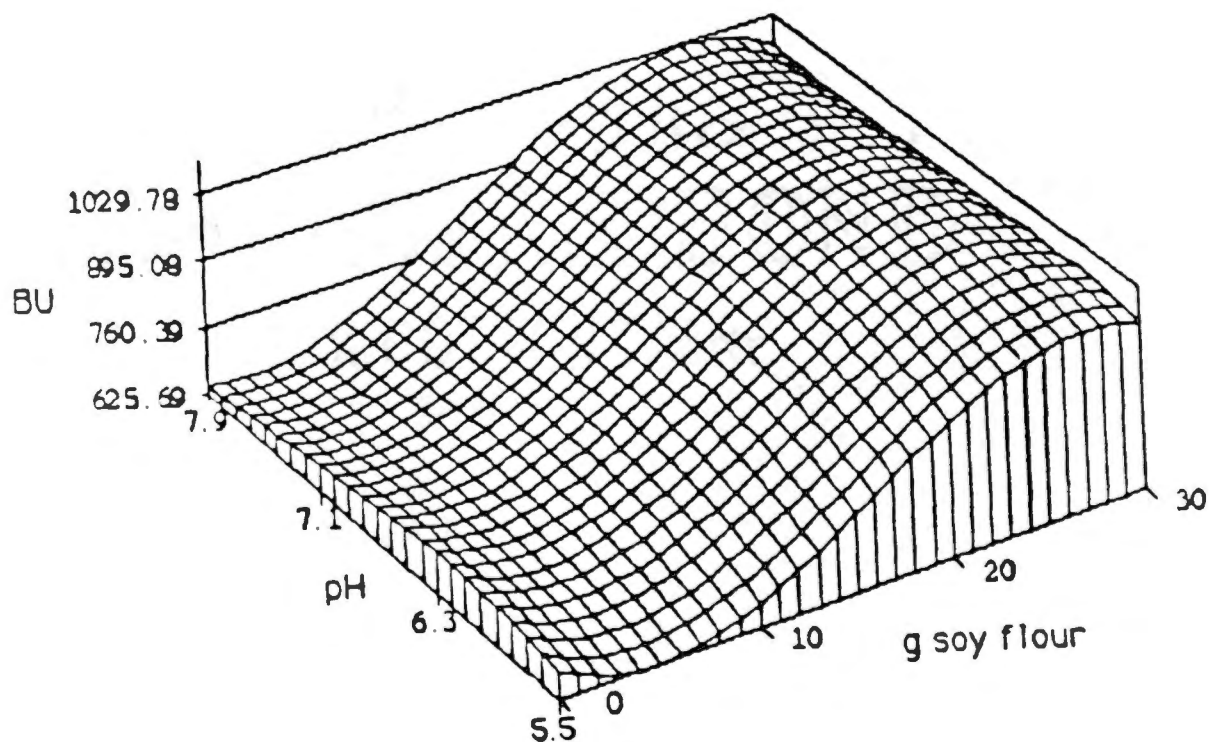


Figure 2. Maximum viscosity (BU) of tapioca starch pastes containing defatted soy flour (PDI 70) as a function of pH and soy flour level.

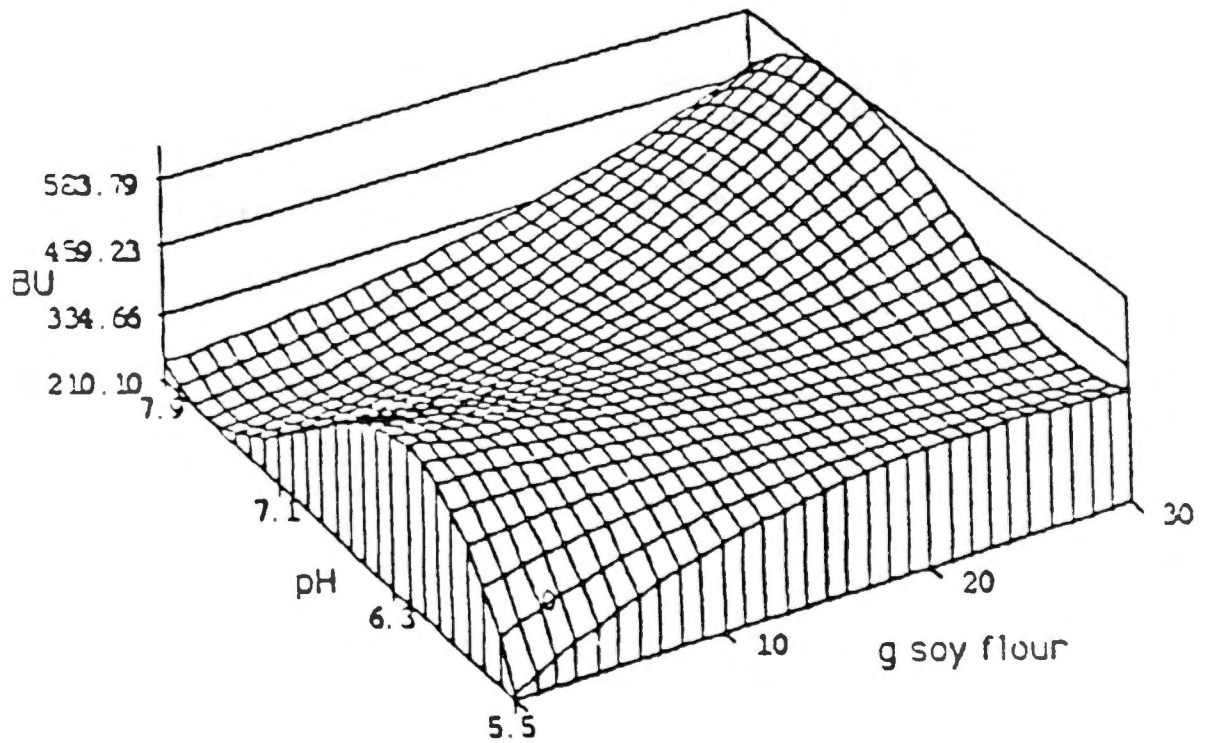


Figure 3. Viscosity at 60 min (BU) of tapioca starch pastes containing defatted soy flour (PDI 20) as a function of pH and soy flour level.

pastes containing 30 g soy flour, the highest viscosity at 60 min was found at pH 7.1. Generally at any pH except 6.0 to 6.6, addition of soy flour increased the viscosity at 60 min. The areas of maximum viscosity at 60 min occurred in pH 7.1 pastes containing 30 g soy flour (585 BU) and areas of minimum viscosity at 60 min were in pastes containing no soy flour at pH 5.5 and 7.7 to 7.9 (210 BU). The viscosity at 60 min in tapioca starch pastes containing PDI 70 soy flour is shown as a function of pH and soy flour level in Figure 4. The equation for this figure is also given in Appendix C. At any soy flour level, pH 7.1 pastes had the highest viscosity at 60 min of all pH levels. At any pH level, the viscosity at 60 min generally increased with increasing soy flour level except in the pH range of 5.5 to 6.0 where it decreased slightly with increasing levels of 25 to 30 g soy flour. In tapioca starch pastes containing PDI 70 soy flour, maximum viscosity at 60 min was observed in pH 7.1 pastes containing 30 g soy flour (500 BU), and minimum viscosity at 60 min in pH 5.5 pastes containing 4 to 5 g soy flour (177 BU).

Increasing maximum viscosity measurements in starch pastes with increasing levels of soy flour indicates that the soy flour did not compete with the tapioca starch for water during gelatinization. Instead the soy protein added to the viscosity by absorbing water and swelling giving a thickening effect. This absorption of water and swelling of protein molecules could also have forced the starch molecules closer together which resulted in the increased viscosity.

Compared with other pH values, the pH of 6.3 - 7.1 generally resulted in higher viscosity at 60 min in pastes containing the higher

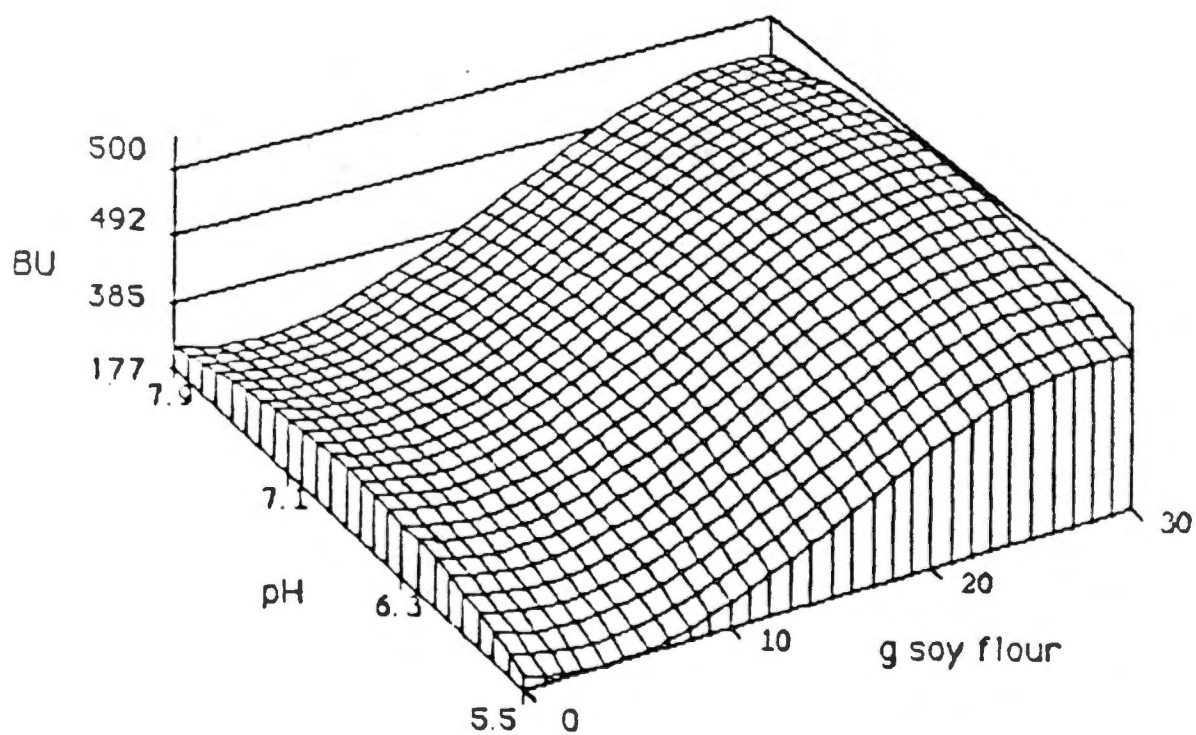


Figure 4. Viscosity at 60 min (BU) of tapioca starch pastes containing defatted soy flour (PDI 70) as a function of pH and soy flour level.

levels of soy flour suggesting a protective effect on starch breakdown in this pH range. The attractive and repulsive interactive forces of proteins and their ability to associate with water are affected by changes in pH (Fennema, 1985). It is possible that in this pH range protein-starch complexes were formed that protected the starch.

Results of this study are really rather straight forward which is not in agreement with Yagi and Okamoto (1976) who reported complex results when different starch:protein combinations were studied. They found denaturation of proteins during heating showed diverse effects on different starches.

II. Chemical Characteristics of Chips

Results from the amylograph study were not conclusive for discarding either type of defatted soy flour as a substitute for meat or fish in a tapioca-based snack food. Therefore, both types of soy flour (PDI 20 and 70) were studied at different levels of substitution for shrimp in a tapioca-based chip.

As shown in the analyses of variance for characteristics of the chip containing shrimp and/or defatted soy flour in Table 8, the protein or fat content of the chip was not significantly affected by the type of defatted soy flour. In contrast, the moisture level was significantly affected by soy flour type. The level of defatted soy flour significantly affected both protein and fat levels in the chip. No significant soy flour type x soy flour level interaction was found for any of the chemical characteristics.

Table 8. Sum of squares for moisture, fat and protein levels in tapioca-based shrimp chips as a function of soy flour type and level

Source	Degrees of freedom	% Protein	% Fat	% Moisture
Soy flour type (T)	1	10.6929	9.0000	.4761 ^a
Soy flour level (SL)	3	194.335 ^a	634.2500	.2290
(SL)	1	192.6432 ^a	561.83 ^b	
(SL) ²	1	2.6406	36.00	
(SL) ³	1	.0512	36.42	
T x SL	3	11.1056	66.5000	.1964
Error	8	32.5643	1040.0000	.6157
Total	15	248.6978	1749.7500	1.5171

^aSignificant at the $P < .05$ level

^bSignificant at the $P < .05$ level when the T x SL interaction is included in the error term.

The moisture level of chips containing different types of defatted soy flour are shown in Table 9. Chips formulated with PDI 20 soy flour had significantly higher moisture levels than those chips formulated with PDI 70 soy flour. Across soy flour level, mean moisture content of the chips ranged from 4.29% to 4.58% with chips formulated from 33.33 g of soy flour appearing to have the lowest moisture level (Table 10).

When orthogonal polynomials were used to separate the soy flour level effects for the protein and fat contents in the chip, a linear relationship was found between each characteristic and the level as shown in Tables 8 and 10. Incorporation of defatted soy flour in the chip resulted in a linear increase in the level of protein in the chip from 1.84% in chips containing no soy flour to 11.18% in chips from the formulation containing 50 g defatted soy flour or 100% substitution for the shrimp (Table 10). Adding soy flour to the chip formulation decreased the fat level in the chip linearly from 42.75% at 0 g soy flour to 25.50% at 50 g soy flour (Table 10). The decrease in fat content with increasing soy flour level are consistent with results found by Siegel and Lineback (1976) who reported that snacks formulated with soy flour absorbed less oil during frying.

The increase in protein level and decrease in fat level might be desirable for the snack food processor who could promote the chip as having lower fat content, elevated protein levels and decreased calorie content. In addition, chips formulated without shrimp meat would also cost the snack processor less to produce compared to the shrimp chip.

Table 9. Average moisture levels for chips formulated from different types of defatted soy flours

Soy flour type	% Moisture ^a
PDI 20	4.67 ^b
PDI 70	4.32 ^c

^an = 8.

^{bc}Means in a column bearing different superscripts are significantly different at the $P < .05$ level.

Table 10. Average^a percentage protein, fat and moisture contents in shrimp tapioca-based chips containing different levels of defatted soy flour substituted for shrimp

Level of soy flour (g) ^b	Moisture (%)	Protein ^c (%)	Fat ^d (%)
0.00	4.58	1.84	42.75
16.67	4.54	4.22	37.75
33.33	4.29	7.17	36.50
50.00	4.58	11.18	25.50

^an = 2.

^bAmount of shrimp replaced by defatted soy flour; 0 = 0%, 16.67 g = 33.33%, 33.33 g = 66.67%, and 50.00 g = 100%.

^cSignificantly affected by soy flour level (X) as shown by the equation, % protein = $1.46 + .1857 X$.

^dSignificantly affected by soy flour level (X) as shown by the equation, % fat = $43.58 - .3180 X$.

The laboratory-produced chips with an average moisture content of 4.50% (n=16) across soy flour levels contained a higher moisture level than commercially processed pork rinds (1.5-2.0% moisture) which are similar in appearance. Further research is needed on the chip containing defatted soy flour to reduce its moisture content because a lower moisture content has been shown to result in a more stable product (Cavaletto and Yamamoto, 1971; Dela Cruz et al. 1966).

III. Physical Analysis

The Hunter Color "L" value was significantly affected by type and level of soy flour and also had a significant type x level interaction as shown in Table 11. Chips containing PDI 70 soy flour had a higher "L" value than chips containing PDI 20 soy flour (Table 12). Means for L value averaged across type of soy flour for each level are given in Table 12; however, the significant effect for level is shown in Figure 5 for each type. Means for the "L" value for soy flour level were separated by orthogonal polynomials for each soy flour type and are shown in Figure 5 as a function of soy flour level. The equations of "L" value for each soy flour type as a function of level are given in Appendix D. The "L" value for chips containing PDI 20 soy flour decreased from approximately 60 at 0 g soy flour to a minimum value of 52.5 before increasing to a maximum of approximately 63 at 41 to 42 g of soy flour. The "L" value then decreased to 56.6 at 50 g of soy flour (Figure 5). In chips containing PDI 70 soy flour, the "L" value decreased in a quadratic manner from 61.1 to 58.9 as soy flour levels increased from 0 to 50 g. The type x level interaction for the "L"

Table 11. Sums of squares for Hunter color values of tapioca-based shrimp chips as a function of defatted soy flour type and level

Source	Degrees freedom	Hunter color values		
		"L"	"a"	"b"
Soy flour type (T)	1	23.0400 ^a	1.2100 ^a	.0156
Soy flour level (SL)	3	47.7075 ^a	8.2050 ^a	22.3869 ^a
(SL)	1			19.9000 ^a
(SL) ²	1			2.4806 ^a
(SL) ³	1			.0062
T x SL	3	45.0600 ^a	5.6150 ^a	.1119
PDI 20				
(SL)	1	.0557	.6767	
(SL) ²	1	.2112	.1250	
(SL) ³	1	85.5567 ^a	11.4483 ^a	
PDI 70				
(SL)	1	4.9704 ^a	.9610 ^a	
(SL) ²	1	1.9812 ^a	.6050 ^a	
(SL) ³	1	.0721	.0040	
Error	8	4.5100	.1800	1.2850
Total	15	120.3175	15.2100	23.7994

^aSignificant at the $P < .05$ level.

Table 12. Mean Hunter color values^a of tapioca-based shrimp chips containing different types and levels of defatted soy flour substituted for the shrimp

Soy flour	Hunter color values		
	"L" ^b	"a" ^c	"b" ^d
<u>Level (g)^e</u>			
0.00	60.30	6.38	17.88
16.67	57.30	8.15	19.63
33.33	61.50	6.80	20.68
50.00	57.85	7.80	20.85
<u>Type</u>			
PDI 20	58.04 ^f	7.55 ^f	19.72 ^f
PDI 70	60.49 ^f	7.00 ^g	19.78 ^f

^a n = 4 for level and 8 for type.

^b See Figure 5 for significant soy flour level effects for each type of soy flour.

^c See Figure 6 for significant soy flour level effects for each type of soy flour.

^d A significant soy flour level (X) was found as shown by the equation, "b" = 17.87 + .1307 X - .001428 X².

^e Soy flour substituted for shrimp at 0.00 g = 0% substitution, 16.67 g = 33.33%, 33.33 g = 66.67% and 50.00 g = 100%.

^{f,g} For type of soy flour, means in a column with different superscripts are significantly different at the P < .05 level.

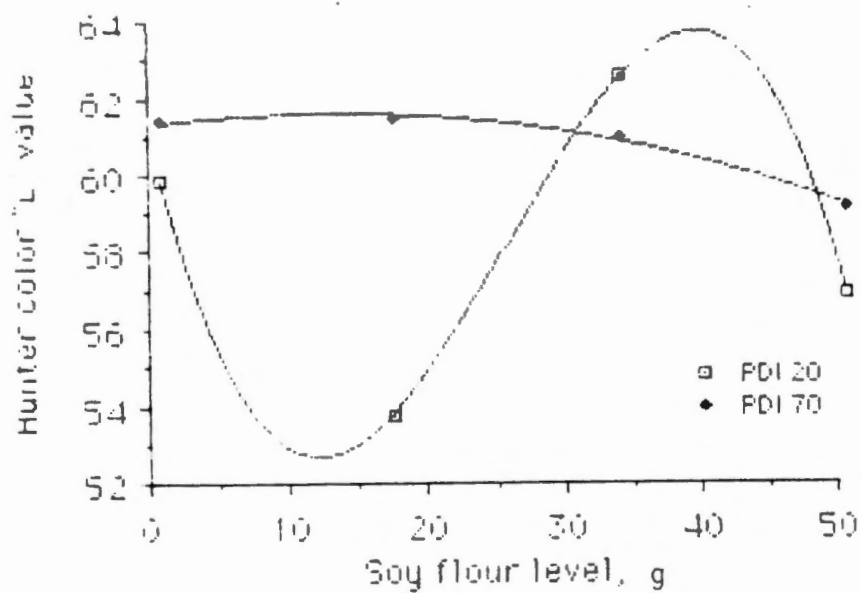


Figure 5. Hunter color "L" value of tapioca-based shrimp chips as a function of the level of two types of defatted soy flour (PDI 20 and PDI 70) substituted for shrimp where 50 g = 100% substitution.

value occurred at approximately 30 and 48 g soy flour where the PDI 20 curve crossed the PDI 70 curve as can be seen in Figure 5.

The Hunter color "a" value was significantly affected by soy flour type and level (Table 11). In addition, a significant type x level interaction was found for the "a" value. Chips made with PDI 20 soy flour had a higher positive "a" value than chips made with PDI 70 soy flour (Table 12) and were, therefore, redder. Although "a" values averaged across type of soy flour are given in Table 12 for each level, the significant level effect for each type is shown in Figure 6. For the PDI 20 soy flour, "a" increased from 6.6 to a maximum of approximately 9.5 at 12.5 g soy flour before decreasing to a minimum of approximately 6.0 at 40 g and then increasing to 8.5 at 50 g soy flour. For the PDI 70 soy flour, "a" increased quadratically from 6.3 at 0 g soy flour to 7.2 at 50 g soy flour. These results indicate that the chip in which 25% of the shrimp had been substituted by PDI 20 soy flour was redder than the other chips. The type x level interaction occurred at approximately 29 and 48 g soy flour where the curve for the PDI 20 soy flour crossed the curve of the PDI 70 soy flour (Figure 6). Equations showing "a" as a function of soy flour level for each type of soy flour are given in Appendix D.

The Hunter color "b" value was not significantly affected by soy flour type nor the interaction, but was affected ($P < .05$) by soy flour level (Table 11). Chips containing no soy flour had the lowest "b" value of all chips (Table 12). As the soy flour level increased from 0 to 50 g, the "b" value increased quadratically from 17.9 to 20.8. The

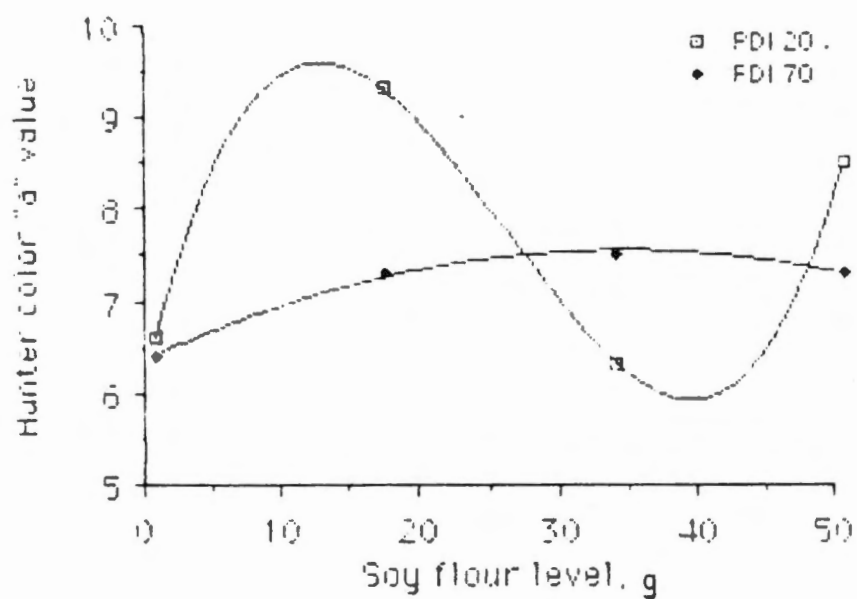


Figure 6. Hunter color "a" value of tapioca-based shrimp chips as a function of the level of two types of defatted soy flour (PDI 20 and PDI 70) substituted for shrimp where 50 g = 100% substitution.

increase in the positive "b" value means that the chips became more yellow with increasing soy flour level.

The analysis of variance for the texture of the chip or the force required to break one chip is given in Table 13. The texture was significantly affected by soy flour level but not soy flour type. The force required to break a chip increased linearly with increasing levels of soy flour as shown in Table 14. Chips containing no soy were more fragile than chips formulated with soy flour compared to all other chips. Chips containing the highest level of defatted soy flour required the greatest amount of force for breaking and this force (585 g) was closest to the 723 g required to break commercially-produced pork rinds. Therefore, the chip containing only defatted soy flour and no shrimp was selected for evaluation by a sensory panel.

IV. Sensory Evaluation

The analyses of variance of how well the panelists liked the chip (Hedonic score) and how often they would eat it if it were available on the market (FACT score) were analyzed as a function of several parameters and are presented in Table 15. Because only one panelist was under the age of 18, those results were grouped with the age group of 18-24 for analysis.

Panelists liked the chip with the low level of flavor significantly more than the chip with the high level of flavor (Tables 15 and 16). The chip with the low level of flavor was scored (5.45) between "like slightly" and "liked moderately." Although there were no significant differences in the FACT score between flavor levels, the

Table 13. Sums of squares for force required to break tapioca-based shrimp chips as a function of soy flour type and level

Source	Degrees freedom	Force
Soy flour type (T)	1	5347
Soy flour level (SL)	3	201711 ^a
(SL)	1	195358 ^a
(SL) ²	1	6206
(SL) ³	1	147
Error ^b	11	141886
Total	15	348944

^a Significant at $P < .05$ level.

^b Includes the T x SL interaction.

Table 14. Mean values for force^a required to fracture chips containing different levels of defatted soy flour substituted for shrimp

Soy flour level ^b	Force ^c (g)
0.00	286
16.67	430
33.33	520
50.00	585

^aN = 4.

^bSoy flour substituted for shrimp where 50 g = 100% substitution.

^cA significant soy flour level effect (X) was found as shown by the equation, force = 307 + 5.9302 X.

Table 15. Sums of squares for sensory evaluation of chips as a function of shrimp flavor, frequency of consumption, intent to purchase, panelist age group, panelist gender and how well panelists liked the flavor of shrimp

Source	Degrees of freedom	Hedonic score	FACT score
Flavor level	1	7.8947 ^a	4.6404
Frequency	2	27.9008 ^a	12.9305 ^a
Intent to buy	1	46.7249 ^a	90.4172 ^a
Age group	3	13.5719	7.4500
Gender	1	.0141	.0212
Attitude toward shrimp flavor	1	4.3664	3.3610
Error	99	171.2814	195.7852
Total	113	271.7544	316.6053

^aSignificant at the $P < .05$ level.

Table 16. Mean Hedonic and FACT scores for soy chips formulated with two different shrimp flavor levels and for panelists' frequency of consumption and buying intention for the shrimp-flavored chips containing 100% substitution of shrimp by defatted soy flour

<u>Category</u> Description	Number of Panelists	Hedonic score ^a	FACT score ^b
<u>Flavor level^c</u>			
Low	57	5.45 ^d	4.96 ^d
High	57	4.92 ^e	4.56 ^d
<u>Frequency of chip consumption</u>			
Weekly	19	4.50 ^d	4.32 ^d
Monthly	28	5.59 ^e	5.10 ^d
Yearly	10	5.40 ^e	4.80 ^d
<u>Intent to buy</u>			
Yes	23	6.04 ^d	5.89 ^d
No	34	4.62 ^e	4.00 ^e

^a8-point scale where 4 = dislike slightly; 5 = like slightly; 6 = like moderately.

^b8-point scale where 4 = "I don't like it but would eat it on occasion;" 5 = "I would eat this if available but would not go out of my way;" 6 = "I like this and would eat it now and then".

^cLow = 50 g chips/1.00 g flavor; high = 25 g chips/1.0 g flavor.

^{d,e}With each category, means within a column followed by different superscripts are significantly different at the $P < .05$ level.

chip with the low level of flavor tended to have the highest score. As determined by FACT score, these panelists didn't really like the chip but would eat it on occasion or would eat the chip if available but would not go out of their way.

Panelists who consumed snack chips several times weekly rated the chips significantly lower hedonically than the panelists who did not consume snack chips as frequently (Tables 15 and 16). These results may indicate that the panelists who eat chips several times a week were more discriminating towards the sample chips than those who consumed snack chips several times a month or year. The frequency of snack chip consumption did not significantly affect mean FACT scores.

There was a relationship between mean hedonic scores and whether panelists would buy the chips if available in the market (Tables 15 and 16). Panelists who would not buy the chips disliked the chips slightly, and panelists who responded that they would buy the chips scored the chips significantly higher corresponding to the hedonic response, "like moderately."

Results were similar for FACT responses (Tables 15 and 16). A relationship was also found between food action scores and whether or not panelists would buy the chips. Twenty-three panelists would buy the chips, while 34 responded negatively. Panelists with negative buying responses gave the chips significantly lower FACT scores than the panelists who would buy the sample.

How well the panelists liked the flavor of shrimp did not significantly affect mean hedonic or FACT scores (Table 15). The majority of the panelists (44) responded that they liked the flavor of shrimp,

while 13 responded that they did not like it or liked the flavor of shrimp only slightly. This may have been a reason why the mean hedonic and mean FACT scores were not higher for the sample chips.

No significant differences among the age groups of panelists were found for the hedonic score (Table 15). The range of the hedonic score among all age groups was 4.0 to 6.5. Also, no significant differences among age groups were found for the FACT score (Table 15). The FACT score ranged from 3.8 to 5.5 among all age groups. In addition, neither the FACT nor the hedonic score was affected by panelist gender ($P < .05$), as shown in Table 15.

V. CONCLUSION

Results of the gelatinization study showed that in the pH range of 5.5 to 7.9, neither type of defatted soy flour competed with tapioca starch for water during heating. Rather, increasing levels (0 to 30 g) of the flour generally increased the maximum viscosity of the starch dispersion. This same effect was found also on the viscosity at 60 min for the PDI 70 soy flour with change in pH having little effect. In contrast, the pH had a much greater effect on the viscosity at 60 minutes in dispersions containing PDI 20 soy flour, and that effect was dependent on soy flour level. While these results were interesting, they were not helpful in selection of either type of soy flour for substitution of shrimp in a tapioca-based chip.

Increasing levels of either PDI 20 or 70 soy flour substituted for shrimp in the chip significantly increased protein content and decreased fat content while increasing the force required to break a

chip ($P < .05$). Complete substitution of defatted soy flour for the shrimp resulted in a chip containing 11.18% protein, 25.50% fat and 4.58% moisture and requiring 538 g to break, a force less than that required to break a commercially produced pork rind chip which was similar in appearance. Chips containing defatted soy flour and no shrimp (the "all-soy" chip) were darker, redder and more yellow than those containing shrimp and no soy flour. The "all-soy" chips when shaken with a shrimp flavor at 1.00 g flavor per 50 g chips were liked between slightly and moderately by a 57-member panel. Twenty-three of the panelists who marked they would buy the chip liked the chip moderately at both flavor levels studied and would eat it now and then.

Substituting defatted soy flour for shrimp meat in the existing snack food formulation would decrease costs to the snack food processor. The processor could also promote the chip as having high protein content, a value-added characteristic, lower fat content and decreased calorie level. It is also possible that the "all-soy" chip could be a suitable carrier for flavors other than shrimp which was used in the present study.

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APPENDICES

APPENDIX A

CHIP SCORECARD

Panelist Number _____

You will receive 2 chips followed by a questionnaire. After tasting each of the chips please rinse your mouth with water.

SAMPLE NUMBER _____

Please taste the chip and describe how well you like the chip.

Like extremely	_____
Like very much	_____
Like moderately	_____
Like slightly	_____
Dislike slightly	_____
Dislike moderately	_____
Dislike very much	_____
Dislike extremely	_____

Indicate how often you would eat this product if it was available in the market.

I would eat this every opportunity I had	_____
I would eat this very often	_____
I would frequently eat this	_____
I like this and would eat it now and then	_____
I would eat this if available but would not go out of my way	_____
I don't like it but would eat it on occasion	_____
I would hardly ever eat this	_____
I would eat this only if there were no other food choices	_____
I would eat this if I were forced to	_____

COMMENTS: _____

APPENDIX B
CHIP QUESTIONNAIRE

Panelist number _____

Thank you for tasting the chip samples. We would appreciate it if you would complete the following questionnaire.

- 1) Gender: Male _____ Female _____
- 2) Age: _____ less than 18
 _____ 18-24
 _____ 25-34
 _____ 35-44
 _____ 45-54
 _____ 55 and over
- 3) Check the frequency with which you eat chips
 _____ Several times a week
 _____ Several times a month
 _____ Several times a year
- 4) List the 3 chips that you consume most frequently

- 5) If the product that you tasted today were available in the market, would you buy it? Yes _____ No _____
- 6) How well do you like the flavor of shrimp?
 Like extremely _____
 Like very much _____
 Like moderately _____
 Like slightly _____
 Dislike slightly _____
 Dislike moderately _____
 Dislike very much _____
 Dislike extremely _____

THANK YOU FOR PARTICIPATING IN OUR SURVEY

APPENDIX C

Table 17. Equations showing significant pH and soy flour level effects on maximum viscosity and viscosity at 60 min of tapioca starch pastes for each type soy flour

Soy flour type	Equation ^a
PDI 20	$MV = 4577 + 12.18(SL) + .3944(SL)^2 - .0176(SL)^3 - 1789(pH) + 272.23(pH)^2 - 13.76(pH)^3 + .3078(SL)(pH).$
PDI 70	$MV = 4411 - 147.97(SL) + 7.936(SL)^2 - .0639(SL)^3 + 2187(pH) - 305.8(pH)^2 + 13.916(pH)^3 + 33.493(SL)(pH) - 2.0212(SL)(pH)^2 - 1.3686(SL)^2(pH) + .0876(SL)^2(pH)^2.$
PDI 20	$V60 = -61336 + 3581(SL) - 16.74(SL)^2 + .00038(SL)^3 + 27358(pH) - 4001(pH)^2 + 192.87(pH)^3 - 1536(SL)(pH) + 217.71(SL)(pH)^2 - 4.802(SL)^2(pH) - .3385(SL)^2(pH)^2 - 10.1997(SL)(pH)^3.$
PDI 70	$V60 = -3798 - 11.5968(SL) + 1.7210(SL)^2 - .0362(SL)^3 + 1527(pH) - 183.26(pH)^2 + 6.8604(pH)^3.$

^aMV= Maximum viscosity (BU), SL = soy flour level in g added to starch paste, pH = pH value and V60 = viscosity at 60 min (BU).

APPENDIX D

Table 18. Equations showing significant soy flour level effects on the Hunter color "L" and "a" values for each type defatted soy flour in the tapioca-based shrimp chips

Hunter color value Soy flour type	Equations ^a
<u>"L" value</u>	
PDI 20	"L" = $59.55 - 1.3998(\text{SL}) + .0795(\text{SL})^2 - .001053(\text{SL})^3$
PDI 70	"L" = $61.01 + .04544(\text{SL}) - .001755(\text{SL})^2$
<u>"a" value</u>	
PDI 20	"a" = $6.50 + .5411(\text{SL}) - .0293(\text{SL})^2 + .000385(\text{SL})^3$
PDI 70	"a" = $6.26 + .0681(\text{SL}) - .009899(\text{SL})^2$

^aSL = soy flour level in g.

VITA

Kim Anderson was born in Cookeville, Tennessee on November 7, 1962. After graduating from Cookeville High School, she entered Tennessee Technological University in Cookeville, Tennessee as an undergraduate. She received a Bachelor of Science in Home Economics with a major in Foods and Nutrition in March 1985. In September 1985 she entered the Graduate School of The University of Tennessee, Knoxville and began working toward a Master of Science degree in Food Technology and Science.

She is a member of the Institute of Food Technologists, The American Oil Chemists Society, Gamma Sigma Delta and the Food Technology Club of The University of Tennessee.