NANCY JOY DUBOST
Development and Optimization of Peanut Soy Spread
(Under the Direction of RONALD R. EITENMILLER)

Peanuts and soybeans have recently gained publicity due to their health benefits. A $3 \times 3 \times 3$ factorial design was used in formulating peanut soy spread (PSS). Based on results from the TA-XT2 Texture Analyser® and predicted values of commercial products and PSS, the optimal combination of ingredients for PSS was determined and developed. Two textural parameters studied were influenced by the interaction of isolated soy protein and stabilizer. Using instrumental analysis (I) significant differences were found between textural parameters of three PSS and two commercial treatments ($\alpha = 0.05$). Descriptive analysis (D) indicated significant differences existed between the treatments. Consumer acceptability (C) testing indicated commercial treatment and three PSS were acceptable. A mathematical relationship ($R^2 = 0.5$) existed between the cohesiveness (I) and cohesiveness (D), cohesiveness (I) and adhesiveness (D), gumminess (I) and adhesiveness (D), adhesiveness (I) and adhesiveness (D), aroma (D) and (C), and aroma and mouthcoating and superior quality.

INDEX WORDS: Peanut butter, Soy protein, Texture Analyser, Texture evaluation, Consumer evaluation, Descriptive analysis

DEVELOPMENT AND OPTIMIZATION OF PEANUT SOY SPREAD

by

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DEDICATION

I dedicate this thesis to my mom and dad, to whom I love and owe so much.

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I would like to thank my parents for their prayers, guidance and love. You always knew what to say at the right time. I couldn’t have gotten this far without you.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Peanut Butter

Many Americans enjoy peanuts and products made from peanuts such as peanut butter. Peanuts (*Arachis hypogea L.*) are an important provider of plant protein and unsaturated oil. It has been reported that on a daily basis Americans consume approximately two million pounds of peanut butter (Peppers, 1996). The production of peanut butter comprises half of the total food use of peanuts (Resurreccion, 1988). Peanut butter was first developed in 1890 and has since become a staple food (Woodroof et al., 1945).

Standard of Identity

With the consumer being more aware of the nutritional aspects of food, the quantity and quality of the ingredients of peanut butter has become very important. There are Standards of Identity established for peanut butter. These standards require that peanut butter must contain at least ninety percent of peanuts with the remaining ten percent consisting of salt, sugar and stabilizer. Peanut butter contains approximately 21.5-28.6 percent protein and no greater than fifty-five percent fat. These ranges can depend upon the peanuts used in the production of peanut butter. Spreadable peanut products that do not meet these Standards of Identity are referred to as “peanut spread” (Woodroof, 1983).

Attributes and Stability

Peanut butter is a dispersion with the protein suspended in the oil phase (Fennema, 1996). The popularity of peanut butter among consumers could be due to its convenience, stability and flavor. It is a semiperishable food with a low moisture content that allows the product to be less susceptible to spoilage (Woodroof, 1983).

There are several factors that affect the stability of peanut butter including genetics, environmental conditions, handling, processing and the varying composition of the raw peanuts. The shelf life of peanut butter is generally one to two years. The shelf life can vary depending on the free oil available, exposure to oxygen and the material used for packaging the peanut butter (Shewfelt and Young, 1977). Off-flavors can develop which are primarily due to auto-oxidation (Woodroof, 1983).

Ingredients

Peanut butter can be easily produced from grinding freshly dry-roasted, blanched peanuts, usually consisting of spanish, virginia and/or runner peanuts. The ingredients will affect the texture of the peanut butter. Peanuts used to make an oilier and softer peanut butter generally are two parts spanish or runner peanuts with one part virginia peanuts (Woodroof et al., 1945; Woodroof, 1983). Runner type peanuts are less expensive and therefore are predominately used (Weiss, 1970). As stated earlier, the product must contain at least ninety percent peanuts to be labeled peanut butter; otherwise, it is considered a peanut spread (Weiss 1970; Woodroof, 1983).

Other ingredients of peanut butter are sugar, salt and stabilizer such as oil or an emulsifier (Ahmed and Ali, 1986). One study showed that the addition of sugar, salt and an emulsifier to peanut butter improved the flavor and overall acceptability by consumers. (El-Shimi, 1996).

A stabilizer such as hydrogenated vegetable oil (including peanut oil) in the amount of 1.6 to 2.0 percent by weight is used to prevent oil separation (Weiss, 1970; Gills and Resurreccion, 2000). The earliest account of using stabilizer involved adding hydrogenated peanut oil in peanut butter (Collins and Sanchez, 1979). Rancidity can occur because of the exposure of the free oil to oxygen and light. One method used to prevent oil separation is to keep the peanut butter cooled to 50°F or lower. The oil becomes less resistant to separation due to an increase in the oil's viscosity. An upper level of stabilizer is between 3.5 and 5.5 percent by weight (Woodroof, 1983).

Sweeteners are also added to peanut butter in a weight between 6.0 and 7.0 percent (Weiss, 1970). Some manufacturers can add up to 7.5 percent sweeteners by weight. Examples of sweeteners would include sucrose and corn syrup solids. Sugar can produce tenderness in the peanut butter and can delay rancidity (El-Shimi, 1992). A fine particle size sweetener can result in a smooth texture.

Salt is added in order to enhance the flavor and act as a preservative. The amount of salt added to peanut butter is usually between 1.0 to 2.0 percent (El-Shimi, 1992). Fine particle salt such as pulverized salt will help prevent a gritty texture in the peanut butter (Woodroof, 1983).

Production

In the United States, peanut butter was first commercially manufactured around 1900. A physician from Missouri first manufactured peanut butter. He recommended it to his patients due to its nutritional content (Woodroof, 1983). Weiss (1970) outlines the major steps of production beginning with shelled peanuts, including roasting, blanching, grading and sorting, grinding and deaeration.

A new labeling system has recently been implemented in the state of Georgia with the hope of other states to follow. As peanuts arrive at a production site, a bar code labeling system allows processors to quickly identify, receive and inventory peanuts. This is the first time a USDA-graded raw agricultural product has had an inventory system of this manner. This type of labeling provides specific information about the products history and source. This in turn allows the product to be easily integrated into the processors internal system (Anonymous, 2000).

The production of peanut butter begins with roasting and cooling down of the peanuts. Roasting can be described as applying dry heat to the peanuts, which results in the peanuts having a darker color and a “roasted peanut” flavor (Woodroof, 1983). Heat treating the peanuts produces a flavor change that increases the palatability of the peanuts. Volatile oils are produced during roasting, which effects the aroma and taste of the peanuts (El-Shimi, 1992). Roasting can be done by a continuous or batch process. A four hundred pound batch is roasted at 320°F for a maximum of sixty minutes. A countercurrent airflow is used for continuous roasting. The continuous process allows for separation of the peanuts during roasting based on variety and moisture content of the peanuts. Roasting may be started and stopped based on the production needs. Larger companies that manufacture peanut butter use a continuous roasting process in order to achieve a more even roast and a lower labor cost. After roasting, the peanuts are cooled by air circulating through perforated trays (Woodroof, 1983).

The peanuts are then dry blanched. Blanching is done to remove the skins of the peanuts. The testa are removed by passing the peanuts through brushes. Hearts of the peanuts are also removed by placing the peanuts on a vibrating sieve (Woodroof, 1983). After blanching, the peanuts are inspected. Undeveloped or moldy peanuts are removed. Grading and sorting involves revolving cages or shaker screens with specific sized openings to remove unwanted peanuts (Weiss, 1970).

The next major process in production is grinding of the peanuts. Hammer, colloidal or attrition mills, homogenizers, disintegrators, or comminuters can be used to grind the peanuts. Grinding is usually completed twice. Peanuts are the only ingredients used in the first grind. The first grinding yields a peanut paste that has a large particle size detectable in the mouth. The other ingredients of the peanut butter are added before the second grinding. The second grinding yields a peanut butter with a smoother texture due to a smaller particle size. When using a mill, the peanuts are ground between two stones with a clearance between 0.032-0.003 inches. The setting of these stones will determine the texture of the peanut butter. Two grindings are used to prevent off-flavors from developing due to too much heat being produced during the grinding process. Cooling of the product is usually done in an internal scraped surface heat exchanger. The temperature is generally 120°F or lower (Woodroof, 1983).

Deaerating the peanut butter prior to packaging removes unwanted air from the peanut butter (Weiss, 1970). Another method to prevent rancidity is reducing or removing the air from the container. Properly packaged peanut butter entails vacuum packaging or nitrogen flushing which helps to prevent rancidity (Woodroof, 1983).

Nutritional Aspects

Peanuts are a desirable plant food source because of the higher amount of protein provided relative to other plants. Peanut butter is a good source of protein and provides essential vitamins and minerals. It is also become a staple food and ideal for processing because of its bland flavor and light color and a low amount of carbohydrates that produce flatulence (El-Shimi, 1992).

Peanut butter does not contain cholesterol and is low in saturated fat. Recently peanuts and peanut-like products have gained even more popularity due to additional health benefits. It was reported that a diet with regular consumption of peanuts and peanut butter reduced the risk of heart disease by twenty-one percent while a low-fat diet reduced the risk by only twelve percent. This particular study supports the view that a diet high in monounsaturated fat from foods such as peanuts and peanut butter is more beneficial for the heart than a low-fat diet (Kris-Etherton et al., 1999).

Peanuts also contain a substantial amount of sterols. Research suggests that phytosterols or plant sterols positively affect blood lipid profiles and possibly provide a protective role in human cancer development. A major sterol in peanuts and peanut oil is β-sitosterol. There is a slight decrease in the amount of sterols in peanut butter due to the processing; however, one hundred grams of peanut butter still provides a substantial amount of sterols. An individual could raise his/her sterol content in their diet by consuming peanuts and peanut products such as peanut butter (Awad et al., 2000).

Americans consume approximately 180 mg of phytosterols on a daily basis versus 400 mg per day in Japan. In fifteen reviewed studies involving 590 subjects, it was seen that various phytosterol mixtures reduced plasma cholesterol levels. LDL cholesterol had a greater decrease than total cholesterol. After sterol or stanol therapy, on average there was a thirteen percent reduction in LDL and a ten percent reduction in total cholesterol. The mechanism behind the cholesterol lowering of sterols is not well understood; therefore, further studies need to be conducted (Moghadasian and Frohlich, 1999).

Soy

Soy based foods are also gaining rapid popularity among Americans. One survey revealed that foods enriched with soy protein would be consumed by two out of three Americans in order to improve their overall health (Ohr, 2000). A method used for labeling of foods and is required by the Food and Drug Administration for evaluating protein quality is referred to as Protein Digestibility-Corrected Amino Acid Score (PDCAAS). This method is based on the human amino acid requirements of a two to five year old child. The protein is evaluated based on the protein's amino acid content, the digestibility of the protein and the protein's ability to supply essential amino acids. A PDCAAS score of 1.00 provides one hundred percent of the essential amino acids after digesting one unit of the food protein. Isolated soy protein has a PDCAAS score of 1.00, which indicates the protein quality of soy is equal to animal proteins (Henley and Kuster, 1994).

Processing of Soybeans

The processing of soybeans includes cleaning, conditioning, cracking, dehulling and then rolling into flakes. The crude oil is extracted by adding a solvent to the flakes. The solvent is then removed and the flakes are dried. From these flakes, isolated soy protein can be produced.

Isolated soy protein has a protein content of at least ninety percent. It is the most concentrated form of soy protein (Liu, 2000). Common steps used for the preparation of isolated soy protein include: defatting of the sample with organic solvents, dispersion of residue in water, precipitation of the major fraction of the protein at a pH near 4.5, centrifugation, removal of the supernatant and neutralization of the wet protein isolate

(Garcia, et al., 1997). The protein is spray dried to yield a product that has a light color and bland flavor, which provides many functional possibilities (Liu, 2000). Functionality of the proteins can be determined on the specific processing parameters. Three factors that influence the functional characteristics of the finished protein are homogenization, pH and heat (Marsland, 2000).

Isoflavones

It has been known since 1931 that soybeans contain high amounts of genistein and daidzein, which are collectively known as isoflavones. They belong to a group of compounds known as flavonoids (Albertazzi et al., 1998). Isoflavones occur in high amounts in soybeans and are heat stable, very soluble in alcohol and slightly soluble in water (King and Young, 1999). From the protein purification process, isoflavones are a co-product. Alcohol washing can be used to obtain soy extract rich in isoflavones (Marsland, 2000).

The amount of isoflavones on a dry weight basis can be between two to four milligrams per gram of soy protein (Marsland, 2000). Genistein comprises about two-thirds of the total isoflavone content, while daidzein and a small amount of glycitin comprise the remainder (Messina et al., 1994). The concentration of these isoflavones depends on several factors such as the variety of soybeans and under what conditions they are grown, the soil used for growing and the processing conditions (Albertazzi et al., 1998).

Bioavailability of soybean isoflavones can be influenced by a variety of factors, including the presence of fiber in the diet, which can initiate growth and/or activity of bacteria residing in the intestines. A high fiber environment may be favorable for the conversion of daidzein to equol, a catabolic product of daidzein, and thus absorption from the colon. The factors that influence the bioavailability of isoflavones are complex and require further research (Lichtenstien, 1998). Both genistein and daidzein bind to estrogen receptor-β (ER-β). This is probably due to their structural similarity with human estrogen. The binding affinity of genistein to ER-β is approximately twenty times greater than the other estrogen receptor known as ER-α (Tikkanen and Adlercreutz, 2000).

Soy and Cardiovascular Disease

Cardiovascular disease is a continuing health concern in the United States and is one of the leading killers in both men and woman (Wong et al., 1998). Studies indicate a relationship exists between high levels of blood cholesterol and low density lipoprotein (LDL) and low levels of high density lipoprotein (HDL) and cardiovascular disease (Lichtenstien, 1998). Consumption of soy protein has been repeatedly shown to reduce total and LDL cholesterol concentrations in the blood of humans and animals.

A meta-analysis involving thirty-eight clinical studies indicated a mean intake of 47 g of soy protein per day resulted in a 12.9 percent reduction in serum LDL cholesterol. This analysis indicated that the decrease was related to the initial serum cholesterol levels. The largest reduction was seen in the subjects with the highest initial levels of cholesterol. Studies concluded that supplementation of the diet with soy derived isoflavones decreased the *in vitro* oxidation of LDL. Esterified isoflavones within the LDLs were shown to have less susceptibility to oxidation *in vitro* than indigenous LDL (Tikkanen and Adlercreutz, 2000).

Potter et al (1998) found that the addition of a solvent extracted isolated soy protein to casein-based diets in male rats resulted in an increase in HDL:LDL cholesterol ratio and a reduction of LDL cholesterol. The exact component and mechanism of soy that is responsible for these results has not been identified. It is inconclusive if there is any exact component of soy that is responsible for the cholesterol lowering mechanism or even how this mechanism occurs. Isoflavone content in soy may be responsible (Potter, 1995). Increased excretion of cholesterol in the bile may be involved. Also consumption of soy protein may directly effect the metabolism of cholesterol in the liver (Waggle and Potter, 2000). Isoflavones are similar in structure to estrogen. There are two estrogen receptors (ER-β and ER-α) in which isoflavones can react. It has been noted that estrogen can effect lipid metabolism. Potter (1995) concluded that it might be likely that the ability of soy protein to lower cholesterol is a result of a combination of components, which act synergistically

The National Cholesterol Educational Program (NCEP) Step I diet is initially prescribed to individuals with cardiovascular disease. This diet restricts the amount of total fat and cholesterol one may consume. A study was done using this specific diet and with the incorporation of soy protein into the diet. The goal of the study was to determine if the addition of soy protein to the NCEP Step I diet could enhance the hypercholesterolemic effect. Twenty-six men with normo-and hypercholesterol levels were recruited for the study. In reviewing the data, the hypocholesterolemic effect of the soy protein was independent of age, weight, order of dietary treatment and pretreatment plasma lipid concentrations. The results indicated the soy protein significantly reduced the plasma concentrations of LDL cholesterol and the ratio of LDL:HDL cholesterol.

The researchers concluded that soy protein enhances the NCEP Step I diet in reducing cholesterol (Wong et al., 1998).

Other studies have shown that soy protein has minimal effect on lipid profiles. Lipoprotein(a) (Lp(a)) is an independent risk factor for coronary heart disease. A recent study had the objective of comparing the intake of soy protein and casein on plasma Lp(a) concentrations. Nine men with normal cholesterol levels were recruited for a cross-over design study. Casein and soy protein was provided in the diet with the duration of the diet being forty-five days. The results indicated that HDL cholesterol was eleven percent higher from the soy protein diet versus the casein diet. However, LDL cholesterol, total cholesterol and blood triglyceride levels were not significantly different when comparing the soy protein diet with the casein diet. In fact, the concentration of Lp(a) increased by twenty percent after switching to the soy protein diet. The researchers concluded that soy protein could increase the concentration of Lp(a) (Nilausen and Meinertz, 1999).

One study involving twenty male subjects with normal cholesterol levels received a supplement for twenty-eight days consisting of soy protein isolate beverage powder (60g per day) or a casein supplement. The researchers noted an increase in plasma concentrations of isoflavones; however, there was no significant difference in total cholesterol and HDL cholesterol and no significant inhibition of platelet aggregation (Gooderham et al., 1996).

Despite studies that may contradict the theory that soy does lower cholesterol, on October 25, 1999, the Food and Drug Administration approved the use of a health claim on food labels for those products containing specific amounts of soy protein (FDA, 1999). This decision was based on forty-three human intervention studies. These studies indicated that when soy protein in the diet is consumed in place of animal protein, an individual's blood cholesterol level is lowered, reducing the risk of cardiovascular disease. Those products containing a minimum of 6.25 g of soy protein per serving and are low in fat (less than 3 g of fat per serving and less than 1 g of saturated fat) and cholesterol (less than 20 mg per serving) are able to make this health claim on the food label. It is believed that a low saturated fat diet containing a total of 25 g of soy protein a day may reduce the risk of heart disease (Liu, 2000).

Soy and Cancer

It has been suggested that countries such as China and Japan where soy consumption is high may account for low rates of breast, colon and prostate cancer. In 1994, Messina et al. reported that seventeen of twenty-six studies reviewed showed that soy has protective effects against cancer. This protective effect was observed in both hormone and nonhormone related cancers. None of the studies demonstrated an increase in tumor development from the intake of soy.

Soy is rich in phytochemicals or more specifically phytoestrogens, which are a broad class of nonsteroidal estrogens originating in the plant kingdom. Genistein and daidzein have weak estrogenic activity as well as antiestrogenic activity. *In vitro* and *in vivo* studies have shown that these phytoestrogens have anticarcinogenic effects. The mechanism behind this is still being debated but this too may be from the isoflavone content of soy. The specific isoflavone, genistein, suppresses the growth of a broad range of cancer cells *in vitro*. At this time, a definitive conclusion regarding the consumption of soy decreasing the risk of cancer can not be made; however, clinical data suggests that soy may have a protective effect against some cancers (Messina et al., 1994).

Mechanisms of soy protein resulting in anticancer effects may include hormonal effects, antioxidant properties, anitangiogenic and antiproliferative effects, inhibition of tyrosine kinases, which have been implicated in the development of certain cancers due to their action in signal transduction cascades, effects on stress response and an effect on the function of the immune system. Further clinical investigation needs to be done to clarify these possible mechanisms (Waggle and Potter, 2000).

Soy and Bone Health

Soy influences bone health. An estimated ten million people in the United States have osteoporosis and eighteen million have low bone mass. Increasing risk factors include lack of estrogen, low consumption of calcium and lack of physical activity (Waggle and Potter, 2000).

A diet high in protein can increase calcium excretion; however, not all proteins have the same effect. Soy protein does not cause hypercalciuria (Waggle and Potter, 2000). One study involving sixty-six postmenopausal women indicated that a diet with isolated soy protein with naturally occurring isoflavones increased both bone mineral content and density in the lumbar spine (Baum et al., 1998).

Soy and Menopause

Another possible health benefit with soy protein is the reduction of undesirable menopausal symptoms in woman. The premise for these studies involving postmenopausal women has been that phytoestrogens lower estrogen levels in a higher estrogen environment and act as estrogen antagonists in a lower estrogen environment.

Various studies have demonstrated that estrogenic effects of soy isoflaovones may exert modest beneficial effects with the cardiovascular system and bone health in peri- and postmenopausal women (Kurzer, 2000).

Fifty-one women who consumed 40 g of isolated soy protein daily for twelve weeks had a forty-five percent reduction of hot flushes by the end of the twelve weeks. This study suggested that consuming soy protein isolate on a daily basis can substantially reduce the number of hot flushes in climacteric women (Albertazzi et al., 1998).

A higher risk of cardiovascular disease in women can occur with menopause. Twenty-one women were recruited to participate in a ten-week study. The subjects consumed 80 mg of isoflavones on a daily basis. Several biomarkers of cardiovascular health were measured. After ten weeks, the results showed a twenty-six percent improvement in the subjects systemic arterial compliance (arterial elasticity); however, there were no significant improvements observed in the blood lipid values (Nestel et al., 1997).

With sixty-six postmenopausal women who consumed on a daily basis 40 g isolated soy protein that contained varying amounts of isoflavones, 2.25 mg of isoflavones per gram positively affected the blood lipid levels and bone mineral content after six months. It was noted that the amount of isoflavone consumed had little effect on blood lipids but was a significant factor in bone measurements. This study suggested that isolated soy protein at varying concentrations can protect against cardiovascular disease by altering blood lipid levels in postmenopausal women. Also, there may be a positive effect on bone health of postmenopausal women with a higher consumption of isoflavones (Potter et al., 1998).

Measuring Textural Attributes

The texture of a food is a very important consideration when developing a new food product. If the texture of the food is not acceptable or does not meet consumer's expectations, the food can be rejected. One study indicated that consumers chose their peanut butter based on the particle size and thus the texture of the peanut butter can determine the consumers decision when purchasing (How and Young, 1985).

Instrumental Analysis

Measuring texture through instrumental methods began in the 1960's (Szczesniak, 1963b). There are three categories of instruments for texture measurement, including instruments designed for a specific food item, instruments that measure the mechanical action on the food item by a single property and instruments that simulate the chewing action of a human (Breenan et al., 1970). Another approach to classifying instruments for texture measurement is through the categorization of three specific tests, fundamental, emperical and imitative.

Fundamental tests are used for measuring the physical or rheological properties of the food. These specific tests can determine ultimate strength, various moduli and Poisson's ratio. The results generally have a poor correlation with textural properties determined by sensory analysis.

Emperical tests are a broad category for various tests such as shear, puncture and extrusion. This category of tests yields one instrumental parameter. The results of these specific tests have been correlated with sensory analysis.

Imitative tests attempt to simulate what actually occurs in the mouth or palate of a human. Several instrumental parameters can be measured through imitative testing.

Instrumental Texture Profile Analysis (TPA) is considered an example of Imitative testing (Szczesniak, 1963b).

The first instrument that attempted to simulate the chewing action of a human was the Denture Tenderometer developed by Food Technology Laboratory at the Massachusetts Institute of Technology. The instrument consisted of a set of motorized dentures that resulted in a force-time curve. With the force time curve, it was difficult to determine textural properties other than peak force. However, this instrument paved the way for the development of other instruments (Bourne, 1978).

Texturometer

The General Foods Corporation Technical Center developed the Texturometer. The original design of the instrument was originally based on the Denture Tenderometer (Breenan et al., 1970). It is comprised of a small flat cylinder that compresses a small piece of food against a plate or base. It simulates the action of a jaw by compressing the food approximately seventy-five percent of the foods original height two times representing two chews. A force time curve is plotted that depicts the entire simulated chewing action (Friedman et al., 1963).

The Texturometer measures the following seven textural parameters, fracturability or brittleness, hardness, cohesiveness, adhesiveness, springiness, gumminess and chewiness. These textural parameters can be determined by the first and second bite compression curves of the Texturometer (Bourne, 1978). Friedman et al. (1963) outlined the procedure used for the Texturometer. Fracturabilty, also referred to as brittleness, is defined as the force produced as seen in the first significant break in the curve. The magnitude of the force is measured by the height of the first break in the curve. Hardness is recorded in the “first bite” as the peak force obtained in the first cycle. The magnitude of the force is measured by the height of the peak as seen in Figure 1.1. Cohesiveness is a ratio of the force area of the second compression to the force area of the first compression (A2/A1 as seen in Figure 1.1). The areas under the curves are a direct function of the work necessary to break the internal bonds of the food sample. Adhesiveness is the negative force area for the first bite (A3 as seen in Figure 1.1). This is the force needed to pull the compressing cylinder away from the food material. Elasticity or commonly known as springiness can be defined as the height in which the food returns between the time of the first and second bite (represented by letter B as seen in Figure 1.1). Gumminess can be determined by multiplying hardness with cohesiveness. Chewiness can be determined by multiplying hardness with cohesiveness with springiness, which is the same as multiplying gumminess with springiness (Friedman et al., 1963).

The Texturometer has been used to characterize textural parameters of a variety of foods including, meat, fruits, vegetables and cake (Breenan et al., 1970), meats (Szczesniak et al., 1963b), twenty three different foods (Szczesniak and Hall, 1975) and various Japanese foods (Tanaka, 1975). When using the Texturometer, one must consider the size and shape of the probe and of the food being tested. Because of these important factors, the test conditions can vary. Breenan and colleagues used a minimum clearance of 2.0 mm between the plunger/cylinder and the sample supporting plate. The samples tested were always fixed on the supporting plate at the same position by clamps or a metal retaining ring. A cycling speed of 12 cycles per minute with a chart speed of 750 mm per minute was consistently used (Breenan et al., 1970; Breenan et al., 1975). When

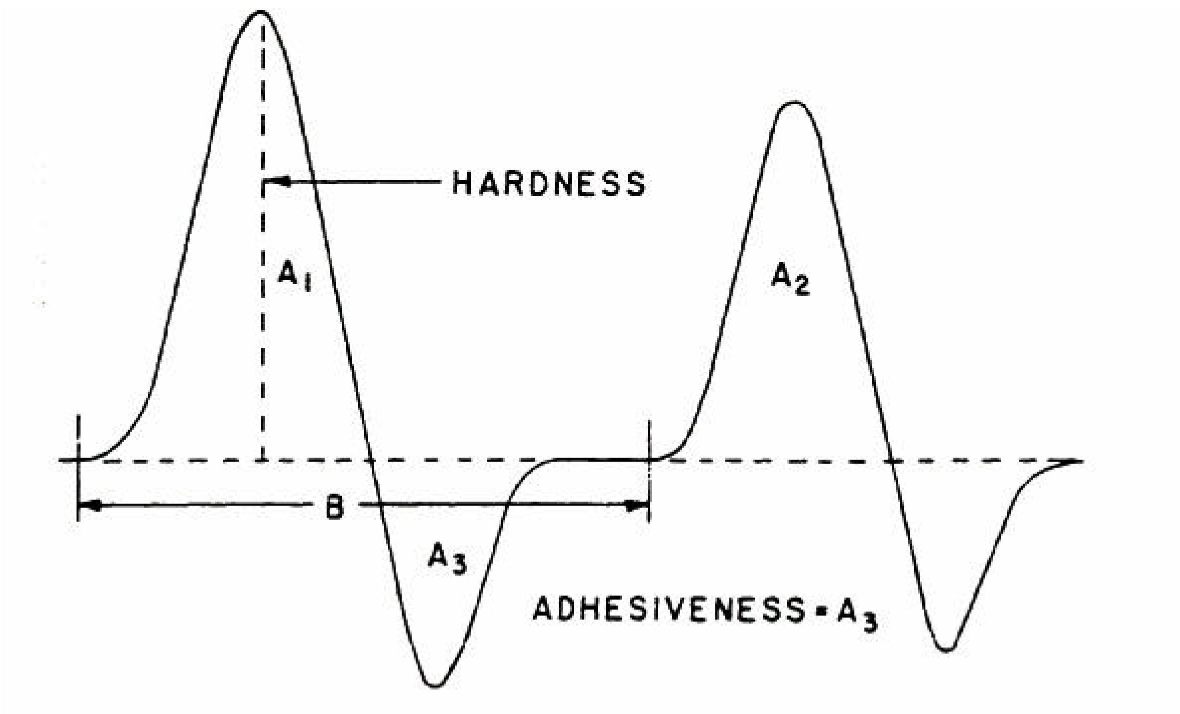

Figure 1.1. A typical texturometer curve (Breene, 1975, Friedman et al., 1963)

the compressing unit or probe is larger in size to the sample being tested, the forces observed are due to compression. When the probe is smaller in size than the sample being tested, the forces are due to compression and shear. In food samples with strongly bound structures such as peanut butter, shear and flow are the main factors affecting force during penetration. In those products with weakly bound structures, flow is the main factor (Breene, 1975).

The Texturometer produces curves with rounded peaks. This is due to the fact that the instrument decelerates as it comes to the end of the compression stroke, stops and then accelerates as it moves into the upward stroke. The speed follows a sine wave pattern, which produces a sine curve. One advantage of the Texturometer following this type of pattern is that the human jaw has been shown to approximately follow a sine wave pattern (Bourne, 1978).

Instron

In 1968, the first published work using the Instron was testing on ripening pears (Bourne, 1968; Breene, 1975). Bourne adapted the methodology of the Texturometer to measure textural parameters; therefore, the analysis and reading of the data is the same as the Texturometer. The Instron also has two compression cycles depicting two bites. There is a difference in the shape of the curves produced by the Instron compared to those produced by the Texturometer. The speed of the compression is constant at all times and then an abrupt change of direction occurs when each bite is completed. This action produces sharp peaked curves that does not follow a sine wave pattern (Bourne, 1978).

Since 1968, the Instron has been extensively used in a variety of foods including fruits, meats, cheeses, confections and desserts. The Instron has been used to characterize the texture profile of peanut butter (Ahmed and Ali, 1986; Collins and Sanchez, 1979; Johnson et al., 1989; Muego et al., 1990).

The size of the compressing unit or plunger or probe can vary. This size can effect the results. Like the Texturometer, if the compressing unit is larger than the sample tested the forces that are recorded are due to compression. If the compressing unit is smaller than the sample tested, the forces are due to both compression and shear (Breene, 1975).

The sample is subjected to seventy-five to eighty percent deformation of its original height. Crosshead speeds can range from 0.2 to 5.0 cm per minute. Chart speed can affect the size and shape of the force distance curves produced. The two absolute values of areas produced (A1, A2) will be affected; but, cohesiveness is not, if the chart speed remains constant during both bites. Adhesiveness defined as the area of the negative peak will be affected by increasing chart speed. The precision of the areas measured could be affected by increasing the chart speed. The chart speed chosen must be held constant throughout the experiment (Breene, 1975).

Sensory Evaluation

Sensory panels involve a selected number of people to evaluate quality or characteristics of food. There are three types of sensory panels, preference/acceptance panels, discriminatory and descriptive.

Preference/acceptance panels use consumers, with no prior sensory training, to determine their likes and dislikes of a specific product. Affective, commonly referred to as consumer testing, involves consumers who regularly consume the product to determine the consumers overall liking/preference of a product or determine the liking/preference of a specific characteristic of the product. Consumer tests ultimately determine whether the product is acceptable or not acceptable (Abbott, 1972).

A nine point hedonic scale can be used (9= like extremely, 1=dislike extremely) for consumer testing. This scale can determine small statistical differences in products (internal validity); however, it does not determine how the product will perform in the market (external validity). The Quality Enhancement model can be used for consumer testing in order to determine both external and internal validity of the product. A three point acceptability scale (3=great, 2=acceptable, 1=unacceptable) or a five-point willingness-to-purchase scale (5=definitely would purchase, 1=definitely would not purchase) can help determine how the product will perform in the marketplace. This type of testing should be done by market segmentation (Shewfelt et al., 1997).

Discriminatory panels use threshold or difference testing to determine detectable differences among samples. Threshold testing involves individuals detecting the smallest change in the intensity of an attribute of designated samples. Difference testing does not measure the magnitude of the difference between samples. It is used just to determine whether there is a difference between samples (Abbott, 1972).

Descriptive testing or Descriptive Analysis indicates the amount or direction of differences among samples (Abbott, 1972). Characteristics (qualitative) and intensity (quantitative) aspects, the order in which these aspects appear and the overall perception of the samples are all constituents of descriptive analysis (Meilgaard et al., 1991). An objective naming of the intensity of the attribute is used rather than the trained panelists personal preference (Abbott, 1972). Objective terms are used to define or describe the sample and generally follow the order of appearance of each attribute, aroma, flavor and texture. The three most common scales used in descriptive analysis are category scaling, magnitude estimation and line scaling (Meilgaard et al., 1991).

Category scaling rates the intensity of the characteristics of interest with equal intervals between categories using minimal words or numbers. Category scaling does not provide a meaningful measure of magnitude when comparing an attribute among samples (Meilgaard et al., 1991).

Magnitude estimation provides scaling by using ratios between numbers in order to mirror the ratio of magnitude of the judged sensation. There are two types of magnitude estimation, one type requires a reference and the other requires no reference. If a reference is used, it is given a fixed numerical value and all samples are compared with this value. If a reference is not used, the first sample receives a numerical value and the remaining samples are rated according to this numerical value (Meilgaard et al., 1991).

Line scaling uses lines that are 150 mm in length with anchors at 12.5 mm and 137.5 mm. Panelists make a mark anywhere on the line which represents the intensity of that attribute for the sample (Meilgaard et al., 1991).

Measurement of Textural Properties through Sensory Analysis

Texture is considered a sensory property that has multi-parameter attributes in which people are able to perceive, describe and quantify. The sensory analysis of texture is a dynamic process. It can be influenced by force, time, temperature and saliva which in turn changes the physical properties of that food (Szczesniak, 1987).

Defining texture requires a composite of definitions in order to develop a classification of textural characteristics. Primary characteristics as well as secondary characteristics (two or more of the terms under primary characteristics) must be considered. There are three important classes of texture, mechanical geometrical and other (Szczesniak, 1963a).

The mechanical characteristics can be defined as the mouthfeel of the material and the way it handles in the mouth. This would include the reaction of the food to stress. There are five basic parameters including, hardness, cohesiveness, viscosity, elasticity and adhesiveness. Hardness is defined as a particular force needed to yield a deformation in the food. Cohesiveness involves the strength of the internal bonds of the food. Viscosity is the rate of flow in a given unit of force. Elasticity is the rate at which the food returns to its original structure after the force producing the deformation is removed. Adhesiveness is the work needed to defeat attractive forces between the surface of the food and those surfaces the food is coming in contact (mouth, teeth, etc.). These five characteristics are under the primary parameters (Szczesniak, 1963a).

Three characteristics that fall under the secondary parameters are, brittleness, chewiness and gumminess. Brittleness is defined as the force needed to fracture the material. This characteristic is related to the primary characteristic of hardness and cohesiveness. In those materials that are brittle there is little cohesiveness but a large amount of hardness, which can result in sound effects when biting down. Chewiness can be defined as the energy needed during mastication of a solid food in order to have the food ready for swallowing. The primary characteristics it is derived from are hardness, cohesiveness and elasticity. Gumminess can be defined as the energy needed during mastication of a semi-solid food in order to have the food ready for swallowing. The primary characteristics it is related to are hardness and cohesiveness (Szczesniak, 1963a).

Geometry can be defined as the physical structure of the material or the way the constituents of the food are arranged, which is reflected in the physical appearance. There are no defined parameters in this characteristic as in the mechanical characteristics. Geometrical characteristics related to the material include size and shape of the particles (related to hardness) and shape and orientation of the particles (Szczesniak, 1963a).

The other characteristic classification depends mainly on the moisture and fat content of the food. When considering moisture, the total amount of moisture present and also the rate at which it is released is observed. The total amount of fat present and the melting point of the fat are important. There are two secondary parameters, oiliness and greasiness. Oiliness is the intense feeling from the amount of oil present in the mouth. This parameter can be related to surface tension and viscosity of the food. Greasiness is related to the solidity of fat and the removal of the fatty film that coats the mouth. This parameter is related to the melting point of the fat. Table 1.1 depicts the popular nomenclature and the classification of textural characteristics. The popular terms demonstrate the degree or different levels of the characteristics (Szczesniak, 1963a).

Based on these textural characteristics standard rating scales were developed in order to quantitatively evaluate the mechanical parameters of texture. Each point on the scale is represented by a particular food and reflects a textural characteristic. The food used in the rating scales possesses the selected intensity of the textural characteristic and

Table 1.1. Popular nomenclature and classification of textural characteristics (Szczesniak, 1963)

Mechanical characteristics		
Primary parameters	*Secondary parameters*	*Popular terms*
Hardness		Soft → Firm → Hard
Cohesiveness	Brittleness	Crumbly → Crunchy → Brittle
	Chewiness	Tender → Chewy → Tough
	Gumminess	Short → Mealy → Pasty → Gummy
Viscosity		Thin → Viscous
Elasticity		Plastic → Elastic
Adhesiveness		Sticky → Tacky → Gooey
Geometrical characteristics		
Class		*Examples*
Particle size and shape		Gritty, Grainy, Coarse, etc.
Particle shape and orientation		Fibrous, Cellular, Crystalline, etc.
Other characteristics		
Primary parameters	*Secondary parameters*	*Popular terms*
Moisture content		Dry → Moist → Wet → Watery
Fat content	Oiliness	Oily
	Greasiness	Greasy

is predominantly that textural characteristic and not overshadowed by other textural characteristics. A good correlation exists using the developed scales between sensory and instrumental (Texturometer) analysis (Sczesniak et al., 1963a).

Texture Profile Analysis (TPA)

A trained or experienced sensory panel is able to determine and express the textural properties of a particular food. Types of descriptive analysis are texture profile analysis and flavor profile analysis. Authur Little Co. developed the flavor profile analysis in 1950. This profile identified flavor-notes using descriptive terminology, order of perception, intensities of the flavor-notes and after-taste experienced (Abbott, 1972).

A lexicon of terms for peanut and peanut based products based on descriptive analysis was developed in 1987. The lexicon identifies desirable and undesirable flavors in peanuts in order to provide definitive, common terms for those in research, production and manufacturing (Johnsen et al., 1988).

Based on flavor profile analysis, a texture profile method was developed in 1963. Texture profile analysis (TPA) evaluates the texture of food based on mechanical, geometrical and other characteristics as described earlier, the intensity of these characteristics and the sequence of the textural characteristics present. The sequence or order of appearance refers to the three stages first bite (initial phase), masticatory (second phase) and residual (third phase) in which the textural characteristics are perceived.

Hardness, brittleness and viscosity encompass the initial phase. Gumminess, chewiness and adhesiveness encompass the masticatory phase. Changes that occur in both mechanical and geometrical characteristics encompass the residual phase (Brandt et al., 1963). To eliminate subjective opinions, standard terminology, standard reference samples and standard evaluation procedures are used with TPA (Civille and Szczesniak, 1973).

Generally at least six panel members are chosen based on a screening procedure. The procedure requires the potential candidate to rank in increasing level of hardness four foods (peanuts, raw carrots, almonds and rock candy), which are based on the hardness scale (Civille and Szczesniak, 1973; Szczesniak et al., 1963a). Candidates should not have any dental problems nor dentures due to the limited perception of textural attributes.

Candidates must also have no known allergies to the foods being tested. Accepted candidates must be willing to be trained by attending all of the training sessions (Civille and Szczesniak, 1973).

After a panel has been selected, a comprehensive training period begins. A panel leader is selected to conduct the training sessions (Brandt et al., 1963). Training sessions can vary in total length from one week to several weeks. Training sessions can meet several times a week with meetings lasting up to three hours each session. Two approaches can be taken to train a panel. A panel that has been trained in the general texture profile method can be used to evaluate texture of many products. Another approach would be to train a panel specifically for the evaluation of one specific product. However terminology and reference samples must be established for that product (Civille and Szczesniak, 1963).

There are several phases to training a panel. First the panel must study the classification of textural characteristics as seen in Table 1.2 entitled Definitions of Textural Characteristics (Civille and Szczesniak, 1963).

Table 1.2. Definitions of Textural Characteristics*

Primary Properties	**Physical**	**Sensory**
Hardness	Force necessary to attain a given deformation.	Force required to compress a substance between molar teeth (in the case of solids) or between tongue and palate (in the case of semi-solids).
Cohesiveness	Extent to which a material can be deformed before it ruptures	Degree to which a substance is compressed between the teeth before it breaks.
Viscosity	Rate of flow per unit force.	Force required to draw a liquid from a spoon over the tongue.
Springiness	Rate at which a deformed material goes back to its undeformed condition after the deforming force is removed	Degree to which a product returns to its original shape once it has been compressed between the teeth.
Adhesiveness	Work necessary to overcome the attractive forces between the Surface of the food and the surface of the other materials with which the food comes in contact.	Force required to remove the material that adheres to the mouth (generally the palate) during the normal eating process.
Secondary Properties	**Physical**	**Sensory**
Fracturability	Force with which a material fractures; a product of high degree of hardness and low degree of cohesiveness	Force with which a sample crumbles, cracks or shatters.
Chewiness	Energy required to disintegrate a semi-solid food to a state ready for swallowing; a product of a low degree of hardness and a high degree of cohesiveness	Length of time (in sec) required to masticate the sample, at a constant rate of force application, to reduce it to a consistency suitable for swallowing
Gumminess	Energy required to masticate a solid food to a state ready for swallowing; a product of hardness, cohesiveness and springiness	Denseness that persists throughout mastication; energy required to disintegrate a semi-solid food to a state ready for swallowing

***Szczesniak, (1963)**

The terms that specifically apply to the product being evaluated are thoroughly studied and must be well understood by panel members. While studying these definitions, textural characteristics are evaluated through standard rating scales (Brandt et al., 1963). These scales teach the descriptive and quantitative parameters of the textural characteristics. The standard rating scales used in sensory analysis were developed to coincide with the instrumental texture measurements developed by Szczesniak et al. (1963b) and Abbott (1972).

Selected references are provided from the standard rating scale that possesses the particular textural characteristic being studied (Brandt et al., 1963). The multiproduct references provide a frame of reference for each of the mechanical parameters. The panelists must follow specific techniques when evaluating the references as seen in Table 1.2 (Civille and Szczesniak, 1973). The technique for evaluating the specific parameter is discussed and several references are provided for each parameter. The panelists are encouraged to discuss and express the variations among references and definitions of parameters (Civille and Szczesniak, 1973).

Panelists must practice using these scales. Panelists receive prepared samples and rate these samples based on the standard scale for the references (Civille and Szczesniak, 1973). Reliability of the panel is determined by providing the panel members various foods and having them evaluate these foods based on the textural characteristics they have learned (Brandt et al., 1963).

Once panelists have an understanding of the basic texture profiling method, the next phase of the training begins. The textural properties are to be evaluated based upon an established terminology, evaluation technique and timing and order of these properties. The panel must consider the manner the food being evaluated is consumed such as, how it is introduced into the mouth, how the food disintegrates in the mouth and what state the food is in prior to swallowing. The panel compiles a list of descriptive words that relates to the product being evaluated. Terms and definitions are developed from this list of words. Specific characteristics will be evident before, during and after mastication. The panel must evaluate these characteristics in the same order (Civille and Szczesniak, 1973).

It is now time for the ballot sheet to be developed for the evaluation process. Panel members can give their input to the panel leader during this process. An open discussion can be conducted during training in order to see if individuals or the entire panel need additional training or clarification. Calibration of a panel is done through evaluating blind controls and duplicate samples. This process can determine the panels' reliability as well as an individual panelist (Civille and Szczesniak, 1973).

Once the panel leader decides the panel members are thoroughly trained in texture profile analysis, testing of the product can begin. Reporting texture profile results should include the following key factors: the goals and objectives of the sensory analysis, the standardization process, terminology and definitions and the testing ballots (Civille and Szczesniak, 1973). Statistical analysis of the results is completed and also reported.

Correlation between Instrumentation and Sensory Analysis

Correlation of instrumental texture profiles with sensory testing can be difficult to accomplish. No instrument can determine a consumer's response or preference because an instrument can not mimic a human's psychological or sensory response.

Instruments can act as “predictors” for the acceptance of a product by consumers (Szczesniak, 1987).

Correlating depends on several factors, including the material being tested, the components of the sets of measurements and the terminology and intensity scales used to identify both the sensory and instrumental testing. The closer the instrumental test conditions can imitate the sensory parameters, the stronger the correlation between the two tests. Correlation will be high when rate and degree of deformation for both instrumental and sensory are the same. One has to keep in mind that there is an absence of saliva and a lower temperature (body temperature at approximately 36°C versus room temperature at approximately 18°C) when performing instrumental tests. These two factors can effect a correlation between instrument and sensory analysis. One must also remember that correlation coefficients do not establish a cause and effect relationship but indicates a possible mathematical relationship with the variables. A correlation can indicate that the variables in the group of samples being studied can change in unison (Szczesniak, 1987).

A statistically significant “r” may not necessarily mean the instrumental test can be used to predict a sensory score. An absolute value of at least 0.7 must be obtained for an instrumental test to be possibly considered as a predictor of sensory score (Bourne, 1982).

A texture relationship study, using twenty-one different foods, was completed using the Instron and TPA. Four parameters were studied including, hardness, springiness, cohesiveness and chewiness. Two parameters (hardness and springiness) were found to have a correlation between sensory and instrumental testing. There was not a significant correlation with cohesiveness and chewiness. The correlation for both hardness and springiness improved when logarithmic transformation of the data was completed (Meullenet et al., 1998).

Another study determined if grind size, salt and sucrose affected peanut butter texture. A texture profile panel, consumer testing and the Instron were used to determine textural differences. Consumers preferred a peanut butter texture with decreased grind size, decreased sucrose concentration and increased salt concentration. There was a lack of correlation between sensory adhesiveness and instrumental hesion (maximum force required in order to pull the upper and lower plates apart) when grind size was increased. There was a correlation between instrumental hesion and sensory adhesiveness when the addition of sucrose decreased. It was determined that the instrumental test did not imitate adhesiveness in the mouth. The author concluded that this may be due to the Instron only measuring vertical force and not also lateral force (Crippen et al., 1989).

In another study, textural characteristics of two peanut butters and a peanut paste were analyzed by a modified texture profile analysis (TPA) using the Instron and a texture profile panel. TPA using the Instron yielded more information in regards to texture in comparison to two other methods that were used (penetrometer and plunger attached to the crosshead of the Instron). There was no correlation between instrumental and sensory analysis with the textural property adhesiveness. TPA and sensory did have a correlation with the textural characteristic spread. TPA could not predict the intensity of heaviness, slipperiness and gumminess (Muego et al., 1990).

Szczesniak et al. (1963a) evaluated various foods for TPA parameters and found a correlation between sensory evaluation and the Texturometer. It appears that statistical correlation was not calculated but rather the authors expressed their judgement in regards to hardness, brittleness, gumminess, chewiness and adhesiveness (Szczesniak et al., 1963a).

Breenan et al. (1970) studied a variety of foods and found a correlation between the Texturometer and sensory evaluation in regards to textural parameters. The textural parameter of hardness for apples was determined by the Texturometer and correlated significantly with both panel firmness and crispness. The authors studied cheese and found that Texturometer hardness correlated significantly with panel firmness. When studying toffee, Texturometer hardness, cohesiveness and chewiness correlated significantly with panel hardness and chewiness. Cake was also studied and a correlation was found with Texturometer hardness and panel assessment of crumbliness. Overall it appeared that Texturometer hardness correlated significantly with sensory firmness/hardness of a variety of foods. The authors concluded that other textural properties need to be studied in more detail with the Texturometer in order to determine whether this instrument is of value in indicating other texture characteristics (Brennan et al., 1970). Breenan and colleagues later suggested that hardness measured by the Texturometer might correlate well with panel assessment of firmness or hardness due to the high initial stress from the edge effect of the plunger. This high initial stress found with the Texturometer may also occur in the mouth when food is introduced in the mouth using incisor or molar teeth (Breenan et al., 1975).

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CHAPTER II

DEVELOPMENT AND INSTRUMENTAL ANALYSIS OF PEANUT SOY SPREADS[1]

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ABSTRACT

A $3 \times 3 \times 3$ factorial design with three levels of added oil concentrations (1, 4 and 7%), three stabilizer concentrations (0.5, 2 and 3.5%) and three concentrations of isolated soy protein (7, 15 and 23%) was used in formulating peanut soy spread. Modified texture profile analysis of commercial peanut butter, soy nut spread and various formulated peanut soy spreads was conducted using a Texture Analyser TA.TX2®. The textural parameters hardness and gumminess were influenced by the interaction of isolated soy protein and stabilizer. No significant interactions or differences were found for adhesiveness and cohesiveness. Based on the instrumental readings of the commercial products and observed and predicted values, the optimal combination of ingredients for a peanut soy spread should be between 4-7% oil, 0.5-0.7% stabilizer and 7-20% isolated soy protein.

INTRODUCTION

On an annual basis in the United States, 2.4 billion pounds of peanuts are consumed. Half of the total food use of peanuts (*Arachis hypogea L.*) is for the production of peanut butter. From 1989 to 1995 the consumption of peanuts decreased by 250,000 tons (Georgia Peanut Producers Association, 2001). This lower consumption of peanuts indicates a need for new peanut products.

Peanut butter provides a substantial amount of plant protein, unsaturated vegetable oil**,** essential vitamins and minerals (El-Shimi, 1992), and a substantial amount of sterols, which has been shown to lower plasma cholesterol levels (Awad et al., 2000). Regular consumption of peanut butter lowers the risk of heart disease (Kris-Etherton et al., 1999).

The Standard of Identity for commercial peanut butter requires the product to contain at least 90 percent peanuts with the remaining 10 percent usually from sugar, salt and stabilizer. Peanut products that do not meet this Standard of Identity are labeled as "peanut spread". The production of peanut butter entails roasting, blanching and grinding of the peanuts. The remaining ingredients are added to the peanut butter or spread during the grinding process (Woodroof, 1983).

Isolated soy protein has a Protein Digestibility-Corrected Amino Acid Score (PDCAAS) of one indicating the protein quality of soy is equal to animal protein (Henley and Kuster, 1994). Isoflavones can be found on a dry weight basis between 2-4 mg per g of soy protein (Marsland, 2000). Regular consumption of isolated soy protein has been shown to have many health benefits including the reduction of cardiovascular disease (Gooderham et al., 1996; Potter, 1995; Tikkanen and Adlercreutz 2000; Wong et al., 1998), a lower risk of cancer (Messina et al., 1994), favorable effects on bone health (Baum et al., 1998; Waggle and Potter, 2000) and a reduction of undesirable menopausal symptoms in women (Albertazzi e al., 1998; Kurzer, 2000; Potter et al., 1998). Recently the Food and Drug Administration (FDA) approved the use of a health claim for those products containing 6.25 g of soy protein per serving and are low in fat (less than 3 g of fat per serving and less than 1 g of saturated fat) and cholesterol (less than 20 mg per serving) (FDA, 1999). It is believed that a low saturated fat diet containing a total of 25 g of soy protein a day may reduce the risk of heart disease (Liu, 2000).

Textural attributes of a peanut spread can affect the overall acceptability of that product (Muego et al., 1989). Imitative testing can be used to characterize textural attributes by attempting to simulate what actually occurs in the mouth or palate of a human. Instrumental Texture Profile Analysis (TPA) is an example of imitative testing (Szczesniak, 1963). The Texturometer can be used for this type of testing and has been used to characterize textural parameters of a variety of foods (Breenan et al., 1970; Szczesniak et al., 1963; Szczesniak and Hall, 1975; Tanaka, 1975).

The general objective of this study was to develop a peanut spread containing soy protein and to better understand the relationships between the factors (amount of isolated soy protein, peanut oil and stabilizer) and the response (textural attributes-hardness, adhesiveness, cohesiveness and gumminess) and to determine the effects of the factors on textural properties. The specific objectives were: (1) determine the textural characteristics of two peanut butter/spread currently in the market and various formulated peanut soy spreads using the Texture Analyser®; (2) determine the optimal combination of ingredients for the peanut soy spread based on the instrumental textural properties of products in the market.

MATERIALS AND METHODS

Experimental Design

Peanut soy spreads were prepared using a 3 x 3 x 3 factorial design with three levels of peanut oil by weight (1, 4 and 7%), three levels of stabilizer by weight (0.5, 2 and 3.5%) and three levels of isolated soy protein by weight (7, 15 and 23%). Twenty-seven samples were prepared and instrumental readings were duplicated. Commercial creamy peanut butter and commercial soy nut butter were used as controls and instrumental readings were replicated.

Peanut Soy Spread Preparation

Shelled, runner peanuts were medium roasted at 165°C for 15 minutes. Peanuts were provided by Tara Foods, Albany, GA (1999 crop) and stored at -12°C until processed. The soy peanut spread was prepared in batches of 300 g according to the appropriate formulation (Table 2.1). Each batch of peanuts was heated in an oven for twenty minutes at 75°C. The whole peanut kernels were then ground using a model "B" Olde Style food product peanut butter grinder (East Longmeadow, MA). The following ingredients were added to the ground peanuts by weight according to the appropriate formulation (Table 2.1): isolated soy protein containing 87.1% soy protein and 2 mg of isoflavones/g of protein (Supro 661, Protein Technologies International, St. Louis, MO), fine salt (Astor Plain Salt, Jacksonville, FL), stabilizer (fully hydrogenated

Table 2.1. Peanut soy spread formulations

Formulation Number*	Stabilizer (%)	Oil (%)	Isolated Soy Protein** (%)	Peanuts (%)
1	0.5	1	7	82.7
2	0.5	1	15	72.9
3	0.5	1	23	63.7
4	0.5	4	7	79.1
5	0.5	4	15	69.9
6	0.5	4	23	60.7
7	0.5	7	7	76.1
8	0.5	7	15	66.9
9	0.5	7	23	57.7
10	2	1	7	80.6
11	2	1	15	71.4
12	2	1	23	62.2
13	2	4	7	77.6
14	2	4	15	68.4
15	2	4	23	59.2
16	2	7	7	74.6
17	2	7	15	65.9
18	2	7	23	56.2
19	3.5	1	7	79.1
20	3.5	1	15	69.9
21	3.5	1	23	60.7
22	3.5	4	7	76.1
23	3.5	4	15	66.9
24	3.5	4	23	57.8
25	3.5	7	7	73.1
26	3.5	7	15	63.9
27	3.5	7	23	54.7

*Sugar and salt contents remained constant for all formulations at 7.2 and 1.2 percent, respectively

**Based on 100% isolated soy protein

blend of rapeseed and cottonseed oils, melting point=65.5°C, Fix-X, Proctor & Gamble, Cincinnati, OH), peanut oil (Lou Ana 100% peanut oil, Ventura Foods Opelousas, LA) and powdered sugar (Domino® 10x, New York, NY). All of the ingredients were manually stirred into the ground peanuts and then ground through a colloid mill (Morehouse Industries, Los Angeles, CA) set at a stone clearance of 0.13 mm (5 notches) and maintained at 54° C with hot water. Each peanut soy spread batch was filled into 150x15 mm petri dishes and the surface layer of the peanut soy spread was scraped off to yield a smooth surface layer equal to the height of the side of the petri dish. The peanut soy spreads were stored at ambient temperature (approximately 23°C) for 24 hours, which then instrumental measurements were taken. For each formulation, duplicate measurements were obtained from two petri dishes (one measurement per dish).

Texture Analyser

A Texture Analyser® (TA-XT2 Texture Analyser, Texture Technologies Corporation, Scarsdale, NY) fitted with a 50 kg capacity load cell located at the United States Department of Agriculture Richard Russell Research Center laboratory, (Athens, GA) was used to measure hardness, cohesiveness, adhesiveness and gumminess of each spread. Parameters for the instrument were established according to a modified Instron procedure by Ahmed and Ali (1986). The instrument is capable of performing TPA and obtains all of the calculated values (hardness-force (kg) and areas under the curve) directly by means of its software (Texture Expert for Windows, Version 1.22). Peanut soy samples, which were stored in the plastic petri dishes (150x15 mm) remained undisturbed for at least one hour prior to taking the readings in order to prevent any shear effects that may have been produced during preparation of the samples. A 5 cm in diameter flat-surfaced stainless steel punch probe was fitted into a crosshead which moved at a speed of 0.5 mm/s. The samples were placed on top of the load cell and were manually held throughout testing in order to prevent samples from moving during penetration and withdrawal of the probe. The crosshead moved downward and penetrated the samples at a distance of 4.0 mm. Once this penetration was reached, the crosshead direction was reversed until the point where the probe initially contacted the sample. The probe then traveled down again 4.0 mm then reversed its direction and returned to the starting position. Force time curves during penetration into the sample and withdrawal from the sample were recorded. Based on the areas of the force deformation curves, hardness (kg), adhesiveness, cohesiveness and gumminess were calculated (refer to Figure 1.1, Literature Review). Hardness was determined by the maximum load (kg) applied to the samples during the first compression. Cohesiveness was determined by the ratio of the area under the curve for the second compression to the area under the curve for the first compression (Area2/Area1). Adhesiveness was determined by the area under the curve (Area 3), which represented the work needed to remove the probe from the samples. Gumminess was determined by multiplying hardness with cohesiveness (Friedman et al., 1963).

Statistical Analysis

Statistical software (SAS Institute Inc. Cary, NC) was used to analyze data. Analysis of Variance (PROC GLM) was used to fit a quadratic response surface with the factors, oil, stabilizer and isolated soy protein. Predicted values were obtained within the range of the factors. A combination of treatments was selected which met the optimal criteria established for all four textural attributes (hardness, adhesiveness, cohesiveness and gumminess). PROC GLM was used to determine significant effects of the treatments, oil, stabilizer and isolated soy protein on all four textural attributes. The coefficient of determination, R^2 was determined using regression (PROC RSQUARE) analysis.

RESULTS

The averages of three readings for commercial peanut butter and commercial soy nut butter were considered as optimal ranges of the four textural attributes studied for each formulation (Table 2.2).

Table 2.2. Average readings* from the Texture Analyser®

	Hardness (kg)	Adhesiveness (unitless)	Cohesiveness (unitless)	Gumminess (unitless)
Commercial Peanut Butter	0.98 ± 0.25	-2.0 ± 0.20	0.71 ± 0.16	0.69 ± 0.01
Commercial Soy Nut Butter	0.52 ± 0.26	-0.78 ± 0.27	0.60 ± 0.28	0.30 ± 0.05

* Average of three readings
** SD (95% CI)

From observed values of textural attributes, a matrix of three factors (oil, stabilizer and isolated soy protein) with their three various levels was designed in order to study the four textural attributes. The matrix identified formulations that fell within the optimal ranges. With the attribute hardness for each formulation obtained from Texture Analyser® (Figures 2.1 through 2.3), the statistical model explained 87% of the variation. There was a significant interaction between stabilizer and isolated soy protein (p value = 0.04 at α = 0.05) indicating that this interaction significantly affected the level of hardness of the peanut soy spread. Figures 2.1-2.3 demonstrate this interaction at each

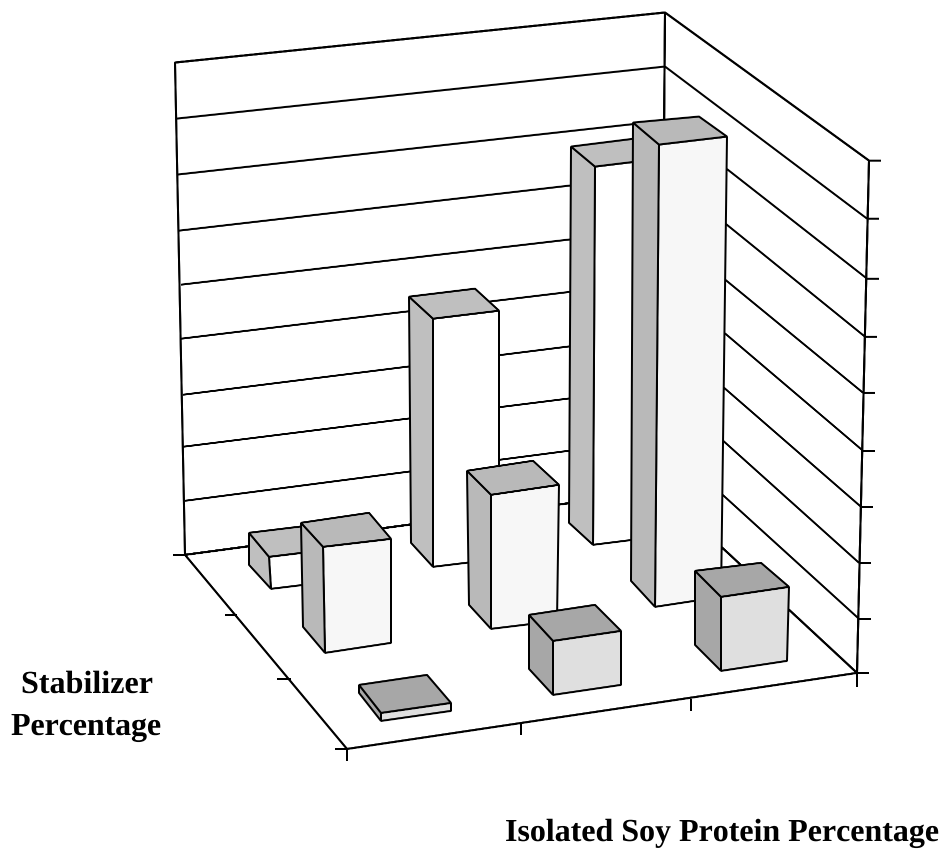

Figure 2.1. Hardness (kg) at 1.0% oil

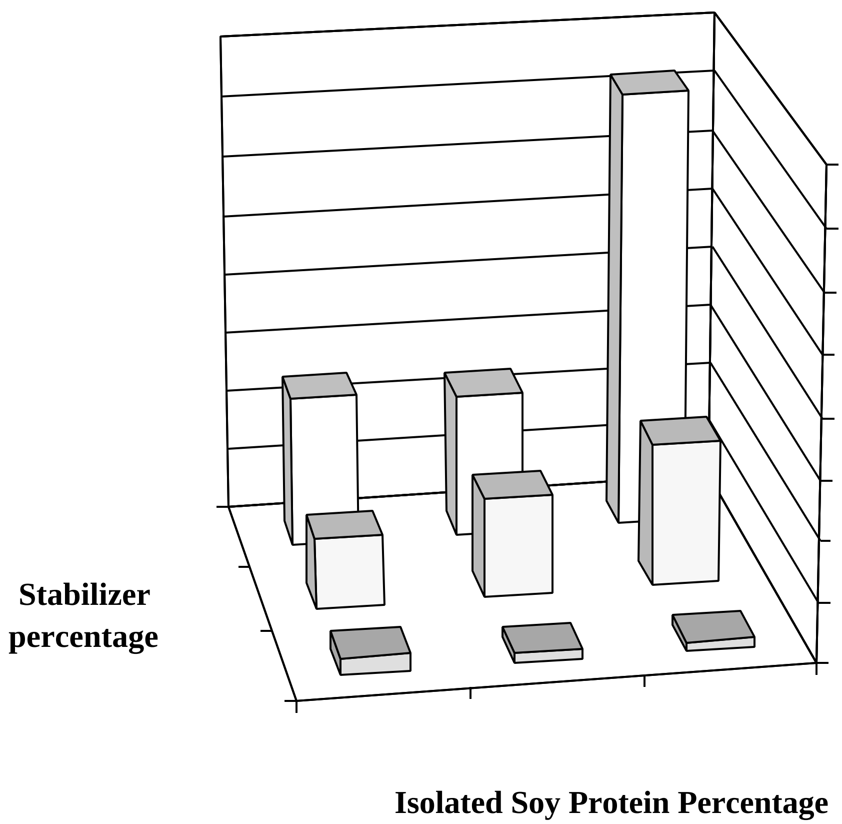

Figure 2.2. Hardness (kg) at 4.0% oil

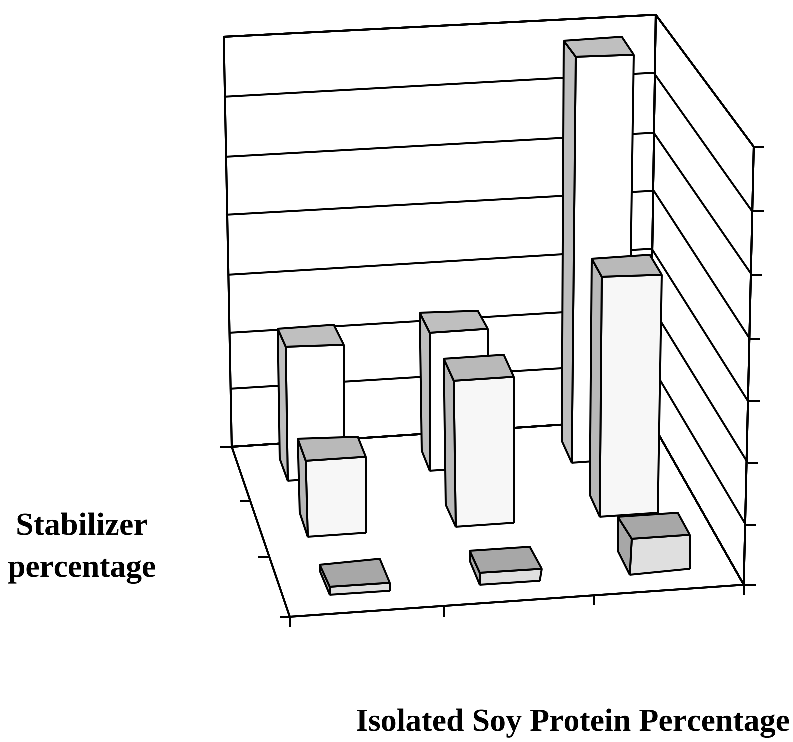

Figure 2.3. Hardness (kg) at 7.0% oil

level of oil. As the levels of stabilizer and isolated soy protein increased, the level of hardness also increased. The formulation with 1% oil, 2% stabilizer and 23% isolated soy protein yielded the largest observed value for hardness (41.7). The formulation with 7% oil, 0.5% stabilizer and 7% isolated soy protein yielded the smallest observed value for hardness (0.6). The observed formulations that were in the optimal range for hardness were numbers 1, 5, 6, 7 and 8 (Table 2.1).

Figures 2.4 through 2.6 depict the observed Texture Analyser® readings for adhesiveness for each of the formulations. Those readings with the largest negative numerical value exhibit the greatest adhesiveness. The statistical model explained 55.5% of the variation for adhesiveness. No significant differences or interactions were noted ($p > 0.05$ at $\alpha = 0.05$). Any specific pattern in adhesiveness values of the peanut soy spreads was not observed (Figures 2.4-2.6). The sample with the greatest adhesiveness (-8.9) for all formulations contained 4% oil, 3.5% stabilizer and 7% isolated soy protein. The least adhesive (-0.6) formulation contained 1% oil, 2% stabilizer and 23% isolated soy protein. Those formulations that were in the optimal range for adhesiveness were numbers 1, 4, 5, 6, 7, 8, 18, 22, 24 and 27 (Table 2.1).

The observed Texture Analyser® readings for cohesiveness for each of the formulations are given in Figures 2.7-2.9. The statistical model explained 60.4% of the variation for cohesiveness. There were no significant interactions or differences ($p > 0.05$). The data indicates inconsistent patterns at the various levels of oil, stabilizer and isolated soy protein for cohesiveness. It was observed that the formulation containing 1% oil, 0.5% stabilizer and 7% isolated soy protein yielded the most cohesive spread (0.66). The least cohesive spread contained 3.5% stabilizer, 7% oil and 15% isolated soy protein

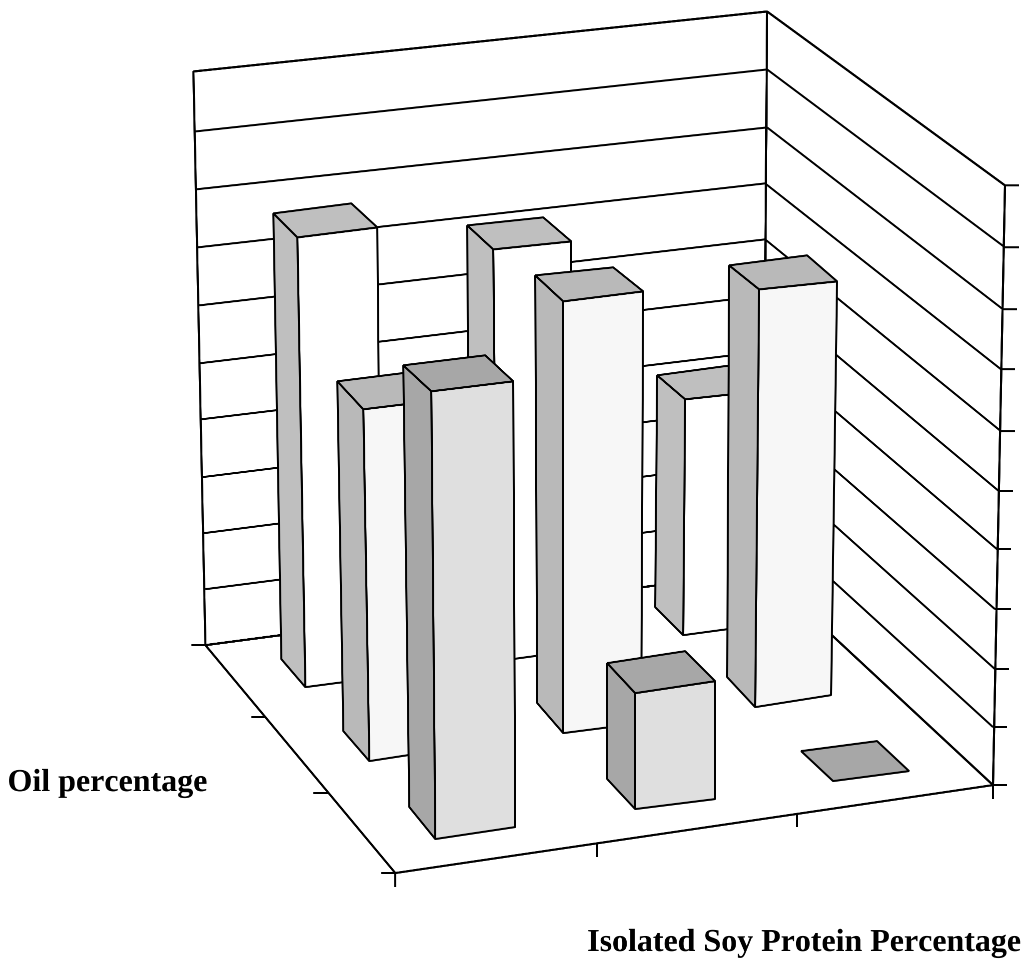

Figure 2.4. Adhesiveness at 0.5% stabilizer

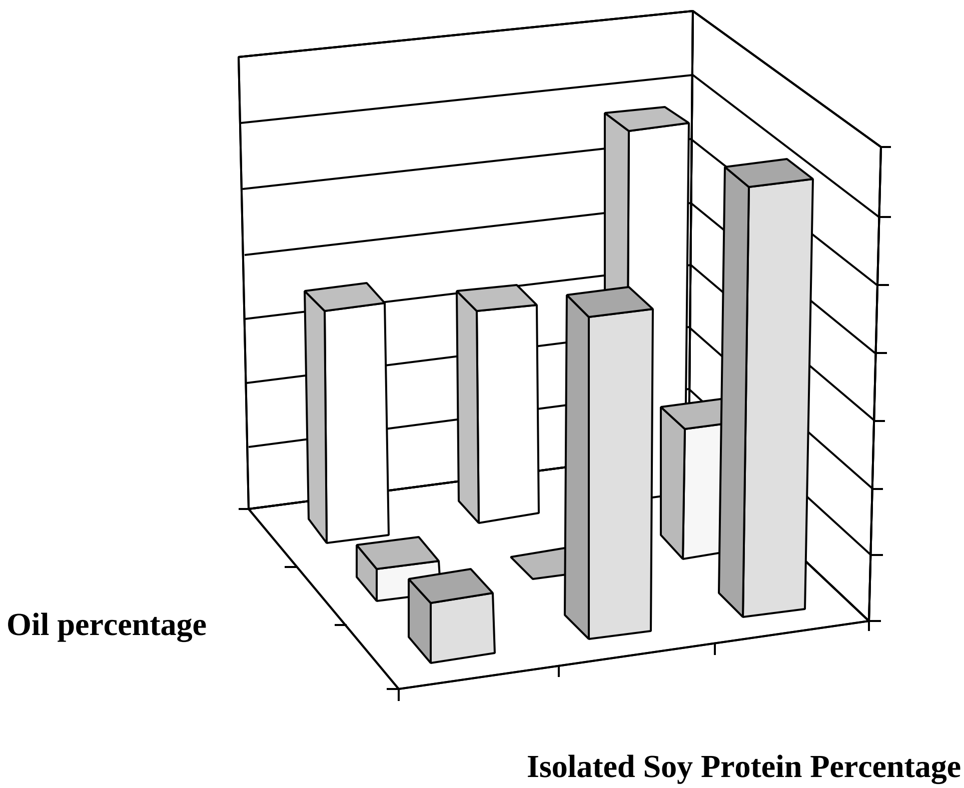

Figure 2.5. Adhesiveness at 2.0% stabilizer

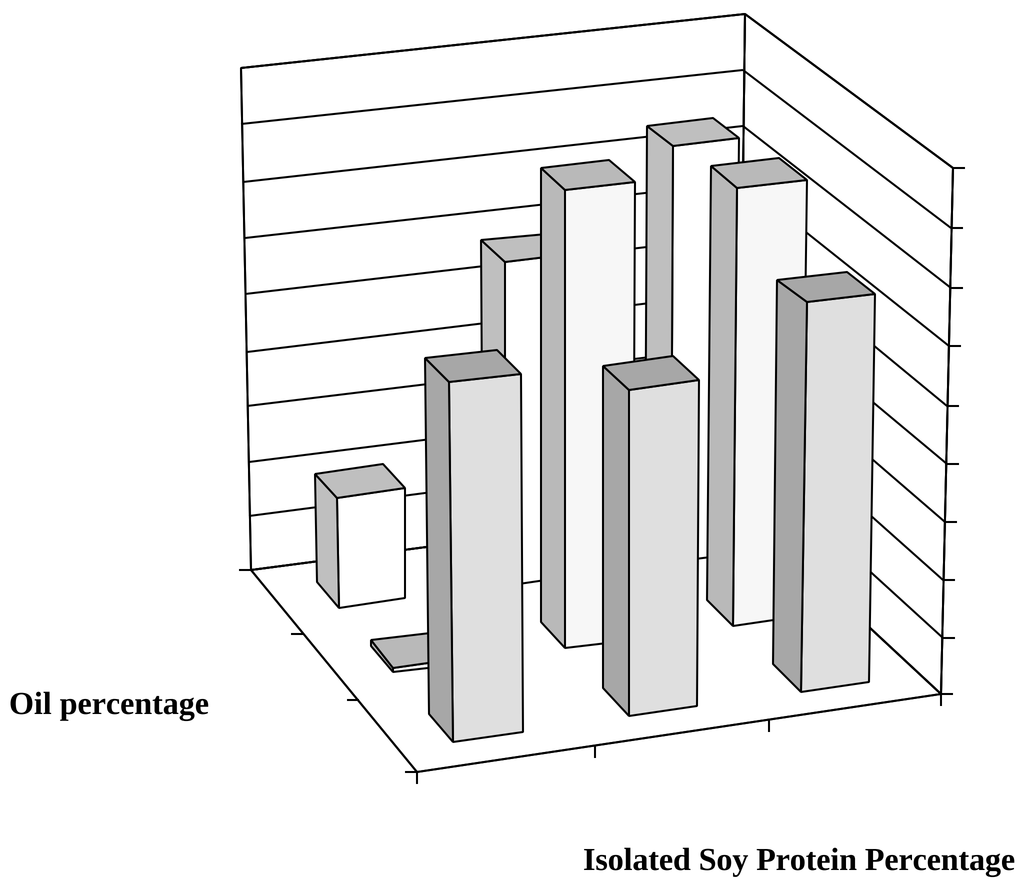

Figure 2.6. Adhesiveness at 3.5% stabilizer

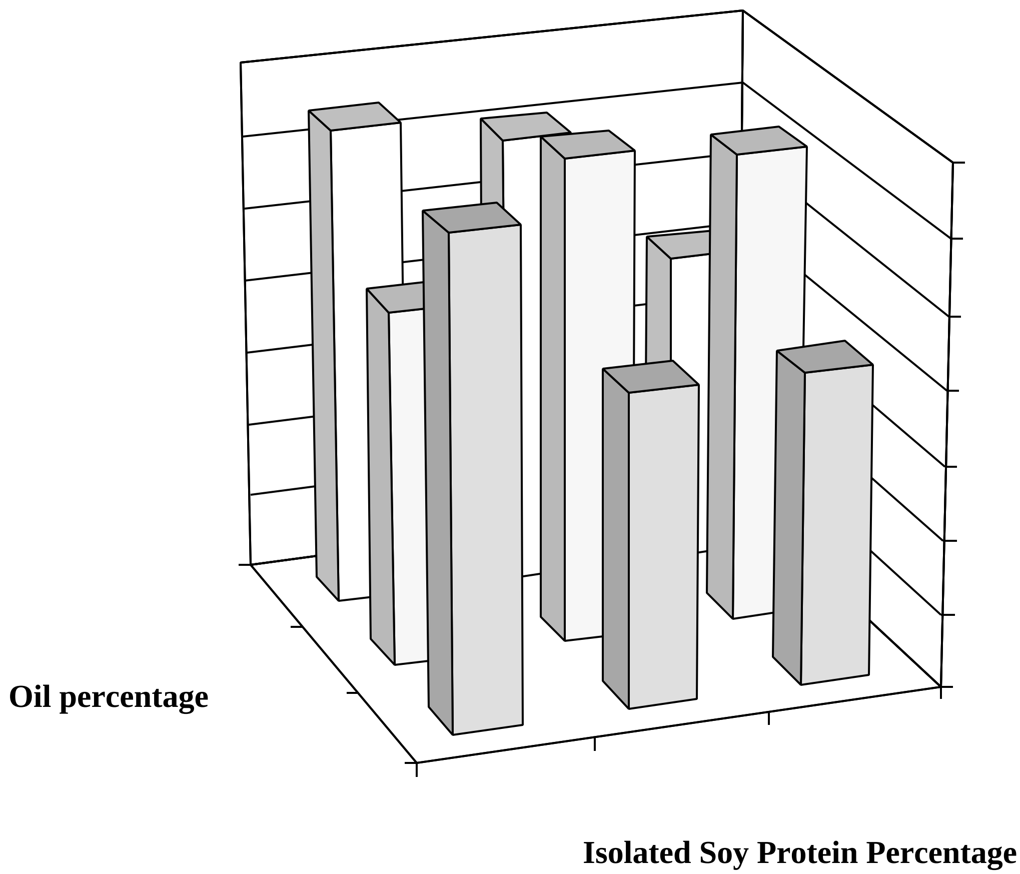

Figure 2.7. Cohesiveness at 0.5% stabilizer

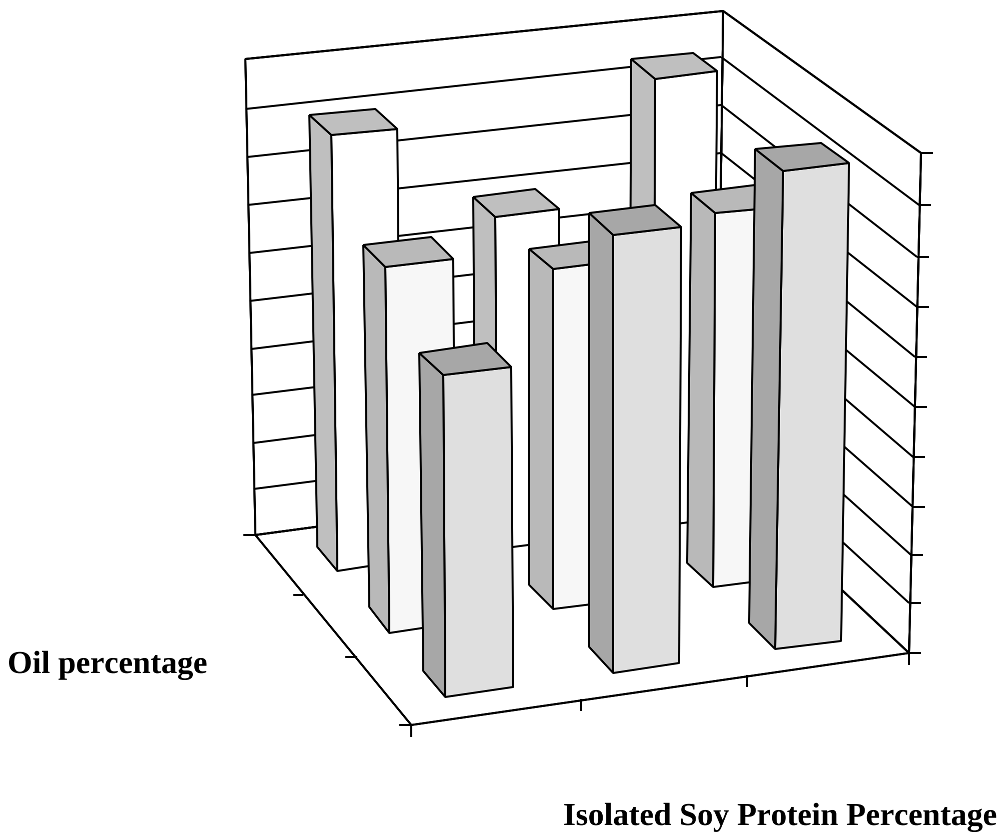

Figure 2.8. Cohesiveness at 2.0% stabilizer

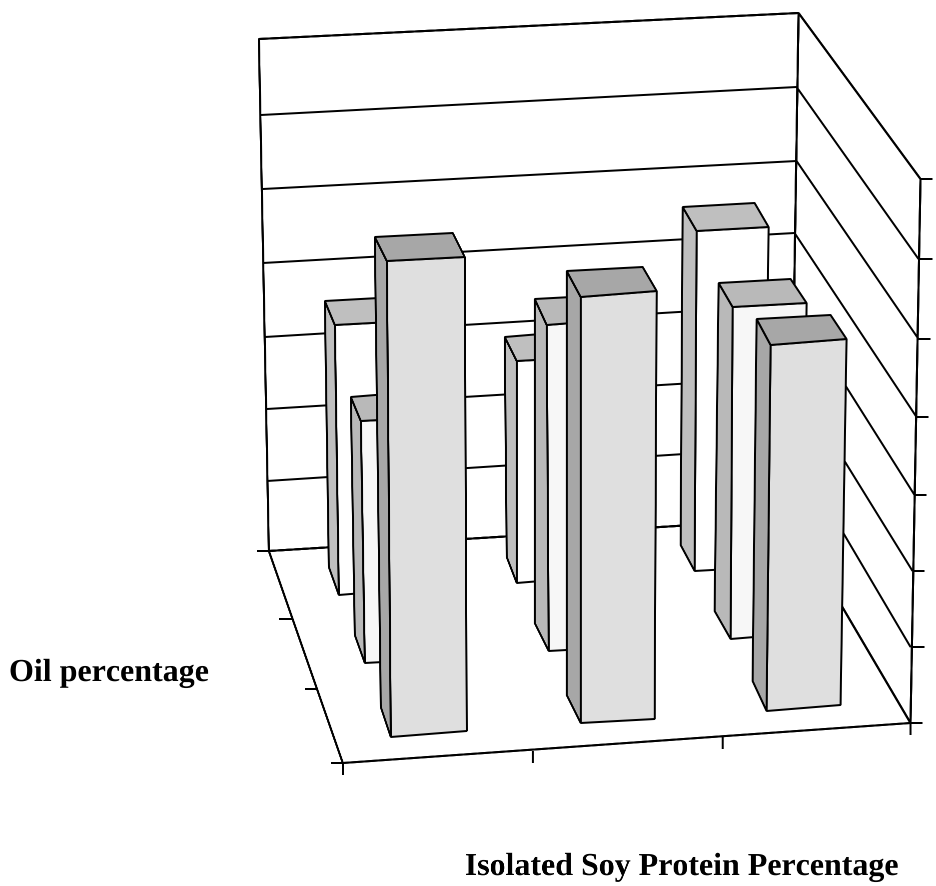

Figure 2.9. Cohesiveness at 3.5% stabilizer

(0.31). Those formulations that were in the optimal range for cohesiveness were numbers 1, 5, 6, 7, 8 and 19 (Table 2.1).

The observed Texture Analyser® readings for gumminess for each of the formulations are shown in Figures 2.10-2.12. The statistical model explained 85.3% of the variability for gumminess. Interaction between stabilizer and isolated soy protein was significant ($p < 0.05$) indicates that their levels in the peanut soy spreads significantly affected the level of gumminess of the spreads. Similar to hardness, as the levels of stabilizer and isolated soy protein increased, the level of gumminess increased. The formulation that had the greatest gumminess (20.1) contained 1% oil, 2% stabilizer and 23% isolated soy protein. The formulation containing 7% oil, 0.5% stabilizer and 7% isolated soy protein was the least gummy (0.4) peanut soy spreads. Those formulations that were in the optimal range for gumminess were 1, 5, 6, 7 and 8 (Table 2.1).

According to the observed values from the Texture Analyser®, these five formulations (1, 5, 6, 7 and 8) were in the optimal range for all four textural attributes studied. Within these formulations, the percentage of oil and isolated soy protein varied but the percentage of stabilizer remained the same at 0.5%. According to the predicted values, four formulations were selected that met the optimal ranges established for all four textural attributes (Table 2.3). These formulations predicted the optimal combination of ingredients for the peanut soy spread between a range of 6-7% for oil, 0.5-0.7% for stabilizer and 8-20% for isolated soy protein.

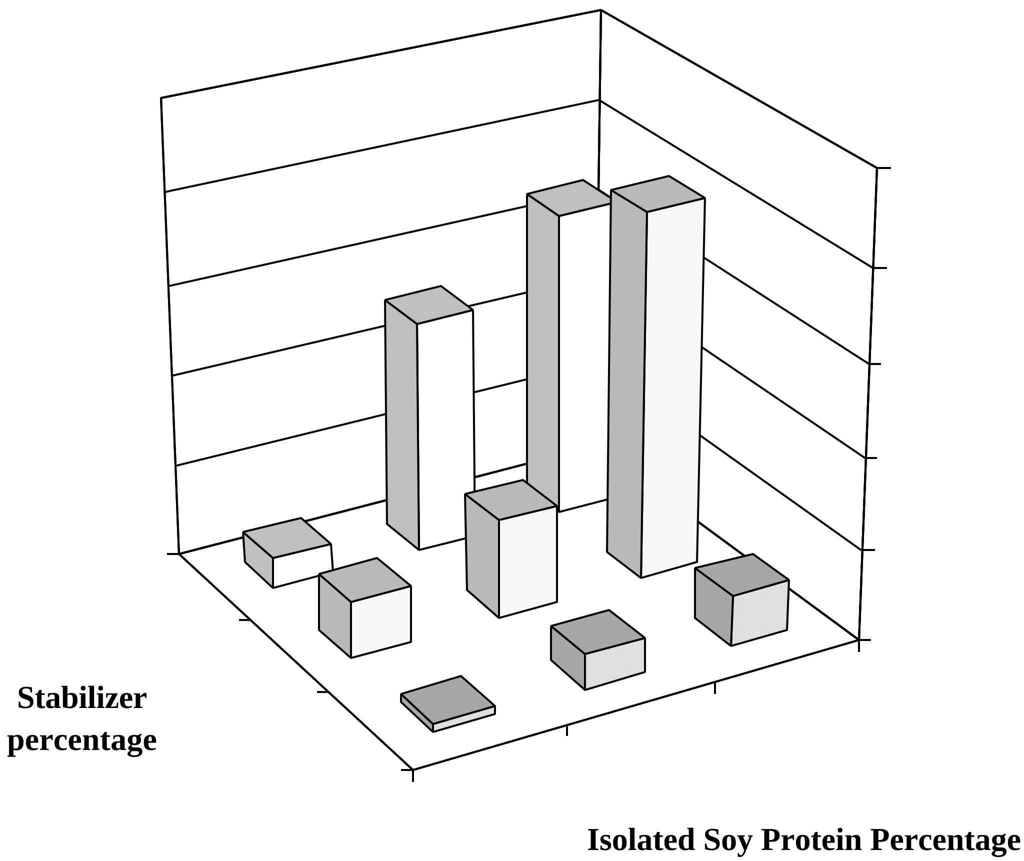

Figure 2.10. Gumminess at 1.0% oil

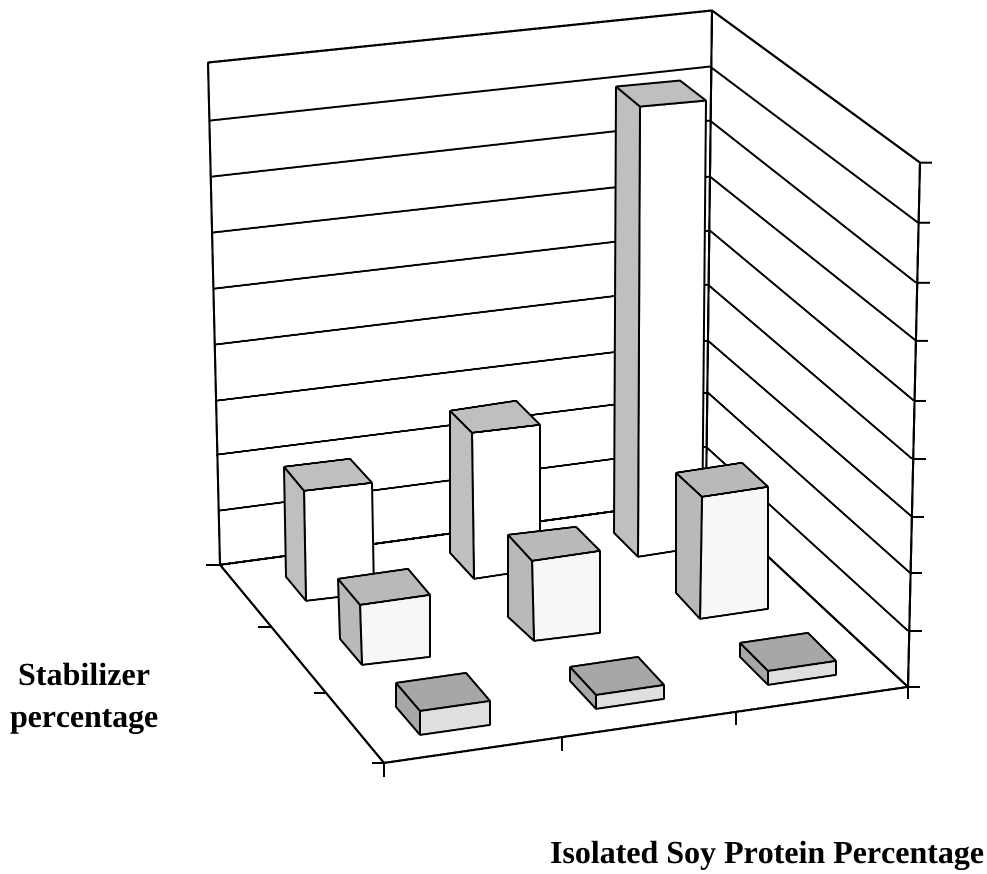

Figure 2.11. Gumminess at 4.0% oil

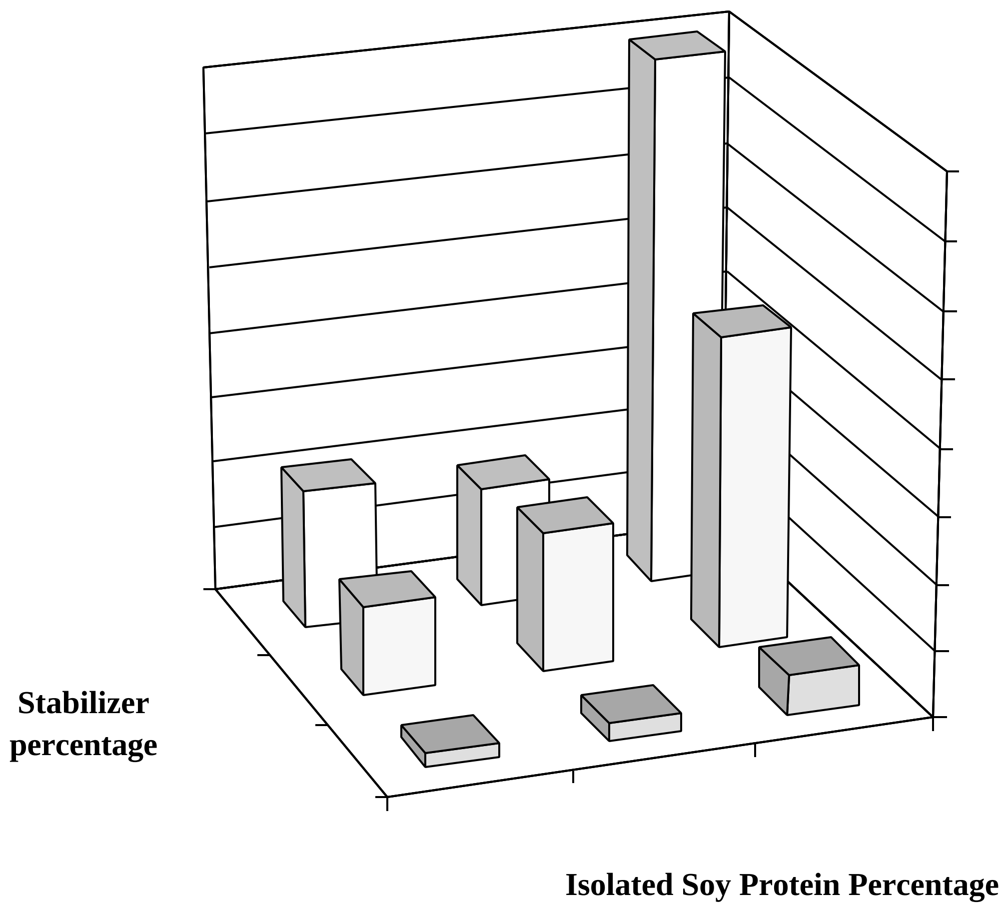

Figure 2.12. Gumminess at 7.0% oil

Table 2.3. Predicted formulations and Texture Analyser® readings that met the optimal conditions established

Oil (%)	Stabilizer (%)	Isolated Soy Protein (%)	Predicted Hardness (kg)	Predicted Adhesiveness (unitless)	Predicted Cohesiveness (unitless)	Predicted Gumminess (unitless)
6	0.5	8	0.667	-1.48	0.654	0.545
6	0.7	10	0.722	-2.07	0.591	0.317
7	0.7	14	0.611	-1.34	0.576	0.471
7	0.7	20	0.845	-1.57	0.537	0.479

DISCUSSION

To the best of our knowledge, this is the first report concerning the interaction of isolated soy protein and stabilizer and its affects on the textural properties of peanut butter/spread. As the amounts of stabilizer and isolated soy protein increased, hardness and gumminess levels also increased. However at the lower level of stabilizer, the optimal conditions for hardness and gumminess were satisfied regardless of the level of isolated soy protein.

The effect of the low level of stabilizer can possibly be explained by the presence of the soy protein. Shelf -life studies on the formulated spreads could further validate this hypothesis. Soy protein can act as an emulsifier but generally is not selected as such in peanut butter/spreads. It is difficult at the interface of an emulsion for the rigid, globular soy protein to undergo extensive conformational changes. Also it is difficult for isolated soy protein to act as an emulsifier due to its low solubility (Fennema, 1996). However the isolated soy protein used for the peanut soy spread contained less than 2% lecithin, which possibly acted as an emulsifying agent, thus lowering the overall amount needed for additional emulsifier.

Tanaka (1975) discovered using the Texturometer that the level of hardness and gumminess for tofu was affected by the presence of soy protein. The primary protein components of soy are 7S and 11S storage proteins with the concentration of these fractions varying. The main difference between these two fractions is the SH group activity. The physical properties that soy protein provides are determined by the balance among the interactions of the 7S and 11S fractions (Tanaka, 1975). In regards to this study, it is possible that different components and levels of stabilizer are interacting with specific fractions of soy protein, which in turn affects texture. Further research would elucidate this hypothesis.

SUMMARY AND CONCLUSION

A factorial design was used to develop peanut soy spreads and the Texture Analyser® measured four textural attributes. Hardness and gumminess were influenced by the interaction of isolated soy protein and stabilizer. However, there were no significant interactions or differences in adhesiveness or cohesiveness among the peanut soy spreads. Based on the instrumental analysis results and predicted values, the optimal combination of ingredients for a peanut soy spread should be between 4-7% oil, 0.5-0.7% stabilizer and 7-20% isolated soy protein in order to match the textural attributes of the commercial products.

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CHAPTER III

CONSUMER ACCEPTABILITY, SENSORY AND INSTRUMENTAL ANALYSIS OF PEANUT SOY SPREADS[1]

[1]Dubost, N.J., Shewfelt, R.L., Eitenmiler, R. R. 2001. To be submitted to *Journal of Food Quality*[1].

ABSTRACT

Textural properties of commercial peanut butter (CPB), commercial soy nut spread (CSN) and three formulated peanut soy spreads with 8, 14, and 20% isolated soy protein (ISP8, ISP14, ISP20) were characterized using the Texture Analyser TA.TX2® (I) and significant differences were found between the textural parameters of the treatments (α = 0.05). Testing of color, aroma and textural attributes by a descriptive analysis panel (D) indicated significant differences existed between the treatments. Based on consumer acceptability testing using a three-point acceptability scale, the commercial peanut butter and all three peanut soy spreads were acceptable products. A mathematical relationship (R^2 = 0.5) existed between the cohesiveness (I) and cohesiveness (D), cohesiveness (I) and adhesiveness (D), gumminess (I) and adhesiveness (D), adhesiveness (I) and adhesiveness (D), aroma (D) and consumer acceptability, and aroma and mouthcoating and superior quality (tastes great). No significant correlations were found between instrumental and consumer acceptability testing.

INTRODUCTION

Evaluating texture parameters by sensory analysis and instrumental measurements is an important step in developing a new product. When attempting to predict consumer response, a correlation is used to analyze the relationship between the sensory and instrumental measurement. No instrument can determine a consumer's response or preference because an instrument can not mimic a human's psychological or sensory response. However instruments have been successful as "predictors" for the acceptance of a product by consumers (Szczensiak, 1987).

Szczesniak (1963a) classified textural attributes into three main categories: mechanical, geometrical and other (fat and moisture). Texture profile analysis (TPA) evaluates the texture of food based on these three categories, the intensity of these characteristics and the sequence of the textural characteristics present. The sequence or order of appearance refers to the three stages first bite (initial phase), masticatory (second phase) and residual (third phase) in which the textural characteristics are perceived. Instrumental Texture Profile Analysis (TPA) is considered an example of Imitative Testing, which generates several instrumental parameters in an attempt to simulate what actually occurs in the mouth of a human (Szczesniak, 1963b). The General Foods Texturometer is an instrument that has been used for TPA on a variety of foods (Breenan et al., 1970; Szczesniak, et al., 1963; Szczesniak and Hall, 1975; Tanaka, 1975).

In connection with instrumental TPA, sensory analysis is also done. Szczesniak (1963a) began work in instrumental and sensory texture profile developing standard rating scales to demonstrate primary mechanical characteristics.

Trained panels can provide qualitative and quantitative information about a product. Consumer testing ultimately determines whether the product is acceptable or unacceptable (Abbott, 1972). The Quality Enhancement (QE) model can be used for consumer testing to determine both external and internal validity of the product. The QE model focuses on quality management to integrate the ideas of consumer driven quality in combination with the technical aspects of product development thus improving the overall success rate of new products. The three point acceptability scale can help determine how the product will perform in the marketplace (Shewfelt et al., 1997; Malundo et al., 1997).

Soy products have rapidly gained popularity in the West during the last few years. One survey revealed that foods enriched with soy protein would be consumed by two out of three Americans, in order to improve overall health. Functional foods have become a means of delivering essential components in a human diet. As the functional food market continues to grow, surveys indicate consumers wish soy to be incorporated into food (Ohr, 2000). An acceptable peanut spread can be produced that contains isolated soy protein to health beneficial levels, which would be significant impact from a functional food standpoint.

The general objective of this study was to better understand the relationship between the levels of isolated soy protein added to peanut spread formulations and several measurable quality characteristics as determined by instrumental analysis, sensory analysis and consumer tests. The specific objectives were (1) to determine the color, aroma and textural characteristics of peanut soy spreads using sensory measurements (experienced panelists and consumer tests) and 2) to establish a relationship between instrumental, sensory and consumer measurements.

MATERIALS AND METHODS

Experimental Design

Peanut soy spreads were prepared using three levels (8, 14, and 20%) by weight of isolated soy protein (ISP) (Supro 661, Protein Technologies International, St. Louis, MO). Commercial peanut butter (CPB) and commercial soy nut butter (CSN) were used as controls. Treatments included peanut soy spreads containing 8, 14 and 20% isolated soy protein (ISP8, ISP14 and ISP20, respectively), commercial peanut butter and commercial soy nut butter. A balanced incomplete block design was used for descriptive and consumer testing (Cochran and Cox, 1957).

Peanut Soy Spread Preparation

Shelled, medium roasted at 165°C for 15 minutes runner type peanuts were provided (1999 crop, Tara Foods, Albany, GA) and stored at –12°C until time of processing. The soy peanut spread was prepared in batches (3.63 kg) according to the appropriate formulation (Table 3.1). Each batch of peanuts was heated in an oven for 20 minutes at 75°C before the initial grind. The whole peanut kernels were then ground in a model "B" Olde Style food product peanut butter grinder (East Longmeadow, MA). The following ingredients were added to the ground peanuts by weight according to the appropriate formulation (Table 3.1): isolated soy protein containing 87.1% soy protein (Supro 661, Protein Technologies International, St. Louis, MO), fine salt (Astor Plain

Table 3.1. Peanut soy spread formulations

Formulation Number	Oil (%)	ISP * (%)	Sugar (%)	Stabilizer (%)	Salt (%)	Peanuts (%)
1	6	9.2	7.2	0.5	1.2	75.9
2	6	16.1	7.2	0.5	1.2	69.0
3	6	23	7.2	0.5	1.2	62.1

* based on 100% soy protein

Salt, Jacksonville, FL), stabilizer (hydrogenated blend of rapeseed and cottonseed oils, melting point = 65.5°C, Fix-X, Proctor & Gamble, Cincinnati, OH), peanut oil (Lou Ana 100% peanut oil, Ventura Foods Opelousas, LA) and powdered sugar (Domino® 10x, New York, NY). All of the ingredients were manually stirred into the ground peanuts and then ground through a colloid mill (Morehouse Industries, Los Angeles, CA) set at a stone clearance of 0.13 mm (5 notches) and maintained at 55°C with hot water. Each peanut soy spread batch was filled into plastic jars, which contained approximately 470 g of spread. The peanut soy spreads were stored at –12°C until needed for the appropriate sensory test.

Texture Analyser

A Texture Analyser® (TA-XT2 Texture Analyser, Texture Technologies Corporation, Scarsdale, NY) located at the United States Department of Agriculture Richard Russell Research laboratory, (Athens, GA) was used to measure hardness (coincides with sensory panel firmness), cohesiveness, adhesiveness and gumminess of each spread. According to a modified Instron procedure by Ahmed and Ali (1986), the following parameters for the instrument were established. A 5 cm diameter flat-surfaced stainless steel probe fitted into a crosshead moved at a speed of 0.5 mm/s and penetrated the samples 4.0 mm. The instrument performed a modified version of TPA and obtained all of the calculated values (hardness-force (kg) and areas under the curve) directly by means of its software (Texture Expert for Windows, Version 1.22).

Based on the areas of the force time curves, hardness (kg), adhesiveness, cohesiveness and gumminess were calculated. During the first compression, the maximum load (kg) applied to the peanut spread samples determined the textural attribute hardness. Cohesiveness was determined by the ratio of the area under the curve for the second compression to the area under the curve for the first compression (Area2/Area1). Adhesiveness was determined as the work needed to remove the probe from the samples, represented by the area under the curve (Area 3). Gumminess was determined by multiplying hardness with cohesiveness (Friedman et al., 1963).

Sensory Methods

Descriptive analysis panels. Ten trained panelists evaluated a total of five samples, in a total of three test sessions over a two-day period. A combination of Spectrum, Quantitative Descriptive Analysis (QDA) and TPA techniques was used for evaluating the samples. Descriptive panel members were recruited from a group of previously trained members who had participated in sensory tests at the University of Georgia, Athens, GA. Criteria for selection included no dentures (Civille and Szczesniak, 1973) no known food allergies, especially to peanuts and regular consumers of peanut butter (at least once a month). Six men and four women, all between the ages of 22-47 met the criteria and agreed to be panelists.

Panelists were trained on TPA techniques (Civille and Szczesniak, 1973) in three training sessions for 1.5 hours each day for a total of 4.5 hours. In the first training session, panelists were given a review of sensory analysis and the basic solutions. To save time in training, panelists were provided with a list of color, aroma (Johnsen et al., 1988) and textural (Civille and Szczesniak, 1973; Meilgaard et al., 1991) terms and definitions previously used to describe peanut butter (Table 3.2). Panelists discussed the attributes and felt that it was comprehensive and well understood. After discussing the lexicon as a whole, each term was reintroduced and thoroughly discussed and reference standards were introduced (Table 3.3). The selected reference standards helped the panel describe the color, aroma and textural terms, for example, using flashcards panelists rated the intensity of the attribute color by first evaluating the references selected and then selecting an intensity rating between 0 and 150. The average was calculated for that intensity rating and used as the attribute intensity rating for color. Each reference standard used for the flavor and texture attributes has a published intensity rating (Johnsen et al., 1988; Meilgaard et al., 1991; Munoz, 1986; Szcesniak et al., 1963)

For the second day of training, the descriptors, definitions and reference standards were again discussed. The procedure for testing and order in which the descriptors would appear were discussed (Szcesnaik et al., 1963). Various peanut butters were provided for testing and each attribute was rated accordingly. The panelists were instructed to mark their ballot sheet according to each attribute listed. The ballot sheets consisted of a 150 mm unstructured line scale with anchors at the 12.5 and 137.5 mm points.

Seven attributes were listed vertically in order of their appearance. After the panelist had marked their ballot sheet, they were instructed to indicate their ratings collectively as a group using their flashcards. Calibration of the panelists was obtained by averaging the ratings that were indicated on their flashcards. If panelists were not within

Table 3.2. Terms and definitions used for descriptive analysis*

Appearance	
Brown Color	The intensity or strength of the color
Aromatics	
Roasted Peanut	The aromatic associated with roasted peanuts
Texture	
<u>First Compression</u>	
Firmness	Force required to compress the sample between tongue and palate
Cohesiveness	Degree to which a substance deforms rather than shears/cuts
Adhesiveness	Force required to remove the sample from roof of mouth
<u>Breakdown</u>	
Gumminess	Energy required to disintegrate the sample to a state ready for swallowing
<u>Residual</u>	
Mouthcoating	Amount of particles left on mouth surface, degree of coating perceived in the mouth

*Civille and Szczesniak, 1973; Meilgaard et al., 1991

Table 3.3. References and intensities used in descriptive analysis of peanut butter

Attribute	Reference	Intensity[1] (mm)
Brown color	Planters Unsalted Peanuts (Nabisco, East Hanover, NJ)	30
	Brach's Milkmaid Caramels (Brach&Brock Confections, Chicago, IL)	70
Roasted Peanut	Planters Medium Roasted Unsalted Peanuts[2] (Nabisco, East Hanover, NJ)	65
Firmness	Kraft Miracle Whip[3] (Glenview, IL)	50
	Kraft Cheez Whiz[3] (Glenview, IL)	80
	Kraft Philadelphia Light Cream Cheese[3] (Glenview, IL)	140
Cohesiveness	Kraft Jello Instant Vanilla Pudding[3] (Rye Brook, NY)	50
	Hunts Tapioca Pudding[3] (Conagra Grocery Products Co., Fulllerton, CA)	110
Adhesiveness	Kraft Philly Cream Cheese[4] (Glenview, IL)	80
	Skippy Creamy Peanut Butter[4] (Best Foods, Englewood Cliffs, NJ)	120
Gumminess	Flour Paste 45%[5] Gold Medal All Purpose Flour (General Mills, Minneapolis, MN)	60
	Flour Paste 55%[5] Gold Medal All Purpose Flour (General Mills, Minneapolis, MN)	120
Mouthcoating	Cooked 100% Corn Starch[3] (Kroger, Cincinnati, OH)	30

[1]rated on 150 mm line scale with anchors at 12.5 mm and 137.5 mm.
[2]Johnsen et al., 1988
[3]Meilgaard et al., 1992
[4]Munoz, 1986
[5]Szczesniak et al., 1963

+/- 10 points of the average, they were asked to re-evaluate the sample. The ratings were adjusted accordingly until a consensus was reached.

On the third and last day of training, descriptors, definitions and procedures for testing were again reviewed. Panelists then practiced evaluating two samples of peanut butter using their ballot sheets. All of the attributes were rated for intensity before a panelist could proceed on to the next test sample. After testing the samples, each panelist's ratings were analyzed for mean ratings and standard deviations. Panelists were made aware of their results. Those panelists that were within +/- 10 points of the mean were considered calibrated. If the whole group was calibrated then the standard deviations for the group was within +/- 10 points from the mean attribute rating. Panelists continued to calibrate themselves on each attribute for the remaining of the session.

Consumer panels. A consumer test using a 3 point acceptability scale (3= tastes great, 2= acceptable, 1=unacceptable) taken from the Quality Enhancement model (Malundo, 1996; Shewfelt et al., 1997) was conducted at the University of Georgia, Athens, GA using 100 panelists. Consumers consisted of students, faculty and university staff between the ages 18-54, had no allergies especially to peanuts and ate peanut butter at least once per month.

Testing

All tests were conducted at the sensory laboratory located in the Food Processing and Research Development Laboratory at the University of Georgia, Athens, GA. All testing was conducted at partitioned booths.

Descriptive analysis. Approximately one hour before each test, 28 g of CPB, CSN, 8ISP, 14ISP and 20 ISP spreads were placed in 28.6 g (1 oz.) plastic sample cups with lids and given a three digit randomized code number. Samples were distributed at room temperature. Three samples were evaluated per panelist at each test session for a total of three test sessions over a two-day period. Every panelist evaluated a total of nine samples. Each peanut butter and peanut soy spread was evaluated a total of 18 times. When evaluating the textural attributes, panelists were instructed to use 1/4 teaspoon of sample for hardness, cohesiveness and adhesiveness (Meilgaard et al., 1991) and 1/2 teaspoon for gumminess. Panelists were instructed to expectorate and rinse their mouths with water between each attribute. Unsalted crackers were also provided for panelists to cleanse their palate. A definition of attribute sheet was posted in each booth (Table 3.2). Scoresheets were provided to panelists that identified the attribute to be tested, the order in which to test and the intensity rating for each reference (Table 3.4).

Consumer test. There was one day of testing, which was conducted between 9:00 am and 2:00 pm. One hundred consumers were recruited to sample three out of the five treatments including, CPB, CSN, 8ISP, 14ISP and/or 20ISP spreads. Ten consumers was the maximum number taken at any one time. Peanut butter and peanut soy spread samples weighing approximately ten g were placed in 28.6 g (1 oz.) cups with lids. The cups were coded with a three digit random number and presented to panelists in random order. Every consumer was presented a testing ballot and three treatments. Consumers were given instructions for testing. Each peanut butter, soy nut butter and peanut soy

Table 3.4. Scoresheet for Peanut Soy Spread

Place a vertical mark through the line scale to indicate the intensity of each attribute (the scale is from 0 to 150).

Appearance

Brown Color peanuts(30) caramel(70)
______|______________|_______________|______________________________|______

Aromatics

Roasted Peanut peanuts(65)
______|_________________________|____________________________________|______

Texture

First Compression

Firmness miracle whip(50) cheeze whiz(80) cream cheese(140)
______|____________________|_______________|______________________________||_____

Cohesiveness vanilla pudding(50) tapioca pudding(110)

______|____________________|_________________________|____________________|_____

Adhesiveness cream cheese(80) peanut butter(120)
______|__________________________|______________________|_________________|_____

Breakdown

Gumminess flour paste(60) flour paste(120)
_______|_______________________|_________________________|_________________|_____

Residual

Mouthcoating cornstarch(30)
_______|_______________|____|____

spread was evaluated on a three point acceptability scale (Table 3.5). Consumer demographics collected in the questionnaire were: their texture preference, smooth or crunchy, what brand of peanut butter they currently purchase, gender and age. Each peanut butter and peanut soy spread was evaluated a total of sixty times.

Statistical Analysis

Statistical software (SAS Institute Inc., Cary, NC) was utilized to analyze the data. Means (PROC MEANS) were calculated for descriptive analysis and instrumental data. Stepwise regression (PROC REG) was utilized to remove any insignificant variables greater than the 0.100 level for all sensory descriptors. Pearson correlation coefficients (PROC CORR) were calculated to determine if statistical relationships existed between instrumental and descriptive analysis, instrumental and consumer and consumer and descriptive analysis results. Duncan's multiple range test (PROC GLM) was used to determine if significant differences existed between mean scores of sensory descriptors for each treatment ($\alpha = 0.05$).

Table 3.5. Consumer scoresheet

Panelist #_____________ Date:________________

Thank you for participating in peanut butter tasting today. You will be presented with three peanut butter samples labeled with 3-digit code numbers. Taste each one of the peanut butter samples individually and answer the questionnaire below. Make sure you write the 3-digit code number and check the appropriate space for each peanut butter sample evaluated. Please do not compare the peanut butter samples with each other- judge each by itself.

Peanut butter code	______	**Peanut butter code**	______	**Peanut butter code**	______
Tastes great	______	**Tastes great**	______	**Tastes great**	______
Acceptable	______	**Acceptable**	______	**Acceptable**	______
Unacceptable	______	**Unacceptable**	______	**Unacceptable**	______

Check the statement that best describes how you like your peanut butter

_____ smooth

_____ crunchy

Please indicate what brand of peanut butter that you purchase?

____

Please circle the age group you are in:

18 and under 19-24 25-34 35-44 45-54 55 and above

Please circle your gender

Male or Female

RESULTS AND DISCUSSION

Sensory Evaluation

Based on the results reported by the descriptive panel, Table 3.6 lists the means of the descriptors used for sensory testing of CPB, CSN, 8ISP, 14ISP and 20ISP spreads. Table 3.6 also indicates if significant differences ($\alpha = 0.05$) existed between treatments for each attribute. CSN showed the greatest average intensity rating for color, indicating it was the darkest colored treatment. This product contains primarily soybeans, which yields a darker color versus a product made with peanuts such as CPB. It was significantly different in color from all other treatments. CPB, 8ISP and 14ISP spreads were not significantly different in color. The spread 20ISP received the lowest average intensity rating for color and was significantly different from 8ISP and CSN.

With the attribute aroma of roasted peanuts, CPB received the highest average rating. CPB contains at least 90% peanuts so of the treatments it would receive the highest average rating. It was significantly different from all other treatments except for 14ISP spread. The treatment CSN received the lowest average rating for aroma due to the product containing no roasted peanuts. It was significantly different from all treatments except for 20ISP spread, which had the smallest percentage of peanuts among the peanut soy spreads. The spread 8ISP was not significantly different from 14ISP and 20ISP spreads ($p > 0.05$), but 14ISP and 20ISP spreads were significantly different ($p < 0.05$). There may have been some difficulty among the panelists testing the intensity of roasted peanut aroma. Perhaps the reference used for aroma (Planters Medium Roasted Unsalted Peanuts, Nabisco, East Hanover, NJ) was not consistent in intensity among the

Table 3.6. Means of descriptors used for commercial peanut butter/spread and formulated peanut soy spreads using descriptive analysis testing (150mm unstructured scale)

Treatments (n=18)	Color*	Aroma	Firmness	Cohesiveness	Adhesiveness	Gumminess	Mouthcoating
Commercial Peanut Butter	51.4 ^{bc}	56.0 ^{a}	94.7 ^{c}	109 ^{b}	116 ^{c}	80.6 ^{c}	103 ^{c}
Commercial SoyNut Butter	67.9 ^{a}	23.6 ^{d}	111 ^{b}	111 ^{b}	124 ^{bc}	93.3 ^{ab}	123 ^{a}
8ISP	54.2 ^{b}	42.5 ^{bc}	98.6 ^{c}	114 ^{b}	128 ^{ab}	81.9 ^{c}	112 ^{b}
14ISP	51.4 ^{bc}	49.4 ^{ab}	115 ^{b}	115 ^{ab}	127 ^{ab}	91.1 ^{b}	114 ^{b}
20ISP	47.7 ^{c}	35.2 ^{dc}	127 ^{a}	123 ^{a}	134 ^{a}	99.2 ^{a}	123 ^{a}

*Different subscripts show significant differences at $\alpha = 0.05$ within each column.

panelists, and therefore there was discrepancies in completely understanding the definition of roasted peanut aroma.

With the attribute firmness, as the amount of ISP increased in the spreads, the average intensity rating also increased. It appears that the amount of soy protein present in the spread significantly affected the level of firmness. CPB and 8ISP spread had the lowest average intensity rating and was significantly less firmer ($p < 0.05$) than all other spreads. The firmness of CSN and 14ISP spreads was significantly different from the rest of the treatments. 20ISP spread had the greatest average intensity rating for firmness and was significantly firmer ($p < 0.05$) from all other formulated peanut soy spreads, commercial peanut butter and commercial soy nut butter.

With the attribute cohesiveness, there was no clear differentiation among the treatments. 20ISP spread had the greatest average intensity rating and was significantly more cohesive from all treatments except for 14ISP spread. From these results, it appears that the levels 14 and 20 % ISP significantly affected the intensity of cohesiveness. With the attribute adhesiveness, 20ISP spread received the greatest average rating; however, its adhesiveness was not significantly different from 8ISP and 14ISP spreads. It appears that the level of isolated soy protein did not affect the average intensity of adhesiveness. Adhesiveness of CSN was not significantly different from 8ISP and 14ISP spreads. CPB received the lowest average adhesiveness rating and was significantly different from all spreads.

With the attribute gumminess, the average intensity rating increased as the levels of ISP increased. It appears that the level of ISP significantly affected the intensity of gumminess. Gumminess of CSN was not significantly different from 14ISP or 20ISP spreads. CPB received the lowest average gumminess rating and was significantly different from all other treatments except for 8ISP spread.

With the attribute mouthcoating, 20ISP spread and CSN received the greatest average rating, and they had significantly higher mouthcoating means than other treatments. This higher level of ISP resulted in a greater average intensity of mouthcoating. The difference in mouthcoating between 8ISP and 14ISP spreads was statistically insignificant. CPB received the lowest average mouthcoating ($p < 0.05$), meaning that CPB gave less mouthcoating than CSN and formulated peanut soy spreads.

Overall 8ISP spread was not significantly different from CPB in color, firmness, cohesiveness and gumminess. 8ISP spread was not significantly different from CSN in cohesiveness and adhesiveness. 14ISP spread was not significantly different from CPB in color, aroma and cohesiveness. 14ISP spread was not significantly different from CSN in firmness, cohesiveness, adhesiveness and gumminess. 20ISP spread was not significantly different from CPB in color but was significantly different in all other attributes. 20ISP spread was not significantly different from CSN in aroma, gumminess and mouthcoating. 8ISP and 14ISP spreads were not significantly different in five of the seven attributes including, color, aroma, cohesiveness, adhesiveness and mouthcoating. 8ISP and 20ISP spreads were not significantly different in aroma and adhesiveness. 14ISP and 20ISP spreads were not significantly different in color, cohesiveness and adhesiveness. CSN and CPB were not significantly different in cohesiveness and adhesiveness.

Consumer Evaluation

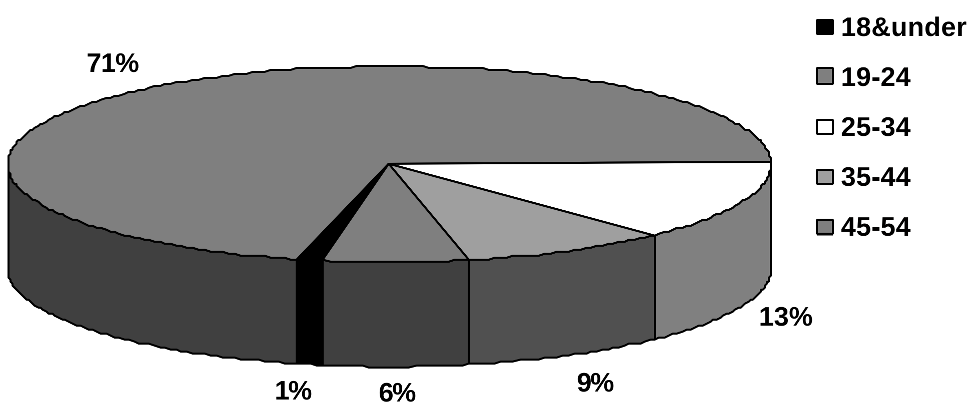
Consumer acceptability is based on the percentage distribution that rated that product as tastes great or acceptable (Shewfelt et al., 1997). Table 3.7 indicates the results of consumer acceptability testing of CPB, CSN and formulated peanut soy spreads. Figure 3.1 depicts demographics of consumers who participated in the consumer acceptability panel for CPB, CSN, 8ISP, 14ISP and 20ISP spreads. The CPB, 8ISP, 14ISP and 20ISP spreads are considered acceptable products (combining tastes great and acceptable percentages), with CPB, 8ISP and 14ISP spreads receiving the highest acceptability 98, 95 and 95%, respectively. Over 50% of the population considered the commercial peanut butter and ISP8 superior quality (tastes great). The CSN is not an acceptable product due to 98% of the testing population considering the product unacceptable. Of the consumers tested, 67% prefer smooth peanut butter, 33% prefer crunchy peanut butter, 55% purchase Jif (Proctor &Gamble, Cincinnati, OH), 12% purchase Peter Pan (Conagra Food Company, Inc., Ivine, CA) and 33% purchase other various brands (Kroger peanut butter, Kroger, Cincinnati, OH), (Skippy Creamy peanut butter, Best Foods, Englewood Cliffs, NJ).

Table 3.7. Consumer acceptability of commercial peanut butter/spread and formulated peanut soy spreads

Treatments*	Tastes Great (%)	Acceptable** (%)
Commercial Peanut Butter	73	98
Commercial Soy Nut	0	2
8ISP	52	95
14ISP	41	95
20ISP	23	68

*N=60 for each treatment
**Total of tastes great and acceptable

Figure 3.1. Demographics of consumers who participated in consumer acceptability panel for commercial peanut butter/spread and formulated peanut soy spreads (Male:Female ratio = 50:50).



Instrument Evaluation

Table 3.8 depicts the average of three readings of the five treatments using the Texture Analyser®. Based on these average readings, with the attributes hardness and adhesiveness, CPB was the hardest and most adhesive ($p < 0.05$). CSN was significantly harder and more adhesive than the formulated peanut soy spreads. The formulated peanut soy spreads were the softest and least adhesive of the treatments, and the difference in hardness and adhesiveness among them was insignificant ($p > 0.05$). These results were not anticipated because the spreads containing higher amounts of isolated soy protein were expected to be harder and more adhesive. The amount of stabilizer added to peanut butter is usually between 1.6 to 2.0% (Weiss, 1970). The hardness readings may have resulted due to the low level of stabilizer (0.5%) present in the peanut soy spreads; thus, allowing more movement and interaction among the ingredients. The addition of oil at 6% may have also yielded a softer spread. Adhesiveness is defined as the work necessary to overcome attractive forces between the surface of the food sample and the surface in which the food sample comes in contact (i.e. tongue, palate) (Szczesniak, 1963a). The amount of work needed to overcome the attractive forces between the spread's surface and probe was smaller in the peanut soy spreads. The levels of oil and stabilizer may also have affected adhesiveness of the spreads.

Table 3.8. Average readings of the five treatments using the Texture Analyser®[*]

Treatments	Hardness[**] (kg)	Adhesiveness (unitless)	Cohesiveness (unitless)	Gumminess (unitless)
Commercial Peanut Butter	0.984 [a]	-2.040 [c]	0.713 [a]	0.695 [a]
Commercial Soy Nut Butter	0.519 [b]	-0.781 [b]	0.598 [ab]	0.298 [b]
8ISP	0.191[c]	-0.312 [a]	0.546 [b]	0.104 [d]
14ISP	0.214 [c]	-0.333 [a]	0.507 [b]	0.109 [d]
20ISP	0.303 [c]	-0.403 [a]	0.459 [b]	0.138 [c]

[*]Average of three readings
[**]Different superscripts within each column show significant differences at $\alpha = 0.05$ within each column.

With the textural parameter cohesiveness, CPB received the greatest average reading. Its cohesiveness was similar to cohesiveness of CSN ($p > 0.05$), but higher ($p < 0.05$) than the formulated peanut soy spreads. Difference in cohesiveness among the three peanut soy spreads was insignificant ($p > 0.05$). Cohesiveness is defined as the strength of the internal bonds within the body of the product (Szczesniak, 1963a). Due to the results it can be stated that the internal bonds of the peanut soy spreads were weaker than CSN and CPB. This too may be a result of the level of ingredients present in the peanut soy spreads.

With the textural parameter gumminess, CPB received the greatest average reading and was significantly more gummy ($p < 0.05$) than all other treatments. CSN had a higher gumminess than the peanut soy spreads ($p < 0.05$). 8ISP and 14ISP spreads gave similar gumminess values ($p > 0.05$). 20ISP spread was significantly more gummy than 8ISP and 14ISP; however, it was less gummy than commercial products.

Gumminess is determined by multiplying hardness with cohesiveness (Friedman et al., 1963). Due to this factor, it is expected that CPB would receive the greatest average gumminess reading based on the results of hardness and cohesiveness. There was a difference seen in gumminess among the peanut soy spreads. 20ISP spread compared with the other two formulated peanut soy spreads yielded a greater average reading due to the fact of the higher amount of isolated soy protein present.

Correlation between instrument and sensory measures

Pearsons correlation coefficients between the four textural parameters as measured by the Texture Analyser® and texture sensory attributes are shown in Table 3.9. Instrumental cohesiveness was negatively correlated with panel cohesiveness ($r = -0.89$, $p = 0.04$) indicating as the panel detected an increase in cohesiveness, the Texture Analyser® detected a decrease in cohesiveness. The panel indicated a high average intensity for cohesiveness, but the average instrumental cohesiveness was low. Meullenet et al. (1998) studied a variety of 21 foods and reported a statistically insignificant correlation between sensory cohesiveness and Instron cohesiveness. Cohesiveness has generally not been used to describe the texture of peanut butter. This attribute was chosen due to anticipated effects of the isolated soy protein. There was not a large variation in average intensity ratings for cohesiveness and also in the average instrument readings. A greater variation within the products may have resulted in greater average intensity ratings and instrumental readings. However, due to the negative correlation, there appears to be a mathematical relationship between sensory cohesiveness and instrumental cohesiveness with the treatments.

Table 3.9. Pearson correlation coefficients and p values for the textural parameters as measured by the Texture Analyser® and descriptive analysis testing.

Instrumental Attribute	Sensory Attributes*			
	Firmness	Cohesiveness	Adhesiveness	Gumminess
Hardness	-0.517	-0.640	-0.842	-0.419
	(0.372)	(0.244)	(0.073)	(0.483)
Cohesiveness	-0.811	-0.887	-0.970	-0.707
	(0.096)	(0.045)	(0.006)	(0.182)
Adhesiveness	0.593	0.647	0.873	0.523
	(0.292)	(0.238)	(0.054)	(0.366)
Gumminess	-0.584	-0.667	-0.875	-0.501
	(0.301)	(0.219)	(0.052)	(0.390)

*Numbers in parentheses are p values (significant differences at α=0.05).

Instrumental cohesiveness was negatively correlated with panel adhesiveness (r = -0.97, p = 0.006) indicating as the panel detected an increase in adhesiveness, the Texture Analyser® detected a decrease in cohesiveness. Instrumental adhesiveness was negatively correlated with panel gumminess (r = -0.88, p = 0.052) indicating as the panel detected an increase in gumminess the Texture Analyser® detected a decrease in adhesiveness. Instrumental adhesiveness was positively correlated with panel adhesiveness (r = 0.87, p = 0.054) indicating as the panel detected an increase in adhesiveness, the Texture Analyser® also detected an increase in adhesiveness. Ahmed and Ali (1986) found the work necessary to remove the peanut butter from the plunger is related with adhesiveness. However there were no trained descriptive panels involved so no correlation could be made between sensory and instrumental measurements. Gills (1998) did not find a correlation between sensory adhesiveness and Instron adhesiveness. This was attributed to the high standard deviations in sensory adhesiveness. However a correlation was found between sensory gumminess and instrumental adhesiveness (r^2 = 0.53).

Previous research reported correlation between sensory firmness and instrumental hardness. Meullenet et al. (1998) showed that sensory hardness correlated with Instron hardness (r = 0.77, p < 0.001) for various foods. Gills (1998) and Muego et al. (1990) found a correlation between maximum force of penetration using the Instron and sensory hardness (r = 0.48) and (r = 0.72), respectively. In this study, there was no significant correlation found between the Texture Analyser hardness and sensory firmness. The standard deviations in the measurements of hardness using the Texture Analyser® were low; however, the standard deviations for sensory firmness (data not shown) were high. Due to this reason, a correlation may not have existed. The variability in response to firmness from the sensory panel may have resulted from a lack of adequate training and understanding of the attribute firmness.

Correlation between sensory and consumer tests

Pearsons correlation coefficients between the sensory attributes and consumer acceptability testing were determined (Table 3.10). This specific correlation considers each attribute separately with no other attribute affecting the results. For acceptability (tastes great and acceptable) of peanut butter/spreads as judged by the consumer panel, there is a positive correlation with aroma (r = 0.91, p = 0.034) as determined by the sensory descriptive panel. A positive correlation between sensory aroma and a product acceptable to the consumer (tastes great/acceptable) was noted (r = 0.94, p = 0.017). Also, for an acceptable peanut butter/spreads there was a negative correlation with mouthcoating (r = -0.95, p = 0.014). When considering acceptability, it can be seen that the most significant characteristic differentiating the peanut butter/spreads is aroma. For superior quality, the most significant attribute, when individually considered, differentiating the peanut butter/spreads are mouthcoating and aroma. No other attributes, when considered independently, including color, firmness, cohesiveness, adhesiveness and gumminess were significant to the consumers when testing the peanut butter/spreads.

Table 3.10. Pearson correlation coefficients and p values for the sensory attributes used for descriptive analysis and consumer acceptability testing*.

Attributes	Tastes Great/ Acceptable**	Tastes Great	Acceptable
Color	-0.840 (0.075)	-0.608 (0.277)	-0.836 (0.078)
Aroma	0.905 (0.034)	0.941 (0.017)	0.521 (0.368)
Firm	-0.320 (0.600)	-0.670 (0.216)	0.265 (0.667)
Cohesiveness	0.159 (0.799)	-0.252 (0.682)	0.648 (0.237)
Adhesiveness	-0.097 (0.876)	-0.514 (-0.375)	0.495 (0.397)
Gumminess	-0.526 (0.362)	-0.802 (0.103)	0.037 (0.953)
Mouthcoating	-0.721 (0.169)	-0.950 (0.014)	-0.148 (0.813)

*Average was taken for sensory attribute scores (n=18), consumer acceptability scores were percentages of the total population (n=60)

**Numbers in parentheses are p values (significant differences at α=0.05).

Stepwise regression analysis indicated acceptability and aroma are positively correlated ($r = 0.82$, $p < 0.05$) and for superior quality, mouthcoating and cohesiveness ($r = 0.90$, $p < 0.05$, $r = 0.99$, $p < 0.05$, respectively) are significant when both of these attributes are present in the model. From these results, it can be determined consumers consider these two attributes together significant when judging the superior quality of peanut soy spreads.

Correlation between consumer and instrument

Pearsons correlation coefficients between the four textural parameters measured by the Texture Analyser® and the consumer acceptability results were shown in Table 3.11. The four textural attributes measured by the Texture Analyser® did not correlate with consumer acceptability. There were no significant interactions or correlations noted.

Table 3.11. Pearson correlation coefficients and p values for the textural parameters as measured by the Texture Analyser® and consumer acceptability testing*.

Instrumental	Tastes Great/ Acceptable**	Tastes Great	Acceptable
Hardness	-0.030 (0.962)	0.388 (0.519)	-0.576 (0.310)
Cohesiveness	0.014 (0.983)	0.472 (0.422)	-0.603 (0.281)
Adhesiveness	-0.112 (0.858)	-0.519 (0.370)	0.473 (0.421)
Gumminess	0.052 (0.934)	0.470 (0.424)	-0.525 (0.364)

*Consumer acceptability scores were percentages of the total population (n=60)
**Numbers in parentheses are p values (significant differences at $\alpha = 0.05$).

SUMMARY AND CONCLUSION

Three peanut soy spreads using varying levels of isolated soy protein (8, 14 and 20%) were developed and commercial peanut butter and soy nut butter were used as controls. Textural attributes (hardness, cohesiveness, adhesiveness and gumminess) of the five treatments were measured by the Texture Analyser® and significant differences were found between the spreads. Descriptive and consumer panels tested the five treatments. Based on descriptive testing, significant differences existed between the five treatments based on color, aroma and texture attributes. Based on consumer acceptability testing (three point scale) the commercial peanut butter and all three peanut soy spreads were acceptable products. Due to the spreads containing more than 3 g of total fat per serving, a health claim can not be made; however, all three spreads provide a means of obtaining soy protein in the diet in order to obtain 25 g of soy protein per day. Over 50% of the population considered the commercial peanut butter and peanut soy spread containing 8% isolated soy protein superior quality.

Instrumental texture profile analysis provided an effective screening technique to select formulations in an acceptable range of important textural characteristics. Within this range, however, aroma and mouthcoating as evaluated by a sensory descriptive panel becomes a much more effective predictor of consumer acceptability than any textural attribute as determined by the sensory or instrumental texture profile analysis.

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CHAPTER IV

SUMMARY AND CONCLUSION

Peanut soy spreads were prepared using a 3×3×3 factorial design with three levels of peanut oil by weight (1, 4, 7%), three levels of stabilizer by weight (0.5, 2 and 3.5%) and three levels of isolated soy protein by weight (7, 15, 23%). Twenty-seven peanut soy spreads were prepared and commercial peanut butter and soy nut butter were used as controls. In order to determine the textural characteristics (hardness, adhesiveness, cohesiveness and gumminess) of the treatments, the Texture Analyser® TA-XT2 was used. Based on the instrumental textural properties of the commercial products, optimal combination of ingredients for the peanut soy spread was determined.

Using statistical software to analyze the data, analysis of variance was used to fit a quadratic response surface with the factors, oil, stabilizer and isolated soy protein. Predicted values were obtained within the range of the factors. A combination of treatments was selected which met the optimal criteria established for all four textural attributes. Hardness and gumminess were influenced by the interaction of isolated soy protein and stabilizer. There were no significant interactions or differences found for adhesiveness and cohesiveness. It was determined through observed and predicted values, the optimal combination of ingredients for a peanut soy spread are between 6-7% oil, 0.5-0.7% stabilizer and 8-20% isolated soy protein. These levels of oil and stabilizer are similar to levels used in commercial peanut butter.

Using the results reported in chapter 2, three peanut soy spreads were developed for further testing. In order to determine the color, aroma and textural characteristics of these three peanut soy spreads containing 6% oil, 0.5% stabilizer and three levels of isolated soy protein (8, 14, and 20%), ten panelists were recruited and trained in descriptive and texture profile analysis techniques. Commercial peanut butter and soy nut butter were used as controls.

Based on descriptive testing, significant differences were found between the five treatments based on color, aroma and texture attributes. The Texture Analyser® was used to measure the texture attributes (hardness, cohesiveness, adhesiveness and gumminess) for all five treatments and significant differences were found between the spreads. To determine overall acceptability of the peanut soy spreads, one-hundred consumers of peanut butter were recruited. Consumers used a 3 point acceptability scale (tastes great, acceptable and unacceptable). Based on consumer acceptability testing, the commercial peanut butter and all three peanut soy spreads were acceptable products. Over 50% of the population considered the commercial peanut butter and peanut soy spread containing 8% isolated soy protein superior quality.

Pearson correlation coefficients were calculated to determine if mathematical relationships existed. A positive correlation was found between sensory adhesiveness and instrumental adhesiveness. Negative correlations were found between instrumental cohesiveness and sensory cohesiveness, instrumental cohesiveness and sensory adhesiveness, and instrumental gumminess and sensory adhesiveness. No significant correlations were found between instrumental and consumer acceptability testing. A correlation existed between sensory aroma and consumer acceptability and aroma and mouthcoating and superior quality.

Although research has been conducted on textural attributes of products with hopes of a high correlation between instrumental, sensory and consumer testing there is still much to understood. Texture analysis is complex and requires further research to fully understand its components in instrumental and sensory analysis. Further consumer testing must be completed to understand consumer preferences. The integration of these three disciplines is vital in order to develop a product acceptable in the marketplace.