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Shelf life of toasted soyflakes and their application in breadmaking, tofu color prediction from the soybeans and soyflakes color

by

Like Yan

A thesis submitted to the graduate faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE

Major: Food Science and Technology

Program of Study Committee:
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2006

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Graduate College
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This is to certify that the master's thesis of

Like Yan

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy
To my family, my parents and my sister, for their love

To my lifetime friends, for them being there for me when I need them
# TABLE OF CONTENTS

## ABSTRACT

## GENERAL INTRODUCTION
- Introduction
- Thesis Organization
- Literature Review
- References

## THE SHELF LIFE STUDY OF TOASTED SOYFLAKES
- Abstract
- Introduction
- Materials and Methods
- Results and Discussion
- Conclusions
- References
- Tables
- Figures

## THE APPLICATION OF TOASTED SOYFLAKES IN BREAD
- Abstract
- Introduction
- Materials and Methods
- Results and Discussion
- Conclusions
- References
- Tables

## PREDICTION OF TOFU COLOR FROM THE COLORS OF SOYBEANS AND MICROSOY FLAKES
- Abstract
- Introduction
- Materials and Methods
- Results and Discussion
- Conclusions
- References
- Figures

## GENERAL CONCLUSIONS
- Conclusions

## APPENDIX A. LINE SCALE


ABSTRACT

Effects of storage time and storage temperature on the functionalities and quality changes of toasted soyflakes were studied. MicroSoy® toasted soyflakes TSX02M (0.2 mm thickness, medium toast level), TSX02H (0.2 mm thickness, high toast level), and TSX12H (1.2 mm thickness, high toast level) were stored at 4°C, 25°C, 35°C, and 45°C for 84 days. Samples were analyzed for water hydration capacity, oil absorption capacity, color, antioxidant capacity, TBA rancidity, free fatty acids (FFA), and nitrogen solubility index (NSI). Both WHC and OAC changed over time, with the rate of change affected by type instead of temperature. WHC decreased over time with TSX02H decreasing the fastest. There was no clear trend in the changes of OAC. Lightness did not change over time. There was decreasing trend in antioxidant capacity and increasing trend in rancidity over time. There was no major change in FFA. The smooth texture, sweet nutty flavor, and nutrition value of toasted soyflakes make them potential ingredients in the bakery products such as bread.

Wheat flour was substituted by MicroSoy toasted flakes TSX02M at 5%, 10%, and 15% levels in our study. Addition of toasted soyflakes darkened the crust and crumb color, lowered the loaf volume. Substitution of 5% did not change the water absorption, crumb color and volume compared with control. Consumer tests showed that control bread and 5% soy fortified bread scored the highest in liking of overall appearance. There were no difference in scores for all breads in liking of overall flavor, and liking of overall texture. Overall, 65% of the participants preferred any soy bread over control bread.

The color relationships among soybeans, soyflakes, and respective tofu made from soybeans and soyflakes were investigated. Companion soybeans and soyflakes were used to make tofu. There were correlations between the “L” of flakes and flake tofu, and between the
“b” of flakes and flake tofu. There was strong correlation between the color of flake tofu and bean tofu. Multiple regression shows that flakes L and b are good predictors of bean tofu L, and beans L and b are good predictors of flake tofu.
GENERAL INTRODUCTION

INTRODUCTION

Soy foods have gained more and more attention due to their health benefits. In addition to being a good source of high quality protein, studies have shown the associations between intake of soy foods and lowered blood cholesterol (Snyder and Kwon 1987), protection from breast cancer (Messina and others 1994), and lowered risk of colorectal cancer (Messina and Messina 1991). The intake of legumes, such as soybeans, also has been associated with reduced risk of obesity and diabetes due to the high fiber content in those foods (Anderson and others 1999). In 1999, the Food and Drug Administration (FDA) approved a soy protein and coronary heart disease health claim “25 g of soy protein a day, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease”.

However, despite the health benefits, acceptability of soy foods is still limited due to its off-flavor, which is described as “green”, “beany”, “painty”, and “grassy” (Wolf and Cowan 1975; Rackis and others 1979). MicroSoy toasted soyflakes are produced from cracked whole soybeans that are flaked and toasted. The heat treatment inactivates the enzyme, lipoxygenase, which is responsible for the formation of off-flavors. Thus the toasted soy flakes have low beany flavor, along with a smooth texture and nutty flavor, which make possible their potential broad application in food products, such as cereal, yogurt, ice cream toppings, pie crust, and other bakery products.

Storage of soybeans has been studied extensively (Saio and others 1980; Saio and others 1982; Narayan and others 1988; Thomas and others 1989; Lambrecht and others 1996; Hou and Chang 1998, 2004). However, there is limited research reported in literature on the quality change of toasted soyflakes due to their new arrival on market. Furthermore, the
application studies of toasted soyflakes in food products are necessary in promoting the marketability of this fairly new product.

Tofu is a traditional food in Asia and it is also gaining popularity in the Western countries (Soyatech 2004). Due to the benefit of less water usage and shortened processing duration, MicroSoy® flakes (MicroSoy, Jefferson, IA) are utilized in soymilk and tofu production, during which the traditional soaking and grinding steps required for the whole soybeans are avoided. Moizuddin and others (1999b) reported that utilization of full-fat soyflakes in the soymilk processing saved 62-65% water compared with the traditional utilization of soybeans, and the hydration time needed was shortened to 10 minutes for flakes compared with the 12 hours for the soybeans. A sensory study (Safir and Wilson 2000) showed that sensory panelists could detect color change in the end products such as tofu when the colored soybeans were present at concentration as low as 1%. Therefore, to propose an appropriate model equation based on the correlation between the color of soybean or companion soyflakes and the tofu produced therefrom, would be useful to the tofu manufacturers in selecting the soybeans with desired color to optimize the final tofu products.

The objectives of our studies were: 1) to investigate the functionality and quality changes of toasted soyflakes when stored at different temperatures over time, thus to provide the manufacturer and industry with the information pertaining to the proper storage or shipping condition; 2) to investigate the dough property changes when wheat flour is partially substituted by toasted soyflakes in breadmaking, also to evaluate the consumer acceptance of the toasted soyflakes fortified bread; and 3) to propose an appropriate model
equation based on the correlation among the colors of soybeans, soyflakes, and the respective tofu.

THESIS ORGANIZATION

There are five chapters in this thesis. The first chapter is a review, which describes the associations between soy foods and health benefits, results from storage studies on soybeans, bread making, soymilk and tofu processing, and sensory evaluation methods. Toasted soyflakes are addressed.

The second, third, and fourth chapters are three manuscripts to be submitted for publication in the Journal of Food Science. They describe a shelf life study on the toasted soyflakes stored at different temperatures over time, a study on the substitution of some of the wheat flour with toasted soyflakes in breadmaking, and a study to predict the tofu color from the soybeans and soyflakes color, respectively. The findings and significance of those studies are described in detail. The fifth chapter gives the general conclusions derived from the studies.

LITERATURE REVIEW

NUTRITIONAL AND HEALTH BENEFITS OF SOY FOODS

Soybeans play an important role in the traditional diet of Asian countries. It is hard to imagine oriental cuisines without the usage of soybeans. Traditional soybean foods can be categorized into two groups: non-fermented and fermented foods. Non-fermented soy foods include soymilk, tofu, deep-fried tofu, soybean protein film (yuba), and texturized soy protein. Soy sauce, miso, tempeh, and fermented whole soybeans (natto) fall into the category of fermented soy foods.
Soybeans are low in saturated fat and cholesterol, and are good sources of proteins (30%-40%) and oil (20%) (Karmas and Harris 1988). Linoleic acid accounts for about 51% of the fatty acids, which is associated with lowered blood cholesterol (Snyder and Kwon 1987). Seven percent of the polyunsaturated fatty acid is linolenic acid, which has an effect in reducing the heart disease risk (Anderson and others 1999).

In 1999, the Food and Drug Administration (FDA) approved a soy protein and coronary heart disease health claim “25 g of soy protein a day, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease”. High intakes of soy protein protect from development of breast cancer (Messina and others 1994). Soy consumption may also lower colorectal cancer risk (Messina and Messina 1991). Soy proteins are rich in lysine but relatively low in methionine, which is a sulfur amino acid (SAA). However, soy proteins are considered a quality protein source along with milk, eggs, meat, etc. Furthermore, studies showed that metabolism of SAAs cause demineralization of bone and excretion of calcium in the urine (Remer and Manz 1994). Thus, soy protein may have an advantage in improving calcium retention compared with animal protein (Messina 1999). Long-term soy protein intake also has a protective effect on renal function compared with animal protein intake (Anderson and others 1999).

Soybean hulls contain about 87% crude fiber (Wilson and others, 1992). Soy fiber can increase stool weight and decrease gastrointestinal transit time (Slavin 1991). The intake of legumes, such as soybeans, has also been associated with reduced risk of obesity and diabetes due to the high fiber content in those foods (Anderson and others 1999). Okara is the residue from soymilk production. It contains some protein and oil, and is very rich in fiber,
which is composed of cellulose, hemicellulose, and lignin (O’Toole 1999). Thus, the addition
of okara in food products reduces calories and increases the fiber intake.

Soybeans also contain vitamins B1, B2, B6, and E (Fernando and Murphy 1990). Some phytochemicals, such as isoflavones, also exist in trace amount. A workshop held by the National Cancer Institute (Messina and Barnes 1991) identified several compounds such as isoflavones, phytosterols, protease inhibitors, phytic acid, and phenolic acids as anticarcinogens, which are in relatively high concentrations in soybeans compared with other beans. Isoflavones are plant chemicals unique to soybeans, which inhibit a number of enzyme reactions and act as antioxidants (Pokorny and others 2001). It has been hypothesized that isoflavones reduce the risk of cancer, heart disease, and osteoporosis, and also help relieve menopausal symptoms. An in vitro study (MacDonald and others 2005) showed that isoflavones reduced the proliferation of human colon tumor cells. Phytosterols are structurally similar to the animal sterol cholesterol. They have the cholesterol-lowering properties and may be anticarcinogens. Studies (Kennedy 1995) showed that protease inhibitor, the Bowman-Birk inhibitor (BBI), suppressed colon, liver, and lung carcinogenesis.

SOYBEAN PROPERTY CHANGES DURING STORAGE AND TOASTED SOYFLAKES

Many studies have been carried out on soybean quality and physicochemical property changes during storage and the effects on the soy products made therefrom. Hydroperoxides, products of lipid oxidation, can break down to form volatile secondary oxidation products, which have off-flavors. A study (Clark and Snyder 1991) conducted to measure the hydroperoxide formation in soybean seeds during a two-year storage period showed that hydroperoxides, though slowly, increased over time. Saio and others (1980) found that the
Nitrogen Solubility Index (NSI) value decreased, the extractability of solids and protein into soymilk decreased, the color of the beans darkened and the acid values of the oil increased as a result of storing soybeans at high storage temperature and relative humidity. The increases in acid value could be explained by the hydrolysis of lipids to fatty acids.

A study on protein denaturation during storage (Salo and others 1982) indicated that NSI of whole soybeans, defatted meals, and full-fat meals decreased with full-fat meals and whole soybeans decreased the most and the least, respectively. Thomas and others (1989) found that protein extractability of beans decreased over storage time under high temperature and relative humidity. The same study also found that there was more solid loss into the soakwater when the beans were used to make soymilk, which indicated increased cell breakdown. Increased solids loss during soaking, darkened beans, decreased NSI, lowered soymilk pH were also observed in a study on the effect of storage on soymilk and tofu production by Lambrecht and others (1996).

Narayan and others (1988a) found that over storage, beans color changed from creamy yellow to brown, peroxide value and free fatty acid content increased, and the total solids and protein loss increased during soaking. Narayan and others (1988b) also showed sensory qualities of the soymilk, tofu and soynuts made from the stored beans in the previous study significantly decreased with the increase of the storage time. Results from another storage study (Hou and Chang 1998) showed that the tofu made from the stored soybeans decreased in lightness and increased in redness, which might be due to the nonenzymatic browning reaction, such as the Maillard reaction. There was also an increase in the off-flavor of tofu as the storage time progressed, which could be explained by the volatile products resulting from the lipid oxidation and secondary break down products of the oxidation.
products. Hou and Chang (2004) found that soybeans stored at adverse conditions (84% RH, 30°C) decreased in lightness, which indicating that beans became darker over storage. A recent soybean storage study by Kuan and Wilson (2005) observed the similar results as those from the above studies. They found that stored beans became darker and less yellow, free fatty acids increased, and solids level in soymilk made from those stored beans decreased.

Untoasted and toasted soyflakes, both of which are patented products by the MicroSoy Corp. (Jefferson, IA), are made from whole soybeans using a mechanical process of de-hulling, cracking, and flaking without the use of solvents or additives. MicroSoy® toasted soyflakes go through toasting process, which removes the beany flavor. They are available in three different thicknesses: 0.2 mm (TSX02), 0.6 mm (TSX06), and 1.2 mm (TSX12), also in three toast levels: light (L), medium (M) and high (H). MicroSoy literature reported that the toasted flakes are full fat with no beany flavor, and have a smooth texture, and sweet-nutty flavor. Thus, they can be used in soy crumbles, pancake mix, hot cereal, cold cereal, pie crusts, salad sprinkles, soy cream cheese, and many other food applications.

Currently, there is very little published research available on the shelf life of the toasted soyflakes. Chong and Wilson (2000) conducted a study on the effects of storage temperature on the functional properties of full-fat soyflakes, which showed that the stored flakes had higher oil absorption at higher temperature, and the water-holding capacities of flakes stored at different temperatures were not significantly different. Results from the same study also recommended low storage temperature (lower than 25°C) to retain the functional properties of soyflakes. Saio and others (1982) showed in their study that whole beans retained better quality than meals, and defatted meals deteriorated slower than full-fat meals.
Thus, the intact intracellular membranes play an important role in retaining quality. Toasted soyflakes are prepared from cracked whole soybeans, thus, the intracellular membranes of toasted soyflakes are damaged and certain functionality or property changes would be expected.

**BREAD MAKING**

Protein malnutrition is a severe problem in developing countries (Muller and Krawinkel 2005), where people’s diet consists mainly of cereal or starchy foods. Soy products have and are being used to increase the protein content due to their high protein quality, low cost, and availability. Additionally, raw soy flour contains enzymes, such as amylases, proteases, and lipoxygenase. Lipoxygenase is the active agent that contributes to the bleaching of flour carotenoid pigments in dough and bread when raw soy products are added in breadmaking (Pyler 1988).

Wheat flour, water, yeast and salt are the four main ingredients for making leavened wheat breads. The quality of wheat flour in breadmaking is mainly determined by its proteins. Gluten is the major storage protein in wheat, which accounts for about 80 - 85% of the total wheat protein (Goesaert and others 2005). After mixing with water, wheat flour proteins will interact developing elastic dough when mixed with water. Gluten is the mixture of proteins responsible for visco-elastic dough properties (Singh and MacRitchie 2001). Gluten is composed of two major proteins glutenin and gliadin. Glutenin contributes to the dough strength and elasticity (Khatkar and others 1995; Belton 1999), while gliadin is responsible for the viscosity to the dough (Khatkar and others 1995). The oxidation of cystein residues of protein results in the formation of disulfide bridges, which are the most remarkable linkages in creating elasticity (Goesaert and others 2005).
Bread baking has several stages, mixing, fermentation, punching/panning, proofing, and baking. The mixing stage is critical in that it blends all the ingredients together and develops the gluten network. The quantity and quality of gluten proteins largely determine the rheological properties of the optimally mixed dough, which thus have effect on the gas retention properties of the fermenting dough (Gan and others 1995). Gas retention is the factor that contributes to the loaf volume and crumb structure of the resulting bread. The uniqueness of wheat flour in bread making, when compared with other cereals, is that wheat flour dough is able to retain gas on expansion (Gan and others 1995).

The addition of foreign proteins may weaken the wheat flour dough due to the dilution of the gluten structure (Knorr and Betschart 1978), thus having a negative effect on the quality of bread, such as lower loaf volume and harder crumb. Soy products, such as soy flour, do not have gluten, thus the replacement of wheat flour by soy products may weaken a gluten network. Tsen and Hoover (1973) conducted a study to investigate the effects of adding full-fat soy flour ranging from 12%-28% to wheat flour in bread making on the rheological properties and baking quality of wheat flour. They found that addition of soy flour increased the water absorption, decreased the dough developing time, and furthermore, rapidly reduced the dough stability. Resulting breads had low loaf volume and poor grain scores, both of which reduced with the increasing percentage levels of addition. A study carried out by Doxastakis (2002) showed increased water absorption, increased mixing time, decreased loaf volume, darkened crust color, more yellow crumb color, and poorer crumb texture with substitution of full-fat soy flour.

The study from Shah and others (1986) showed the effects of substitution level up to 12% with roasted soy flour or enzyme active soy flour on the rheological properties of wheat
flour. The results showed that either type of soy flour increased the mixing tolerance and mixing time up to 15% and 18% level for enzyme active soy flour and roasted soy flour, respectively. Dough stability and elasticity increased with the increasing level of roasted soy flour although to a lesser extent compared with enzyme active soy flour. Enzyme active soy flour consistently decreased loaf volume, while roasted soy flour increased the loaf volume at 6 and 9% substitution. The sensory data showed lower scores on appearance, crust color, grain structure, texture and flavor of soy added breads than those of control. However, roasted soy bread was ranked higher than enzyme active soy bread and the quality of bread at 12% level was still satisfactory. Misra and others (1991) studied the effect of defatted soy flour on bread making qualities. The results showed that mixing time increased with the level of defatted soy flour increased up to 10% and the loaf volume of bread decreased as the soy flour level increased over 2%.

Raw soyflakes preserve the wholesome quality of the soybeans due to little heat treatment during the process. They have a natural yellow appearance. Their applications include soymilk, tofu, hummus, processed meats, and instant mashed potato. The replacement of potato flakes by soyflakes in instant mashed potato reduces the carbohydrate content while increasing the protein. In a consumer test, participants reported that the soyflakes could be added at up to 40% in mashed potatoes, the taste, flavor and appearance of which is still acceptable (Pszczola 2004). The lacking of beany flavor of the toasted flakes attributes to the toasting procedure. Due to the properties they have, toasted soyflakes have broad potential applications in cereal, yogurt, ice cream toppings, pie crust, and other bakery products. There is no literature on the bread dough property changes when toasted soyflakes are added to replace some of the wheat flour since these are fairly new products.
SOYMILK AND TOFU PROCESSING

The nutritional and health benefits of soybeans and soy foods are well known. However, the off-flavor makes them undesirable and unacceptable to most western consumers, thus limiting the marketability of soybeans products in those countries. The off-flavors of soybeans and soybean foods have been described as “green”, “beany”, “painty”, and “grassy” (Wolf and Cowan 1975; Rackis and others 1979). The enzyme lipoxygenase plays an important role in the development of those flavors from lipids because the off-flavors are formed by the oxidation of unsaturated fatty acids by lipoxygenase during seed grinding. A study by Torres-Penaranda and others (1998) showed that soymilk made from lipoxygenase-free soybeans had less beany aroma and flavor compared with that from the normal soybeans. Wolf (1975) suggested heat treatment to inactivate the lipoxygenase during processing of soybeans, such as grinding with hot water and blanching. Products from such processes have improved flavor, however, there may be some functionality loss due to the decreased protein solubility due to high temperature. Wilson and others (1992) also indicated that development of off-flavors could be decreased by inactivating lipoxygenase by heat, which also helps volatilizing some of the off-flavor compounds, and improving nutritional quality as well.

Soymilk is an aqueous extract of soybeans and an intermediate product in the tofu production. There are different ways to produce soymilk from soybeans, such as the traditional method (Chinese or Japanese), Cornell method, Illinois method, and Rapid Hydration Hydrothermal Cooking (RHHC).

Traditional method (Shurtleff and Aoyagi 1983) is the most commonly used soymilk production method, which requires the soybeans to be soaked for 8-10 hours in cold water.
before ground into slurry with added water, followed by either heating or extracting. In the Chinese method, the slurry is extracted before heating. Thus, the lipoxygenase is activated, which causes the beany flavor in the soymilk. While in the Japanese method, slurry is heated before filtering so the lipoxygenase activity is inhibited by heat treatment, which produces soymilk with less beany flavor compared with that in Chinese method.

The Cornell method improves the soymilk flavor by grinding beans in hot water, followed by cooking at 100°C for 10 minutes and then filtering. Hot grinding inhibits the off-flavors formation, however, the heat treatment denatures protein, thus decreasing the extractability (Wilkens and others 1967).

The Illinois method (Nelson and others 1976) produces soymilk without beany flavor through soaking beans in sodium bicarbonate and blanching at 100°C for 10-20 minutes. Grinding and cooking to 82°C are followed. Sodium bicarbonate is neutralized by addition of an acid. This method produces soymilk with the highest solids yield among all the methods, which could be explained by the reserving of okara in the soymilk.

Steam infusion is utilized in RHHC method (Johnson and others 1981). The beans are ground to flour and then made into slurry, which is then cooked at 154°C for 30 seconds and filtered. The short heating process at high temperature results in soymilk with high solids yield, which indicates high protein recovery. Also, the soymilk does not have beany flavor.

There are two main steps in the tofu production: the preparation of soymilk and the coagulation of soymilk to form curds which are then pressed to form tofu. Tofu texture and yield can be affected by many factors, such as the percent solids and heating temperature of soymilk, type and amount of coagulant, and stirring and temperature in coagulation (Saio 1979). The amount of coagulant needed to coagulate the protein can be determined according
to the results of a study by Moizuddin and others (1999a). A coagulating agent, usually a calcium or magnesium salt, such as calcium sulfate dihydrate (CaSO$_4$·2H$_2$O) or magnesium chloride (MgCl$_2$), can then be added to heated soymilk followed by quick stirring to disperse the coagulant evenly and then letting it sit to gel. After the soymilk is completely coagulated, the gel is cut into smaller curds and the whey is separated at the same time. The curds are then transferred to a perforated press box lined with a cloth, followed by pressing to expel whey from the curd. Depending on the desired softness or firmness, different forces are used for pressing to make soft to extra-firm tofu. There is no pressing when making silken tofu.

Due to the benefit of less water usage and shortened processing duration, full-fat soyflakes are utilized in soymilk and tofu production, during which the traditional soaking and grinding steps required for the whole soybeans are avoided. It was reported by Moizuddin and others (1999b) that utilization of full-fat soyflakes in the soymilk processing saved 62-65% water compared with the traditional utilization of soybeans, and the hydration time needed was shortened to 10 minutes for flakes compared with the 12 hours for the soybeans. The result from the same study also showed that the tofu produced from the flakes had lower fat content compared with that from the soybeans. Furthermore, the tofu made from the flakes and soybeans showed no difference in lightness or redness. There was a slight difference in yellowness but it could not be differentiated visually.

There have been many attempts to identify the soybean characteristics that can be used in predicting the end product quality of soy foods. Studies (Saio 1979; Wang and others 1983; Johnson and Wilson 1984; Lim and others 1990; Schaefer and Love 1992; Wang and Chang 1995; Moizuddin and others 1999a) have focused on the effects of cultivars or processing conditions (such as concentration of coagulants, temperature, etc) of soybeans on
the yield and quality of tofu. Storage studies (Saio and others 1980; Saio and others 1982; Narayan and others 1988; Thomas and others 1989; Lambrecht and others 1996; Hou and Chang 1998; Hou and Chang 2004) were also designed to investigate the effects of storage conditions on the property changes and quality of soybeans or tofu. However, there has been limited research on the prediction of tofu color by the soybean or soyflakes color. Color from the seed coat and cotyledon can be carried into soymilk and therefore into tofu, which make them unacceptable to the consumers. Sensory study (Moizuddin and Wilson 2000) showed that sensory panelists could detect color change in the end products such as tofu when the colored soybeans are present at concentration as low as 1%. Therefore, to propose an appropriate model equation based on the correlation between the color of soybean and the tofu produced therefrom, would be useful to the tofu manufacturers in selecting the soybeans with desired color to optimize the final tofu products.

SENSORY EVALUATION

Sensory evaluation emerged in the late 1940s due to the rapid growth of the food companies. It has been defined as a scientific method used to evoke, measure, analyze, and interpret those responses to products as perceived through the senses of sight, smell, touch, taste, and hearing (Stone and Sidel 1993). The reason to conduct sensory evaluation is that instruments lack the sensitivity of human sensory systems. Instruments cannot simulate the way foods are tasted by human. Also, the instrumental assessment can only give values but not the explanation of sensory experience, which can only be obtained by human brain.

Sensory evaluation tests can be categorized into discrimination tests, descriptive analysis, acceptance and preference testing (Lawless and Heymann 1998). Discrimination tests are used to test if there is a difference between two samples. Triangle tests, duo-trio
tests, paired comparison tests are the commonly used discrimination tests. Descriptive analysis techniques are very useful when specific sensory attributes of a single product or detailed information on what differences are among several products are desired. Some examples of those techniques are Flavor Profile®, Quantitative Descriptive Analysis®, Texture Profile®, and Sensory Spectrum®. When the panelists are well trained and are consistent over time, those techniques are good for shelf life testing. Preference tests include paired preference testing and preference ranking, which are used in determining preference of one product over the others. Acceptance tests can be used to indicate the degree of liking or disliking of a product.

Scaling is used to apply numbers to quantify sensory experience, which makes statistical analysis, prediction, or modeling possible. Commonly used scaling techniques include line marking, category scales, and magnitude estimation (Lawless and Heymann 1998). When a line-marking scale is used, panelist makes a mark on a line where best describes the intensity of the attribute of interest to the tester. Sometimes the anchors are indented to prevent the reluctance of panelists to use the ends of scale. Compared with line-marking scale, panelists usually have limited choices in the category scales. Magnitude estimation indicates the ratios of intensity between samples by assigning numbers to products.

Line-marking scale is recommended by Stone and others (1974) to be used with the Quantitative Descriptive Analysis®, during which panelists are trained to generate a consensus vocabulary at the beginning and evaluate samples individually by seating in isolated booths for the final evaluation. Usually a 6-inch line scale anchored with words generated by the panelists is used. Consensus training aims at developing the sensory
vocabulary, thus ensuring all the panelists share a common list of sensory attributes and have a common understanding of all the terms used. Usually wide ranges of products are demonstrated and chemicals or materials may be used as standards to illustrate specific flavor notes and texture as well. When different terms occur, panelists will be assisted in moving toward consensus.

Sensory consumer tests can provide product developers information on the level of the consumer acceptability or the possible problems of the product perceived by the consumers. Consumers are not trained for the product evaluation. Economic loss could be avoided when such problems are discovered using inexpensive tests such as consumer test. Therefore, it is best used before launching a new product into market.

Therefore, the aims for our studies are: 1) to investigate the functionality and quality changes of toasted soyflake when stored at different temperatures over time, thus to provide the manufacturer and industry with the information pertaining to the proper storage or shipping condition; 2) to investigate the dough property changes when wheat flour is partially substituted by toasted soyflakes in breadmaking, and to evaluate the consumer acceptance of the toasted soyflakes fortified bread; and 3) to propose an appropriate model equation based on the correlation among the colors of soybeans, soyflakes, and the respective tofu.

REFERENCES


Chong E. 2000. The effects of storage temperature and food pH's on the functional


triticale addition to wheat flour doughs and their effect on rheological properties.

Fernando SM, Murphy PA. 1990. HPLC determination of thiamin and riboflavin in


Wheat flour constituents: how they impact bread quality, and how to impact their

Hou HJ, Chang SKC. 1998. Yield and quality of soft tofu as affected by soybean physical

Hou HJ, Chang KC. 2004. Storage conditions affect soybean color, chemical composition

Johnson LA, Deyoe CW, Hoover WJ. 1981. Yield and quality of soymilk processed by

Johnson LD, Wilson LA. 1984. Influence of soybean variety and the method of
processing in tofu manufacturing: comparison of methods for measuring soluble

Kennedy AR. 1995. The evidence for soybean products as cancer preventive agents. J.


Messina M, Messina V. 1991. Increasing use of soyfoods and their potential role in


Moizuddin S, Wilson LA. 2006. Influence of Seed Coat Color on the Quality of Soymilk and Tofu. (Personal communication)


O'Toole DK. 1999. Characteristics and use of okara, the soybean residue from soymilk


Wilkens WF, Mattick LR, Hand DB. 1967. Effect of processing method on oxidative off-


THE SHELF LIFE STUDY OF TOASTED SOYFLAKES

A paper to be submitted to the Journal of Food Science

L. Yan, L.A. Wilson

ABSTRACT

The effects of storage time and temperature on the functionality and quality changes of toasted soyflakes were studied. Three types of MicroSoy® toasted soyflakes, TSX02M (0.2 mm thickness, medium toast level), TSX02H (0.2 mm thickness, high toast level), and TSX12 H (1.2 mm thickness, high toast level) were stored at 4°C, 25°C, 35°C, and 45°C for 84 days. Samples were taken at two-week intervals to determine water hydration capacity (WHC), oil absorption capacity (OAC), and color. Sensory evaluations were conducted at 4-week intervals. Antioxidant capacity, 2-thiobarbituric acid (TBA) rancidity, free fatty acids (FFA), and nitrogen solubility index (NSI) were measured at the beginning and the end of the study. Both WHC and OAC changed over time, with the rate of change affected by type instead of temperature. WHC decreased over time with TSX02H decreasing the fastest. There was no clear trend in the changes of OAC. There was no change in the lightness of the samples. Antioxidant capacity decreased over time with the increase of storage temperature, with the lowest at 45°C. Rancidity increased over time with increasing storage temperature with the highest at 45°C. There was no major change in free fatty acids (FFA). Nitrogen Solubility Index (NSI) decreased over time and also decreased with the increase of storage temperature. There was no significant difference between treatments in protein content. Temperature higher than 25°C is not recommended for shipping or storage mainly due to the
quality change by rancidity. Medium toast level seems to retain better quality compared with
the high toast level due to less heat treatment.

INTRODUCTION

Traditionally, soymilk, tofu, and other soy foods are produced from soybeans. As a
patented product, MicroSoy® flakes (MicroSoy, Jefferson, IA) are gaining more attention
and interest in their applications, both in the traditional soymilk and tofu processing and in
many other food applications. The benefits of utilizing flakes in soymilk and tofu production
are less water usage and shortened processing duration due to the skipping of soaking and
grinding steps (Moizuddin and others 1999), which are required for the whole soybeans.
MicroSoy® toasted soyflakes have broad applications in nutrition bars, mashed soy potatoes,
cereal, yogurt, ice cream toppings, pie crust, and bakery products, etc, due to their natural
yellow appearance, low beany flavor note, as well as a smooth texture and sweet nutty flavor.

Currently, there is limited research on the shelf life of toasted soyflakes. However, a
great number of storage studies (Saio and others 1980; Saio and others 1982; Narayan and
others 1988; Thomas and others 1989; Lambrechts and others 1996; Hou and Chang 1998,
2004) were designed to investigate the effects of storage conditions on the property changes
and quality of whole soybeans and tofu made thereof. Results from those studies showed
decreased NSI, increased peroxide value, increased FFA, increased off-flavor of tofu, and
darkened bean color. Chong and Wilson (2000) conducted a study on the effects of storage
temperature on the functional properties of full-fat soyflakes, which showed the stored flakes
had higher oil absorption at higher temperature, while water-holding capacities of flakes
stored at different temperatures were not significantly different. Also, Saio and others (1982)
showed in their study that whole beans retained better quality than meals, and defatted meals
deteriorated slower than full-fat meals, which indicates that the intact intracellular membranes play an important role in retain of quality.

Toasted soyflakes are prepared from cracked whole soybeans, which are then flaked and toasted. Thus, the intracellular membranes are damaged. The heat treatment of toasted flakes during processing, along with the full fat they contain, may increase oxidation. Therefore, certain functionality or property changes of toasted flakes during storage would be expected.

The objectives of this study were to investigate the shelf life of toasted soyflakes stored under different temperatures, as well as to compare the stability differences among toasted flakes with different toast levels and thicknesses. Thus, the ideal condition could be determined to best retain the quality of toasted flakes during storage and shipping. The changes of functionalities such as OAC and WHC are also of interest due to their properties in fat binding and moisture retaining in food systems, such as cooked meat or bakery products, thus influencing the texture, flavor of these food products.

**MATERIALS AND METHODS**

**Samples**

Commercial full-fat toasted soyflakes TSX02M, TSX02H, and TSX12H were provided by MicroSoy Corp. (Jefferson, IA). TSX02M is the medium toasting level soyflake with the thickness of 0.2 mm. TSX02H and TSX12H are the high toasting level soyflake with the thickness of 0.2 mm and 1.2 mm, respectively. Samples were kept in 20-kg heat sealed polyethylene-paper lined bags until the day of analyses.
Study design

Six individually sealed bags of each of the three types of samples were stored in incubators at 4°C, 25°C, 35°C, and 45°C, respectively. Samples were stored up to 84 days, during which one bag of each of the three samples stored at 4°C, 25°C, 35°C, and 45°C was taken out on day 14, 28, 42, 56, 70, and 84 to determine water hydration capacity, oil absorption capacity, and color. Sensory evaluations were also conducted with 12 trained panelists on day 28, 56, and 84. Due to instrumental break down, antioxidant capacities were only compared between the samples at the beginning (day 0) and the end (day 84) of the study. Tests on TBA rancidity, free fatty acids, NSI, and protein were only conducted on day 0 samples and day 84 samples due to limited funding.

Water hydration capacity (WHC)

WHC was measured using AACC Method 88-04. 5 g of toasted soyflakes were weighed into a pre-weighed 50 mL centrifuge tube. 15 mL of distilled water was added. The mixture was stirred with a glass rod and then the tube was centrifuged at 2000 x g for 10 minutes. The tube and sediment were weighed after the supernatant was discarded. The WHC was calculated as (weight of tube + sediment) – (weight of tube + 5) / 5 and expressed as the ml of water absorbed per gram of sample (as is basis).

Oil absorption capacity (OAC)

Method for OAC was modified from the method described by Onuma Okezie and Bello (1988). Samples were grounded first using a mortar and pestle. 2 g of ground sample was weighed into a preweighed 50 mL centrifuge tube and 10 mL of Mazola Corn Oil (The J.M. Smucker Co., Orrville, OH) was added. The mixture was allowed to sit at the room temperature for 30 minutes and then centrifuged at 2000 x g for 30 minutes. The OAC (g
oil/g) was calculated as (weight of tube + sediment) – (weight of tube + 2) / 2 and expressed as the grams of oil absorbed per gram of sample (as is basis).

**Color**

LabScan XE spectrophotometer (HunterLab, Reston, VA, USA) was used with Universal Software®4.1. A port size 1.2”, area view of 1.00” and D65/10 (Illuminant/Standard Observer) were set for the measurement of the color of samples. All the samples were placed into 60 x 15 mm plastic petri dishes (Fisher Scientific, Fair Lawn, NJ). Data is reported as Hunter L, a, b, where “L” indicates lightness with 0 is black and 100 is white, “a” indicates red-green with positive values are red and negative values are green, and “b” indicates yellow-blue with positive values are yellow and negative values are blue.

**Antioxidant capacity**

The PhotoChem (AnalytikjenaAG, Germany) uses photochemiluminescence to evaluate the end products of a free radical reaction. A photosensitizer substance is optically excited by UV-light in the system to produce superoxide anion radicals, which are detected by a chemiluminogenic substance, which is then detected in the Photochem by a photomultiplier. The antioxidative capacity is determined based on the radical scavenging capacity of the antioxidants in the sample, which is quantified by using a phenolic antioxidant, Trolox, as a standard.

Antioxidative capacity of lipid soluble compounds in the samples was measured at the beginning and the end of the study, which are day 0 and day 84, respectively. Sample was prepared as: 1 g of ground toasted soyflakes was mixed with 10 mL of HPLC grade methanol in a centrifuge tube. The mixture was extracted in a water bath shaker for 5 minutes, which was then filtered using a syringe with a 0.45 µm cellulose acetate filter into a new test tube to
run on PhotoChem. The antioxidant capacity, which also is expressed as antioxidant concentration, was calculated using the following formula:

\[
\text{Concentration (µg/mg)} = \frac{\text{Quantity} \times \text{Dilution} \times \text{M} \times \text{Volume}}{\text{Pipetted volume} \times \text{Weighted sample}}
\]

Quantity: Trolox equivalents in nmol

M: Molar mass of Trolox (250.3 ng/nmol)

Pipetted volume: Volume (in µL) injected into PhotoChem

Weighted sample: 1000mg

Volume: 10 mL

Dilution: 10 (at 1:10 dilution factor)

**2-thiobarbituric acid (TBA) rancidity**

Because lipid oxidation may have occurred during the toasting process, the breakdown products of oxidation may accumulate during the storage. In preliminary testing, TBA was found to be better correlated with rancidity than peroxide values. Therefore, TBA rancidity test was conducted to measure the malonaldehyde, which is the breakdown product of lipid oxidation. Day 0 and day 84 samples were sent to Eurofins (Des Moines, IA, USA) for analysis using the method by Tarladgis and others (1960). Each sample was analyzed in one replicate due to limited funding.

**Free fatty acids**

Day 0 and day 84 samples were sent to Eurofins (Des Moines, IA, USA) for analysis using AOCS method Ca 5a-40 (2003-2004). Each sample was analyzed in one replicate due to limited funding.
Nitrogen solubility index

Day 0 and day 84 samples were sent to Eurofins (Des Moines, IA, USA) for analysis using AOCS method Ba 11-65 (2003-2004). Each sample was analyzed in one replicate due to limited funding.

Protein

Day 0 and day 84 samples were sent to Eurofins (Des Moines, IA, USA) for protein combustion using AOCS Ba 4e-93 (2003-2004). Each sample was analyzed in one replicate due to limited funding.

Sensory evaluation

Sensory evaluation procedures described by Lawless and Heymann (1998) were followed in this sensory study. 13 participants, 8 males and 5 females, from Iowa State University campus, were trained for 2 weeks on campus prior to the sensory evaluation tests. For the final evaluation, panelists were seated individually in isolated booths. A 6-inch (or 15 cm) line scale anchored with words (Appendix A) generated by the panelists was used. TSX02M, TSX02H, and TSX12H stored at 4°C, 25°C, 35°C, and 45°C for 28 days, 56 days, and 84 days were evaluated. The sensory attributes evaluated were aroma (toasted, beany, rancid, and overall intensity), appearance (lightness, and yellowness), flavor (sweetness, bitterness, toasted, beany, and rancid), and texture (mushy-crispy). Due to the possible bias by the difference in color, samples were served in opaque plastic cups and the panelists were asked not to look into the cups when they evaluated the attributes of aroma before they proceeded to evaluate other attributes (Appendix A).
The human subject research was approved by the Institutional Review Board (IRB) of Iowa State University. All the panelists were asked to sign the consent forms (Appendix B) before they proceeded to the study.

**Statistical analyses**

The statistical design is a randomized study of storage time, storage temperature, and soyflakes. Data are summarized graphically and are complemented by a one-way analysis of variance (ANOVA). Exploratory data analysis and linear models were conducted using a statistical computing environment called R (R Development Core Team 2004).

Antioxidant, rancidity, NSI, FFA, and protein had limited data points. The difference between temperatures and types at day 84, and differences between day 0 and day 84 averaged over all temperatures and types were investigated using ANOVA followed by the post hoc comparison using Tukey’s HSD procedure when there was a significant difference among groups. A $p < 0.05$ was considered significant.

OAC, WHC, and color measurements were modeled with a linear model incorporating day, temperature and type effects with all interactions. A $p < 0.05$ was considered significant.

**RESULTS AND DISCUSSION**

**Water holding capacity**

The change of water holding capacity (WHC) was significantly different ($p < 0.05$) averaged over all temperatures and types, which showed a decreasing trend for each type with the fastest being TSX02H (Figure 1). Temperature was not a factor in the changes, which could be explained by the completion of temperature induced changes during the toasting treatment or changes had not occurred in such a short period of storage. There were
significant differences among types (p < 0.05) with the highest and lowest being TSX02M and TSX12H, respectively. The highest WHC of TSX02M may be due to the least extent of protein denaturation due to the lower toast level. During heat treatment, protein denatures which exposes more nonpolar regions, thus becomes more hydrophobic (Tanford 1973). The lowest WHC of TSX12H may be explained by the thickness, which prevented some of the protein from getting contact with water. Study results from Narayan and others (1988) indicated that the losses in hygroscopicity of proteins and carbohydrates during storage might result in decreased water absorption during soaking.

**Oil absorption capacity**

The change of oil absorption capacity (OAC) (Figure 2) was significantly different (p < 0.05) averaged over all temperatures and types. There was no difference in all temperatures, which indicates that temperature was not a factor in the changes. There was difference in all types (p < 0.05). Due to the random distribution of data, there was no clear trend observed. Model shows the trends of the raw data of each type at each temperature. However, because of the low regression coefficient ($R^2 < 0.7$), there was no correlation between OAC and storage time for all types.

**Color**

The change of “L” (Figure 3) was not significantly different averaged over all temperatures and types, which indicates that there was no change over storage time. Study (Narayan and others 1988) showed that the color of the beans darkened with the increase of the storage time, which may be explained by the enzymatic and non-enzymatic browning reactions. Toasted soyflakes in this study did not show major changes in lightness, which may be explained by the completion of non-enzymatic browning reaction during toasting.
treatment or a shorter storage period of time in this study compared with other soybean storage studies (Salo and others 1980; Saio and others 1982; Narayan and others 1988; Thomas and others 1989; Lambrecht and others 1996; Hou and Chang 1998, 2004). TSX02M was significantly different in lightness comparing with the other two samples. TSX02M was the lightest among all, which was indicated by the highest “L” value (Figure 3). The lighter color of TSX02M could be explained by the low toast level, during which non-enzymatic browning reaction occurred to a lesser extent compared with the high toast level. The plots in model also showed no changes over storage time for each type.

The change of “a” was not significantly different averaged over all temperatures and types, which indicates that there was no change over storage. The plots in model also showed no changes over storage for each type. TSX02M had the lowest “a” value.

The change of “b” was significantly different averaged over all temperatures and types (P < 0.05). The plots in model showed a decreasing trend for all types with faster decrease at higher temperature. TSX02M had the highest “b” value.

**Antioxidant capacity**

Because each data point was from only one measurement, the statistical analyses were done in a way to compare the types when averaged over temperatures, or to compare the temperatures when averaged over types. There were differences among temperatures (p < 0.05) and types (p < 0.05) at day 84 (Table 1). There was no difference between day 0 and day 84 averaged over all temperatures and types. When averaged over all temperatures, there were significant differences between TSX02H and TSX02M (p < 0.05), between TSX02H and TSX12H (p < 0.05), but no significant difference between TSX02M and TSX12H. TSX02H had the highest antioxidant concentration among all the samples. When averaged
over types, there was no significant difference between 4°C and 25°C, while there was significant difference between 25°C and 35°C (p < 0.05), and between 25°C and 45°C (p < 0.05). The antioxidant capacity decreased with the increase of temperature with the lowest at 45°C. Due to limited data points, no further statistical statements could be made. When looking at the samples individually, antioxidant capacity of each sample showed a decreasing trend when comparing day 84 with day 0 (Table 1). Also, each sample showed decreased antioxidant capacity at day 84 with the increasing of temperature, with the lowest at 45°C (Table 1). The study by Kuan and Wilson (2005) showed increased antioxidant capacity of stored beans, which were not toasted. However, those beans were stored at high temperature and relative humidity, and the beans were sampled every 3 months during the storage time. Thus, no data is available from their study for the changes in the antioxidant capacity during the first 3 months. Humidity also played an important role in their study, which does not apply to our study. In our study, the antioxidant capacity data agreed with the rancidity data below.

2-thiobarbituric acid (TBA) rancidity

Because each data point was from only one measurement, the statistical analyses were done in a way to compare the types when averaged over temperatures, or to compare the temperatures when averaged over types. There were differences among temperatures (p < 0.05) and types (p < 0.05) at day 84 (Table 2). There was no difference between day 0 and day 84 averaged over all temperatures and types. When averaged over all temperatures, there were significant differences between TSX02H and TSX02M (p < 0.05), between TSX02H and TSX12H (p < 0.05), but no significant difference between TSX02M and TSX12H. TSX02H had highest rancidity among all the samples. When averaged over types, there was
no significant difference between 4°C and 25°C, while there was significant difference between 25°C and 35°C (p < 0.05), and between 25°C and 45°C (p < 0.05). Rancidity increased with the increase of temperature with the highest at 45°C. Due to limited data points, no further statistical statements could be made. When looking at the samples individually, rancidity of each of the three samples showed an increasing trend when comparing day 84 with day 0. Also, the rancidity of each sample at day 84 increased with the increasing of temperature with the highest at 45°C (Table 2). The lowest rancidity of TSX02M may be due to its lower toast level, which has lower oxidation effect. TSX02H and TSX12H are high toasted, thus both had higher rancidity than TSX02M although the difference between TSX12H and TSX02M was not significantly different. TSX12H is thicker than TSX02H, thus TSX12H has less surface area due to its higher thickness and is probably less prone to oxidation than TSX02H, which explains the lower rancidity of TSX12H than TSX02H.

The increasing trends of rancidity in all the samples agreed with the decreasing trends of antioxidant concentration, which could be explained by the depletion of antioxidants by the oxidation during the storage and under heat stress. There were also correlations between the antioxidant concentration and rancidity, the R values are 0.96, 0.95, and 0.94 (Figure 4) for TSX02M, TSX02H, and TSX12H, respectively. Therefore, the PhotoChem antioxidant capacity could be used to predict the rancidity.

Sensory data showed major increase of rancid aroma and rancid flavor at 45°C (Figure 5a, 5b, 5c), thus the shelf life of each of the three samples stored at 25°C (Table 3a) and 35°C (Table 3b) was calculated based on the days needed to reach the rancidity of sample at day 84 at 45°C. TSX02M had lowest rate constant and thus, longest shelf life at
25°C, while TSX12H had longest shelf life at 35°C. Toasted aroma and toasted flavor showed major decrease at 45°C (Figure 5a, 5b, 5c), which could be explained by the masking effect of increasing rancid aroma and rancid flavor, or chemical breakdown of the toasted aromas due to oxidation.

The rate constants of all samples at 25°C, 35°C and 45°C (Table 4a) were calculated from the sensory data. The duration of time (Mizrahi 2000) needed for samples to reach a specific intensity of rancid aroma and rancid flavor, when stored at those temperatures, could thus be predicted (Table 4b, 4c). For rancid aroma, TSX02M had longest shelf life at 25°C, while TSX02H had longest shelf life at 35°C (Table 4b). For rancid flavor, TSX12H had longest shelf life at both 25°C and 35°C (Table 4c), which could be explained by its thickness, which resulted in less exposure to oxidation due to less surface area comparing with the thinner flakes.

Figure 6 shows the Arrhenius plots of the toasted aroma of TSX02H and TSX12H due to the correlation at 25°C, 35°C and 45°C (R-squares are 0.8282, 0.9664 and 0.9460 for TSX02H, and 0.9616, 0.8655 and 0.8677 for TSX12H). Given the high R values, which are 0.82 and 1 for TSX02H and TSX12H, respectively, the rate constant of toasted aroma of these two samples at storage temperature can be calculated using the equations given in Figure 6, thus the shelf life of toasted aroma at specific temperature can be predicted when the starting and expected toasted aroma intensity are given. The activation energy (Ea) was calculated using slope = Ea/R, thus the Ea was 11.72 KJ/mol and 41.73 KJ/mol for the toasted aroma of TSX02H and TSX12H, respectively. Therefore, TSX12H was less prone to toasted aroma loss than TSX02H, which agrees with the longest shelf life of TSX12H for rancid flavor.
Free fatty acids

Because each data point was from only one measurement, the statistical analyses were done in a way to compare the types when averaged over temperatures, or to compare the temperatures when averaged over types (Table 5). There were differences among types (p < 0.05) while there was no difference among temperatures at day 84. There was difference between day 0 and day 84 averaged over all temperatures and types. When averaged over all temperatures, there were significant differences between TSX02M and TSX02H (p < 0.05), between TSX02M and TSX12H (p < 0.05), but no significant difference between TSX02H and TSX12H. TSX02H and TSX12H had higher FFA compared with TSX02M. When averaged over types, there was no significant difference among temperatures. Due to limited data points, no further statistical statements could be made. When looking at the samples individually, TSX02M seemed to decrease as storage proceeded and did not show difference among temperatures at day 84. Both TSX02H and TSX12H did not have major changes over storage time and at each of the storage temperatures at day 84. Storage studies on soybeans (Narayan and others 1988; Hou and Chang 1998) showed that FFA increased over time, which was attributed to the hydrolytic changes in fat components. However, those soybeans were stored at high temperature along with relative humidity. The humidity in our study was very low (about 11%), which may explain the little change in FFA in the toasted flakes. The higher FFA of TSX02H and TSX12H could be explained by the higher oxidation effect by the high toast level, which resulted in more FFA from the breakdown of oxidation products. The FFA of TSX02M at day 0 was higher compared with day 84, which may be explained by the loss of volatile free fatty acids during storage.
Nitrogen solubility index

Because each data point was from only one measurement, the statistical analyses were done in a way to compare the types when averaged over temperatures, or to compare the temperatures when averaged over types (Table 6). There were significant differences among types (p < 0.05) while there was no difference among temperatures at day 84. There was no difference between day 0 and day 84 averaged over all temperatures and types. When averaged over all temperatures, there were significant differences between TSX02M and TSX02H (p < 0.05), between TSX02M and TSX12H (p < 0.05), but no significant difference between TSX02H and TSX12H. TSX02H and TSX12H had lower NSI compared with TSX02M. When averaged over types, there was no significant difference among temperatures, which could be explained by the completion of reaction during the toasting treatment. Due to limited data points, no further statistical statements could be made. When looking at the samples individually, NSI of each of the three samples decreased over storage period of time. NSI of each sample also decreased with the increase of temperature at day 84. Tanford (1973) indicated that more nonpolar regions of protein were exposed as the protein denatures, which decreases the solubility of protein. Heat treatment denatures protein and thus insolubilizes soy proteins rapidly (Smith and Circle 1978). The decrease in NSI in stored soybeans at high temperatures is observed in some storage studies (Saio and others 1980; Saio and others 1982; Narayan and others 1988; Thomas and others 1989; Lambrecht and others 1996). TSX02M had the highest NSI, which could be explained by the lower toast level, which indicates less heat treatment and thus less denature in protein.
Protein

Because each data point was from only one measurement, the statistical analyses were done in a way to compare the types when averaged over temperatures, or to compare the temperatures when averaged over types. There was no difference between types. There was no difference between temperatures at day 84. There was no difference between day 0 and day 84 averaged over all temperatures and types. Due to limited data points, no further statistical statements could be made. When looking at the samples individually (Table 7), there was no major change. This could be explained by the test method used, which was protein combustion, thus no nitrogen lost was expected.

Sensory evaluation

TSX02M was the lightest in color (Figure 7), which agreed with the instrumental results discussed above. Lightness ("L") did not change over time or at different temperatures, which was also consistent with the instrumental test results. Rancid aroma became stronger at higher temperature, especially at 45°C, and also with the storage proceeded (Figure 5). Rancid flavor showed major increase at 45°C, and also increased with the increase of storage time (Figure 5). Both toasted aroma and toasted flavor decreased at 45°C, and showed decreasing trends over storage time (Figure 5), which may be due to the masking effect by the increasing rancid aroma and rancid flavor.

CONCLUSIONS

Storage of soybeans has been studied extensively (Saio and others 1980; Saio and others 1982; Narayan and others 1988; Thomas and others 1989; Lambrecht and others 1996; Hou and Chang 1998, 2004). However, there is limited research study in literature on the quality change of toasted soyflakes due to its new arrival on the market. Our study showed
that higher storage temperature did not have a major impact on water hydration capacity and oil absorption capacity. However, storage temperature had a more significant effect on antioxidant capacity and rancidity. Furthermore, storage duration affected WHC, antioxidant capacity, rancidity, and NSI. Neither storage temperature or storage period affected lightness. Sensory evaluations were a good tool to help understanding the data from the chemistry tests. Temperature higher than 25°C is not recommended for shipping or storage mainly due to the quality change by rancidity. Medium toast level retained better quality than did the high toast level due to less heat treatment. Our study also showed the potential of using antioxidant capacity to predict the rancidity due to the high correlations between them.

Further studies need to be carried out on the effect of both humidity and storage temperature on the shelf life of toasted soyflakes. A longer storage period of time may be desirable too. More samples, such as TSX12M, could be introduced into future studies. Overall, quality changes of stored toasted soyflakes should be evaluated in food systems to obtain the information on acceptability to consumers, thus to determine the maximum storage period of time.

REFERENCES


The stability and shelf-life of food. Boca Raton: CRC Press LLC.


Niu S, Mitchell DC, Litman BJ. 2005. Trans fatty acid derived phospholipids show increased membrane cholesterol and reduced receptor activation as compared to their cis analogs. Biochem. 44:4458-65.


changes during model storage studies. Cereal Chem. 57(2):77-82.


Table 1. Antioxidant capacity of TSX02M, TSX02H, and TSX12H at day 0 and day 84

<table>
<thead>
<tr>
<th>Sample</th>
<th>Antioxidant Capacity (µg/mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 0</td>
</tr>
<tr>
<td></td>
<td>4°C°a*</td>
</tr>
<tr>
<td>TSX02M**</td>
<td>1.82</td>
</tr>
<tr>
<td>TSX02H°</td>
<td>2.60</td>
</tr>
<tr>
<td>TSX12H°</td>
<td>1.82</td>
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*Antioxidant capacity at temperature with different letter code showed significant differences (p < 0.05), same letter code showed no significant differences when averaged over types.

**Types with different letter code showed significant differences (p < 0.05), same letter code showed no significant differences when averaged over temperatures.
Table 2. 2-thiobarbituric acid (TBA) rancidity of TSX02M, TSX02H, and TSX12H at day 0 and day 84

<table>
<thead>
<tr>
<th>Sample</th>
<th>TBA Rancidity (mg/Kg)</th>
<th>Day 0</th>
<th>Day 84</th>
<th>Day 84</th>
<th>Day 84</th>
<th>Day 84</th>
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<tbody>
<tr>
<td></td>
<td>4°C&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25°C&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35°C&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45°C&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSX02M&lt;sup&gt;***&lt;/sup&gt;</td>
<td>1.4</td>
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<td>2.8</td>
<td>4.4</td>
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<tr>
<td>TSX02H&lt;sup&gt;y&lt;/sup&gt;</td>
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<td>2.3</td>
<td>2.8</td>
<td>4.0</td>
<td>6.4</td>
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</tr>
<tr>
<td>TSX12H&lt;sup&gt;x&lt;/sup&gt;</td>
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<td>1.8</td>
<td>2.2</td>
<td>2.8</td>
<td>5.2</td>
<td></td>
</tr>
</tbody>
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*TBA rancidity at temperature with different letter code showed significant differences (p < 0.05), same letter code showed no significant differences when averaged over types.

**Types with different letter code showed significant differences (p < 0.05), same letter code showed no significant differences when averaged over temperatures.
Table 3a. The prediction of shelf life of TSX02M, TSX02H, and TSX12H at 25°C to reach the rancidity at day 84 at 45°C

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rancidity at day 84 at 45°C (mg/kg)</th>
<th>Rancidity at day 0 (mg/kg)</th>
<th>Rate constant K at 25°C (mg/kg/day)</th>
<th>Days needed (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSX02M</td>
<td>4.4</td>
<td>1.4</td>
<td>0.005</td>
<td>600</td>
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<tr>
<td>TSX02H</td>
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<td>1.8</td>
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<tr>
<td>TSX12H</td>
<td>5.2</td>
<td>1.7</td>
<td>0.006</td>
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</tr>
</tbody>
</table>

Table 3b. The prediction of shelf life of TSX02M, TSX02H, and TSX12H at 35°C to reach the rancidity at day 84 at 45°C

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rancidity at day 84 at 45°C (mg/kg)</th>
<th>Rancidity at day 0 (mg/kg)</th>
<th>Rate constant K at 35°C (mg/kg/day)</th>
<th>Days needed (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSX02M</td>
<td>4.4</td>
<td>1.4</td>
<td>0.017</td>
<td>176</td>
</tr>
<tr>
<td>TSX02H</td>
<td>6.4</td>
<td>1.8</td>
<td>0.026</td>
<td>177</td>
</tr>
<tr>
<td>TSX12H</td>
<td>5.2</td>
<td>1.7</td>
<td>0.013</td>
<td>269</td>
</tr>
</tbody>
</table>
Table 4a. The rate constants of sensory rancid aroma and flavor of TSX02M, TSX02H, and TSX12H at 25°C, 35°C, and 45°C.

<table>
<thead>
<tr>
<th></th>
<th>TSX02M</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k at 25°C</td>
<td>k at 35°C</td>
<td>k at 45°C</td>
</tr>
<tr>
<td>Attribute (mg/kg/day)</td>
<td>(mg/kg/day)</td>
<td>(mg/kg/day)</td>
<td>(mg/kg/day)</td>
</tr>
<tr>
<td>Rancid aroma</td>
<td>0.001</td>
<td>0.0025</td>
<td>0.0217*</td>
</tr>
<tr>
<td>Rancid flavor</td>
<td>0.0062</td>
<td>0.0069*</td>
<td>0.0192</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>TSX02H</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k at 25°C</td>
<td>k at 35°C</td>
<td>k at 45°C</td>
</tr>
<tr>
<td>Attribute (mg/kg/day)</td>
<td>(mg/kg/day)</td>
<td>(mg/kg/day)</td>
<td>(mg/kg/day)</td>
</tr>
<tr>
<td>Rancid aroma</td>
<td>0.0057</td>
<td>0.0014</td>
<td>0.0268*</td>
</tr>
<tr>
<td>Rancid flavor</td>
<td>0.0062</td>
<td>0.0029</td>
<td>0.0202*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>TSX12H</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k at 25°C</td>
<td>k at 35°C</td>
<td>k at 45°C</td>
</tr>
<tr>
<td>Attribute (mg/kg/day)</td>
<td>(mg/kg/day)</td>
<td>(mg/kg/day)</td>
<td>(mg/kg/day)</td>
</tr>
<tr>
<td>Rancid aroma</td>
<td>0.0035</td>
<td>0.0059</td>
<td>0.0352*</td>
</tr>
<tr>
<td>Rancid flavor</td>
<td>0.00008</td>
<td>0.0022</td>
<td>0.0374*</td>
</tr>
</tbody>
</table>

* R-square value > 0.7
Table 4b. The prediction of shelf life of TSX02M, TSX02H, and TSX12H at 25°C and 35°C to reach the rancid aroma at day 84 at 45°C using the sensory data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rancid aroma at day 84, 45°C</th>
<th>Rancid aroma at day 0</th>
<th>K at 25°C</th>
<th>Days needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSX02M</td>
<td>4.93</td>
<td>1.54</td>
<td>0.0010</td>
<td>3390</td>
</tr>
<tr>
<td>TSX02H</td>
<td>3.85</td>
<td>1.69</td>
<td>0.0057</td>
<td>379</td>
</tr>
<tr>
<td>TSX12H</td>
<td>4.93</td>
<td>2.32</td>
<td>0.0035</td>
<td>746</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rancid aroma at day 84, 45°C</th>
<th>Rancid aroma at day 0</th>
<th>K at 35°C</th>
<th>Days needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSX02M</td>
<td>4.93</td>
<td>1.54</td>
<td>0.0025</td>
<td>1356</td>
</tr>
<tr>
<td>TSX02H</td>
<td>3.85</td>
<td>1.69</td>
<td>0.0014</td>
<td>1543</td>
</tr>
<tr>
<td>TSX12H</td>
<td>4.93</td>
<td>2.32</td>
<td>0.0059</td>
<td>442</td>
</tr>
</tbody>
</table>
Table 4c. The prediction of shelf life of TSX02M, TSX02H, and TSX12H at 25°C and 35°C to reach the rancid flavor at day 84 at 45°C using the sensory data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rancid flavor at day 84, 45°C</th>
<th>Rancid flavor at day 0</th>
<th>K at 25°C</th>
<th>Days needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSX02M</td>
<td>3.77</td>
<td>2.05</td>
<td>0.0062</td>
<td>227</td>
</tr>
<tr>
<td>TSX02H</td>
<td>3.36</td>
<td>1.66</td>
<td>0.0062</td>
<td>274</td>
</tr>
<tr>
<td>TSX12H</td>
<td>1.88</td>
<td>1.88</td>
<td>0.00008</td>
<td>37375</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rancid flavor at day 84, 45°C</th>
<th>Rancid flavor at day 0</th>
<th>K at 35°C</th>
<th>Days needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSX02M</td>
<td>3.77</td>
<td>2.05</td>
<td>0.0069</td>
<td>249</td>
</tr>
<tr>
<td>TSX02H</td>
<td>3.36</td>
<td>1.66</td>
<td>0.0029</td>
<td>586</td>
</tr>
<tr>
<td>TSX12H</td>
<td>1.88</td>
<td>1.88</td>
<td>0.0022</td>
<td>1359</td>
</tr>
</tbody>
</table>
Table 5. Free fatty acid content of TSX02M, TSX02H, and TSX12H at day 0 and day 84

<table>
<thead>
<tr>
<th>Sample</th>
<th>Free Fatty Acid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 0</td>
</tr>
<tr>
<td></td>
<td>4°C</td>
</tr>
<tr>
<td>TSX02M**</td>
<td>0.7</td>
</tr>
<tr>
<td>TSX02H‡</td>
<td>0.5</td>
</tr>
<tr>
<td>TSX12H‡</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*FFA at temperature with same letter code showed no significant differences when averaged over types.

**Types with different letter code showed significant differences (p < 0.05), same letter code showed no significant differences when averaged over temperatures.
Table 6. Nitrogen solubility index of TSX02M, TSX02H, and TSX12H at day 0 and day 84

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0</th>
<th>Day 84</th>
<th>Day 84</th>
<th>Day 84</th>
<th>Day 84</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4°C&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25°C&lt;sup&gt;a&lt;/sup&gt;</td>
<td>35°C&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45°C&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>TSX02M***</td>
<td>56.9</td>
<td>51.5</td>
<td>54.9</td>
<td>48.4</td>
<td>40.5</td>
</tr>
<tr>
<td>TSX02H&lt;sup&gt;y&lt;/sup&gt;</td>
<td>20.6</td>
<td>18.5</td>
<td>19.7</td>
<td>17.8</td>
<td>14.6</td>
</tr>
<tr>
<td>TSX12H&lt;sup&gt;y&lt;/sup&gt;</td>
<td>27.1</td>
<td>22.1</td>
<td>23.1</td>
<td>21.9</td>
<td>24</td>
</tr>
</tbody>
</table>

*NSI at temperature with same letter code showed no significant differences when averaged over types.

**Types with different letter code showed significant differences (p < 0.05), same letter code showed no significant differences when averaged over temperatures.
Table 7. Protein content of TSX02M, TSX02H, and TSX12H at day 0 and day 84

<table>
<thead>
<tr>
<th>Sample</th>
<th>Day 0</th>
<th>Day 84</th>
<th>Day 84</th>
<th>Day 84</th>
<th>Day 84</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>4°C³</td>
<td>25°C³</td>
<td>35°C³</td>
</tr>
<tr>
<td>TSX02M*</td>
<td>41.18</td>
<td>41.25</td>
<td>41.44</td>
<td>41.18</td>
<td>41.06</td>
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<tr>
<td>TSX02H*</td>
<td>40.37</td>
<td>41.39</td>
<td>41.21</td>
<td>40.35</td>
<td></td>
</tr>
<tr>
<td>TSX12H*</td>
<td>41.94</td>
<td>39.68</td>
<td>38.76</td>
<td>39.00</td>
<td>41.03</td>
</tr>
</tbody>
</table>

*Protein at temperature with the same letter code showed no significant differences when averaged over types.

**Types with the same letter code showed no significant differences when averaged over temperatures.
Figure 1. Water hydration capacity (ml/g) at 0, 14, 28, 42, 56, 70, and 84 days over the 84-day storage period of time. “All” graph are the plots of the raw data; “By temp” are plots when data are averaged over types; “By type” are plots when data are averaged over temperatures; “Model” are the plots showing the trends of the raw data of each type at each temperature. Blue = 4°C, Yellow = 25°C, Orange = 35°C, Red = 45°C, + = TSX02M, --Δ = TSX02H, --× = TSX12H.
Figure 2. Oil absorption capacity (g oil/g) at 0, 14, 28, 42, 56, 70, and 84 days over the 84-day storage period of time. “All” graph is the plots of the raw data; “By temp” are plots when data are averaged over types; “By type” are plots when data are averaged over temperatures; “Model” are the plots showing the trends of the raw data of each type at each temperature. Blue = 4°C, Yellow = 25°C, Orange = 35°C, Red = 45°C, ⋅⋅ = TSX02M, −Δ = TSX02H, = −× = TSX12H.
Figure 3. Color “L”, “a”, and “b” of TSX02M, TSX02H, and TSX12H at 0, 14, 28, 42, 56, 70, and 84 days over the 84-day storage period of time. L =100 lightness and L = 0 darkness; a = + red and a = - green; b = + yellow and b = - blue. Blue = 4°C, Yellow = 25°C, Orange = 35°C, Red = 45°C, + + = TSX02M, --Δ = TSX02H, ---× = TSX12H.
Figure 4. The correlation between antioxidant capacity and TBA rancidity at day 84 at 4°C, 25°C, 35°C, and 45°C.
Figure 5a. The sensory rancid and toasted attributes of TSX02M at 25°C, 35°C, and 45°C over the 84-day storage period of time.
Figure 5b. The sensory rancid and toasted attributes of TSX02H at 25°C, 35°C, and 45°C over the 84-day storage period of time.
Figure 5c. The sensory rancid and toasted attributes of TSX12H at 25°C, 35°C, and 45°C over the 84-day storage period of time.
Figure 6. The Arrhenius plot of toasted aroma of TSX02H and TSX12H.
Figure 7. Sensory lightness of TSX02M, TSX02H, and TSX12H at 4°C, 25°C, 35°C, and 45°C over the 84-day storage period of time.
THE APPLICATION OF TOASTED SOYFLAKES IN BREAD

A paper to be submitted to the Journal of Food Science

L. Yan, L.A. Wilson

ABSTRACT

The smooth texture, sweet nutty flavor, and nutrition value of toasted soyflakes make them potential ingredients in the bakery products such as bread. In this study, wheat flour was substituted by intact MicroSoy toasted flakes TSX02M at 5%, 10%, and 15% levels in bread. Crust color was darker with the increasing amount of soyflakes with 15% substitution being the darkest. The lightness of crumb color was not different between the control and 5% or between 10% and 15%. However, 10% and 15% were darker than the control and 5%. There was no difference in volume between the control and 5%, or between 10% and 15%. The volumes of 10% and 15% were lower compared with those of the control and 5%. There was no difference in hardness. Consumer tests showed that the control bread and 5% soy fortified bread scored the highest in liking of overall appearance. There were no difference in scores for all breads in liking of overall flavor, and liking of overall texture.

INTRODUCTION

Because of the health benefits of soy foods, there has been an increase in the soy consumption in human foods. The market for soy-based foods in the U.S. grew to $4 billion in 2003 (Soyatech 2004). Toasted soyflakes are a patented new product. They have smooth texture and sweet nutty flavor. Furthermore, the toasting procedure reduces the beany flavor normally seen in soy flour or raw soyflakes. Therefore, toasted soyflakes can be used as an
ingredient in many food products, such as cereal, yogurt, ice cream toppings, pie crusts, and bakery products.

Wheat flour will develop elastic dough when mixed with water. The elasticity is a restoring force, which tends to return the material to its original dimensions when the material is extended. Gluten is the mixture of proteins responsible for visco-elastic dough properties (Singh and MacRitchie 2001). Gluten is composed of two major proteins glutenin and gliadin. Glutenin contributes to the dough strength and elasticity (Belton 1999), while gliadin is responsible for the viscosity to the dough (Khatkar and others 1995). The oxidation of cystein residues of protein results in the formation of disulfide bridges, which are the most remarkable linkages in creating elasticity (Goesaert and others 2004), although interchain hydrogen bonding also plays a role in the association of high molecular weight subunits of proteins (Belton 1999). The quantity and quality of gluten proteins largely determine the rheological properties of the optimally mixed dough, which thus have effect on the gas retention properties of the fermenting dough (Gan and others 1995). Gas retention is the factor that contributes to the loaf volume and crumb structure of the resulting bread.

The addition of foreign proteins may weaken the wheat flour dough due to the dilution of the gluten structure (Knorr and Betschart 1978), thus to have a negative effect on the quality of bread, such as lower loaf volume and harder crumb. Soy products do not have gluten, thus the replacement of wheat flour by soy products may weaken a gluten network. King and others (2001) showed that bread made with 20% soy flour had greater yellow color. Results from studies (Tsen and Hoover 1973; Shah and others 1986; Doxastakis 2002) indicated that substitution of full-fat soy flour resulted in bread with decreased loaf volume, poorer crumb texture, and darkened crust color. Studies (Tsen and Hoover, 1973; Doxastakis
2002) also observed increased water absorption and increased mixing time with the addition of soy flour in breadmaking.

The objectives of this study were to investigate changes in dough properties when wheat flour is partially substituted by toasted soyflakes in breadmaking and to evaluate the consumer acceptance of the toasted soyflakes containing bread.

MATERIALS AND METHODS

Samples

Commercial full-fat toasted soyflakes TSX02M were provided by MicroSoy Corp. (Jefferson, IA). TSX02M is the medium toasting level soyflakes with the thickness of 0.2 mm. Samples were kept in 20-kg heat sealed polyethylene-paper lined bags.

Pillsbury bread wheat flour (General Mills, Minneapolis, MN), salt, sugar, yeast, and shortening were purchased from HyVee, a local grocery store.

Study design

Control and 5%, 10%, and 15% soyflakes containing breads were prepared at the same day. One batch of each sample, which produced 4 loaves, was baked. One loaf of each sample was randomly selected to determine weight, volume, color and texture the following day, on which the consumer test was also conducted. There were three replicates on weight, volume, color and texture of samples, which were baked on three different days. Consumer tests were also conducted on three separate days.

Dough properties

A 10-gram Mixograph (Lincoln, NE, USA) operated with MixSmart Version 4.0 was used to analyze dough property. Procedures in the Mixograph Handbook were followed.
Optimum water absorption and peak mixing time were determined from the graphs obtained from Mixograph.

**Breadmaking**

Preliminary study showed that soyflakes substitution level higher than 15% was not acceptable due to dark crumb color and strong beany flavor, thus 15% was set as the highest substitution level for this study. 600 g bread wheat flour was placed in the mixing bowl for making control bread or wheat flour and toasted soyflakes at 5%, 10%, and 15% replacements were mixed together for making treatment breads. Then a well was made in the middle of the flour. Melted shortening (25 g) was poured in the well, followed by predissolved 45 g sugar and 4 g salt, and then 5 g yeast which was grown in 200 g warm water for 10 minutes. A dough mixer (KitchenAid, Michigan, USA) was used and the speed was set at “2”. Flour mixes with different levels of soy addition were mixed at respective peak mixing time obtained from the Mixograph. After mixing, dough was placed in a greased bowl to let ferment for 1 hour. The dough was then cut into four loaves of approximate equivalent weight and placed in greased loaf pans, which underwent fermentation for another 1 hour. Then the loaves were baked in a conventional oven for 25 minutes at 400°C. The loaves were removed from the pans and cooled on a wire rack. After cooling, loaves were wrapped in foil and plastic bags and stored at room temperature until sensory evaluation and measurements the following day.

**Color**

A handheld MiniScan XE Plus (HunterLab, Reston, VA, USA) was used to determine color. Data is reported as Hunter L, a, b, where “L” indicates lightness with 0 is black and 100 is white, “a” indicates red-green with positive values are red and negative values are
green, and “b” indicates yellow-blue with positive values are yellow and negative values are blue.

**Texture**

A TA-XT2 Texture Analyzer with a 36mm cylinder probe (Texture Technologies Corp., New York, USA) was used. The bread firmness was determined using the AACC (74-09) standard method. Three 25mm thick slices from each bread sample were obtained for analysis. The crust was cut off before the compression test. The firmness was expressed in g force.

**Volume**

Volumes of loaves of bread were determined by rapeseed displacement.

**Sensory evaluation**

Consumer tests were conducted in the Food Science Building on ISU campus. Sensory evaluation procedures described by Lawless and Heymann (1998) were followed in this sensory study. 85 participants from Iowa State University campus participated this study. A box scale (Appendix C) was used, each box of which was assigned a number for statistical analyses. The sensory attributes evaluated were overall appearance, overall flavor and overall texture. Participants were also asked to note the favorite and least favorite samples.

The human subject research was approved by the Institutional Review Board (IRB) of Iowa State University. All the participants were asked to sign the consent forms before they proceeded to the study.
Statistical analyses

The instrumental data was analyzed using a two-way analysis of variance (ANOVA). For each variable of the sensory data, a mixed model was fitted with panelist as a random effect and treatment as a fixed effect.

RESULTS AND DISCUSSION

Dough properties

Substitution of 5% toasted soyflakes for wheat flour did not change the water absorption compared with the control (Table 1). Substitution of 10% and above increased water absorption, however, 10% and 15% had the same water absorption. The peak dough mixing time was increased by toasted soyflake substitution and it was increased the most by 15% substitution. Substitution of 10% had shorter peak mixing time compared with 5% substitution. The increased water absorption and increased mixing time are consistent with what other researchers found in their study of breadmaking with addition of soy flour (Tsen and Hoover 1973; Doxastakis 2002).

Bread quality

There was significant difference in crust lightness (p < 0.05) (Table 2). The lightness decreased with the addition of soyflakes, as well as with the increasing amount of soyflakes. There was significant difference in the crumb lightness among samples (Table 2). 10% and 15% soy substitution had darker crumb than control and 5%. However, there was no difference between 10% and 15%, as well as between control and 5%.

The volume of soyflakes bread decreased compared with that of control. The volume also decreased with the increasing amount of soyflakes substitution. There was significant difference in volume among samples (Table 3). There was no difference in volume between
control and 5% soy substitution, as well as between 10% and 15%. There was no significant difference in the hardness among all samples (Table 3).

**Consumer acceptance**

There was no difference in scores of liking of overall appearance (Table 4) for control and 5%, as well as for 10% and 15%. Control and 5% scored higher than 10% and 15%. This indicates that 5% soyflakes substitution does not noticeably change the appearance of the bread compared with control. The scores of intensity of appearance (Table 4) indicated that the soy fortified breads were darker than the control, and 10% and 15% were darker than 5%. However, panelists did not detect the difference between 10% and 15%.

There was no difference in scores of liking of overall flavor (Table 5) among all the samples. However, the scores of flavor intensity (Table 5) showed that there was an increasing trend in control, 5%, 10%, and 15% bread although there was no significant difference between control and 5%, as well as between 10% and 15%.

There was no difference in liking of overall texture (Table 6) among all the samples. There was no difference in texture intensity (Table 6) either. Overall, 35% of the consumers liked the control bread the most, while 65% liked any level soyflakes bread the most, which indicated that most people preferred soy breads over control bread in this study.

**CONCLUSIONS**

The addition of toasted soyflakes darkened the crust and crumb color of bread. The crust color also darkened more with the increasing amount of toasted soyflakes. In this study, 5% toasted soyflakes substitution did not change the crumb color compared with control. However, there was noticeable crumb color change with 10% or higher soyflakes substitution although 10% and 15% darkened the crumb color to the same level.
Substitution of toasted soyflakes decreased the volume of bread. Substitution of 5% did not change the volume compared with control. Substitution of 10%, as well as 15%, decreased the volume although 10% and 15% decreased the volume to the same extent. Substitution of soyflakes up to 15% did not change the hardness of the bread.

Our study indicates that the appearance, flavor, and texture of 5% toasted soyflakes added bread are not different comparing with those of control bread. Furthermore, more consumers preferred soyflakes containing bread over control bread. Thus, there is a high potential of using toasted soyflakes in breadmaking in improving the nutritional value with acceptable appearance, flavor and texture.

REFERENCES


Table 1. Optimum water absorption and peak mixing time of the dough (on a 300 g flour or flour and toasted soyflakes mix basis) for control and treatment breads

<table>
<thead>
<tr>
<th>Sample</th>
<th>Optimum water absorption</th>
<th>Peak mixing time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>165</td>
<td>3.6</td>
</tr>
<tr>
<td>Toasted soyflakes 5%</td>
<td>165</td>
<td>4.1</td>
</tr>
<tr>
<td>Toasted soyflakes 10%</td>
<td>180</td>
<td>4.0</td>
</tr>
<tr>
<td>Toasted soyflakes 15%</td>
<td>180</td>
<td>5.6</td>
</tr>
</tbody>
</table>
Table 2. Crust and crumb color “L” of control and treatment breads

<table>
<thead>
<tr>
<th>Sample</th>
<th>Crust “L”*</th>
<th>Crumb “L”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>42.35 ± 1.51a**</td>
<td>74.75 ± 1.01x</td>
</tr>
<tr>
<td>Toasted soyflakes 5%</td>
<td>36.01 ± 2.49b</td>
<td>74.95 ± 1.28x</td>
</tr>
<tr>
<td>Toasted soyflakes 10%</td>
<td>33.63 ± 2.24c</td>
<td>69.45 ± 0.33y</td>
</tr>
<tr>
<td>Toasted soyflakes 15%</td>
<td>29.41 ± 0.37d</td>
<td>69.37 ± 2.30y</td>
</tr>
</tbody>
</table>

*L = 100 indicates lightness and L = 0 indicates darkness

**Means in each column with different letter code showed significant differences (p < 0.05), means in each column with the same letter code showed no significant differences.

Table 3. Volume and hardness of control and treatment breads

<table>
<thead>
<tr>
<th>Sample</th>
<th>Volume cm³</th>
<th>Hardness g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>570.33 ± 39.72a*</td>
<td>1341.25 ± 202.00x</td>
</tr>
<tr>
<td>Toasted soyflakes 5%</td>
<td>542.33 ± 18.50a</td>
<td>1338.60 ± 210.50x</td>
</tr>
<tr>
<td>Toasted soyflakes 10%</td>
<td>509.67 ± 8.96b</td>
<td>1712.08 ± 93.30x</td>
</tr>
<tr>
<td>Toasted soyflakes 15%</td>
<td>494.00 ± 32.42b</td>
<td>1766.35 ± 214.20x</td>
</tr>
</tbody>
</table>

*Means with different letter code showed significant differences (p < 0.05), means with the same letter code showed no significant differences.
Table 4. Sensory scores for overall appearance of control and treatment breads

<table>
<thead>
<tr>
<th>Sample</th>
<th>Liking*</th>
<th>Intensity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.65a**</td>
<td>3.01x</td>
</tr>
<tr>
<td>Toasted soyflakes 5%</td>
<td>6.44a</td>
<td>3.80y</td>
</tr>
<tr>
<td>Toasted soyflakes 10%</td>
<td>5.93b</td>
<td>5.36z</td>
</tr>
<tr>
<td>Toasted soyflakes 15%</td>
<td>6.01b</td>
<td>5.54z</td>
</tr>
</tbody>
</table>

*Numbers are out of a scale from 1-9 with 1 indicates dislike extremely and 9 indicates like extremely for liking, with 1 indicates light and 9 indicates dark for intensity.

**Means in each column with different letter code showed significant differences (p < 0.05), means in each column with the same letter code showed no significant differences.

Table 5. Sensory scores for overall flavor of control and treatment breads

<table>
<thead>
<tr>
<th>Sample</th>
<th>Liking*</th>
<th>Intensity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.26a**</td>
<td>4.24x</td>
</tr>
<tr>
<td>Toasted soyflakes 5%</td>
<td>5.91a</td>
<td>4.39x</td>
</tr>
<tr>
<td>Toasted soyflakes 10%</td>
<td>5.67a</td>
<td>5.07y</td>
</tr>
<tr>
<td>Toasted soyflakes 15%</td>
<td>5.71a</td>
<td>5.39y</td>
</tr>
</tbody>
</table>

*Numbers are out of a scale from 1-9, with 1 indicates dislike extremely and 9 indicates like extremely for liking, with 1 indicates light and 9 indicates dark for intensity.

**Means in each column with different letter code showed significant differences (p < 0.05), means in each column with the same letter code showed no significant differences.
Table 6. Sensory scores for overall texture of control and treatment breads

<table>
<thead>
<tr>
<th>Sample</th>
<th>Liking*</th>
<th>Intensity*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.28$^{a**}$</td>
<td>5.26$^x$</td>
</tr>
<tr>
<td>Toasted soyflakes 5%</td>
<td>5.92$^a$</td>
<td>5.15$^x$</td>
</tr>
<tr>
<td>Toasted soyflakes 10%</td>
<td>5.78$^a$</td>
<td>5.46$^y$</td>
</tr>
<tr>
<td>Toasted soyflakes 15%</td>
<td>6.00$^a$</td>
<td>5.40$^y$</td>
</tr>
</tbody>
</table>

*Numbers are out of a scale from 1-9, with 1 indicates dislike extremely and 9 indicates like extremely for liking, with 1 indicates dry and 9 indicates moist for intensity.

**Means in each column with different letter code showed significant differences (p < 0.05), means in each column with the same letter code showed no significant differences.
PREDICTION OF TOFU COLOR FROM THE COLOR OF SOYBEANS
AND SOYFLAKES

A paper to be submitted to the Journal of Food Science

L. Yan and L.A. Wilson

ABSTRACT

The color relationships among soybeans, soyflakes, and respective tofu made from soybeans and soyflakes were investigated. 100 g of each of the 15 different soybeans and their soyflakes were used to make tofu using traditional Japanese method. Color of soybeans and soyflakes, along with their respective tofu, was measured. Data was reported as Hunter L, a, b. Simple linear regression and multiple regressions were used to determine relationships. There were correlations between the “L” of flakes and flake tofu ($R^2 = 0.86$), and between the “b” of flakes and flake tofu ($R^2 = 0.70$). There was strong correlation between the color of flake tofu and bean tofu ($R^2 = 0.83, 0.73, 0.72$ for L, a, and b, respectively). Multiple regression shows that flakes L and b are good predictors of bean tofu L, and beans L and b are good predictors of flake tofu, with $R^2 = 0.84$ and $0.92$, respectively. These relationships will allow seed company and soyfood processors to select beans and soyflakes that will produce predictable tofu color.

INTRODUCTION

Traditionally, soymilk, tofu, and other soy foods are produced from soybeans. As a patented product, MicroSoy® flakes (MicroSoy, Jefferson, IA), is gaining more attention and interest in their applications both in the traditional soymilk and tofu processing and many
other food applications. The advantages of utilizing flakes in soymilk and tofu production are less water usage and shortened processing duration due to the skipping of soaking and grinding steps, which are required for the whole soybeans. Moizuddin and others (1999a) reported that utilization of full-fat soyflakes in the soymilk processing saved 62-65% water compared with the traditional utilization of soybeans, and the hydration time needed was shortened to 10 minutes for flakes compared with the 12 hours for the soybeans. Their results also showed that the tofu made from flakes and soybeans showed no difference in lightness or redness. There was a slight difference in yellowness but it could not be differentiated visually.

It is a common practice to attempt to identify the soybean characteristics that can be used in predicting the end product quality of soy foods. Studies (Saio 1979; Wang and others 1983; Johnson and Wilson 1984; Lim and others 1990; Schaefer and Love 1992; Wang and Chang 1995; Moizuddin and others 1999b) have focused on the effects of cultivars or processing conditions (such as concentration of coagulants, temperature, etc) of soybeans on the yield and quality of tofu. However, there has been limited research on the prediction of tofu color by the soybean or soyflakes color. Wilson and others (2004) found that different soybean cultivars produced different color tofu, and soybeans with clear hilum and seedcoat produced lighter color tofu. Wilson and others (2005) showed similar results, which indicated that the color of tofu was affected by the color of seedcoat, hilum, and cotyledon. Sensory study (Moizuddin and Wilson 2006) showed that sensory panelists could detect color change in the end products such as tofu when the colored soybeans are present at concentration as low as 1%. Therefore, to define an appropriate model equation based on the correlations among the color of soybean, the color of soyflakes counterpart, and the tofu produced
therefrom, would be useful to the tofu manufacturers in selecting the soybeans or soyflakes counterpart with desired color to optimize the final tofu products.

The objectives of this study were to investigate the relationships in color among soybeans, soyflakes, and respective tofu made from soybeans and soyflakes, thus to provide appropriate model equations for predicting the color.

**MATERIALS AND METHODS**

**Samples**

Fifteen companion soybeans and soyflakes from different grower, location, variety, and blend (Appendix D) were provided by MicroSoy Corp. (Jefferson, IA). All the samples were stored in 20-kg heat sealed polyethylene-paper lined bags at room temperature until the day of tofu processing.

**Study design**

Soybeans and soyflakes color was measured at the beginning of the processing. Then soybeans and soyflakes were processed to make tofu. The color of tofu was measured right after the tofu was made. For each soybeans/soyflakes pair, two separate batches of tofu were made to obtain the duplicate data. All the processing was conducted in the sensory kitchen in Food Sciences Building at Iowa State University.

**Tofu processing procedure**

The method by Moizuddin and others (1999b) was modified for kitchen scale tofu production. When soybeans were used, 100 g whole soybeans were soaked in 1000 mL of water for 12 hours. Then the soaked soybeans were drained, rinsed under running water and weighed. Processing water needed was calculated as 1000 g – (weight of soaked soybeans – 100 g). About 400 g of the processing water was added to soaked soybeans in a blender (GE,
Fairfield, CT) and then it was ground for 20 seconds with the speed set at “Hi” and setting at “liquify”. The slurry was poured into a saucepan. The remaining processing water was used to rinse the blender and then poured into the same saucepan. The slurry was heated with continuous stirring until it reached 95°C, which then was held for 7 minutes. Then okara was separated by squeezing the soymilk out of a commercial soybean press bag. The solid content of soymilk was measured using a handheld refractometer. The weight of soymilk was measured. Calcium sulfate dihydrate (CaSO₄·2H₂O) was used as a coagulant, the amount needed to coagulate the soymilk was calculated as N x Tv x M, where N is the normality of calcium sulfate dihydrate, Tv is the total volume (L) of soymilk to be coagulated, and M is the half molar weight of calcium sulfate dihydrate (86.0g). Calcium sulfate dihydrate was dissolved in small amount of water. Then the soymilk was heated to 85°C in the same saucepan, after which the coagulant was mixed in and then left undisturbed for 10 minutes. The curd was then broken and poured into a lined 100 g tofu press box. The total weight placed to press tofu was 2.55 kg. During the first 15 minutes, 1.34 kg weight was used and then the remaining weight to total 2.55 kg was added on for the second 15 minutes. The tofu was weighed and placed in cold water before the color was measured. When soyflakes were used to make tofu, the same procedure was followed except that there was no soaking and grinding, and the amount of processing water was 1000 g. Each sample was analyzed in duplicate.

Color

LabScan XE spectrophotometer (HunterLab, Reston, VA) was used with Universal Software®4.1. A port size 1.2 inch, area view of 1.00 inch and D65/10 (Illuminant/Standard Observer) were set for the measurement of the color of samples. Samples were placed into 60
x 15 mm plastic petri dishes (Fisher Scientific, Fair Lawn, NJ). Data is reported as Hunter L, a, b, where “L” indicates lightness with 0 is black and 100 is white, “a” indicates red-green with positive values are red and negative values are green, and “b” indicates yellow-blue with positive values are yellow and negative values are blue.

Statistical analyses

Relationships between colors of soybeans, soyflakes, and tofus from bean and tofus from flakes were investigated with a series of linear regressions showing the relationship between the color attributes for each pair of interest. Relationships were also investigated with multiple regressions with adjusted R².

RESULTS AND DISCUSSION

There was no strong correlation between the “L” of beans and “L” of the tofu made therefrom as indicated by R² = 0.41 (Figure 1). The correlation was expressed as “L” of tofu made from beans = -69.2 + 1.45 x of beans L. There was no correlation as to “a” and “b” (R² = 0.045 and 0.016, respectively).

There was a correlation between the “L” of flakes and “L” of the tofu made therefrom as indicated by a R² = 0.86 (Figure 2). The correlation is expressed as “L” of tofu made from flakes = -0.671 + 0.928 x flakes L. There was also correlation for “b” (R² = 0.70). The prediction of the “b” of tofu made from flakes was 14.1 + 0.814 x flakes b. However, there was no correlation for “a” due to a low R² value (0.17).

There was no strong correlation between the companion beans and flakes as to the “L”, “a”, and “b”, the R² of which are 0.37, 0.059, and 0.15 (Figure 3), respectively. However, there was strong correlation between the flake tofu and bean tofu, the R² of which was 0.83, 0.73, and 0.72 for L, a, and b, respectively (Figure 4).
Multiple regression analyses show that flakes L and b are good predictors of bean tofu, with $R^2 = 0.83$. The prediction can be expressed as beans tofu L $= 5.58 + 0.91 \times$ flakes L $+ 0.16 \times$ flakes b. Beans L and b are good predictors of flake tofu L ($R^2 = 0.92$). The prediction can be made using flakes tofu L $= 14.93 + 0.88 \times$ beans L $+ (-0.39) \times$ beans b. The bean tofu b can be predicted using beans tofu b $= 23.96 + (-0.21) \times$ flakes L $+ 0.49 \times$ flakes b ($R^2 = 0.70$). The flake tofu b can be predicted using flakes tofu b $= 23.89 + (-0.27) \times$ beans L $+ 1.07 \times$ beans b, with $R^2 = 0.70$. However, due to the small sample size, no further statistical statement could be made.

**CONCLUSIONS**

There was no correlation between the lightness of soybeans and the beans tofu. However, there was relatively strong correlation between the lightness of companion soyflakes and the tofu made therefrom. There was also strong correlation between the flakes tofu and beans tofu. Thus, the predictions can be made by using the equations provided. Because multiple regression analyses account for the variables, they are good predictors of the correlations.

These relationships will allow seed companies and soy food processors to select soybeans and soyflakes that will produce predictable tofu color. However, more work needs to be done to validate mathematical models for predicting tofu color. More samples should be included in the future study for more possible correlations, which may not be observable in this study due to limited sample size.

**REFERENCES**


Moizuddin S, Wilson LA. 2006. Influence of Seed Coat Color on the Quality of Soymilk and Tofu. (Personal communication)


Wilson LA, French SJ, Perchonok M. 2005. Use of irradiation as a HACCP, CCP step for bulk soybeans prior to their transit to Mars: influence on microbial load,
functional properties, and yield of soymilk and tofu. ICES 2005-01-2925: 16-29
Figure 1. Correlations of color “L”, “a”, and “b” between beans and beans tofu. L =100 lightness and L = 0 darkness; a = + red and a = - green; b = + yellow and b = - blue.
Figure 2. Correlations of color “L”, “a”, and “b” between flakes and flakes tofu. L =100 lightness and L = 0 darkness; a = + red and a = - green; b = + yellow and b = - blue.
Figure 3. Correlations of color “L”, “a”, and “b” between beans and flakes. L = 100 lightness; a = + red and a = - green; b = + yellow and b = - blue.
Figure 4. Correlations of color “L”, “a”, and “b” between flakes tofu and beans tofu. L =100 lightness and L = 0 darkness; a = + red and a = - green; b = + yellow and b = - blue.
CONCLUSIONS

This storage study showed that storage duration instead of storage temperature has a major impact on water hydration capacity, oil absorption capacity, nitrogen solubility index of toasted soyflakes of various thickness and toast level. The lightness of toasted soyflakes is not affected either by storage temperature or storage period of time. However, antioxidant capacity and rancidity are affected by both storage temperature and storage duration. Sensory evaluations are good tool in observing the acceptability of the soyflakes at different stage of the storage. Temperature higher than 25°C is not recommended for shipping or storage mainly due to the quality change by rancidity. Medium toast level seems to retain better quality compared with the high toast level. Further studies need to be carried out on the effect of both humidity and storage temperature on the shelf life of toasted soyflakes. A longer storage period of time may be desirable too. Due to limited funding, TBA rancidity, free fatty acids, NSI, and protein were only measured in one replicate, thus, no statistical statements could be made on the observed results. Therefore, duplicate analyses are necessary in the future research. Such analyses on samples during the storage are also desirable to be able to investigate clearly the trends of change. More samples, such as TSX12M, could be introduced into future studies, thus to allow more complete comparisons which make possible conclusions drawing on whether type or toast level has more significant impact on the quality changes during storage. Overall, quality changes of stored toasted soyflakes should be evaluated in food systems to obtain the information on acceptability to consumers, thus to determine the maximum storage period of time.

In breadmaking, when some of the wheat flour is replaced by toasted soyflakes, both the crust and crumb color of bread are darkened. The crust color also darkens more with the
increasing amount of toasted soyflakes. The toasted soyflakes substitution also decreases the
volume of bread. The hardness of the bread remains the same with different levels of
soyflakes substitution up to 15%. Overall, bread with 5% soyflakes substitution does not
change in the crust color, crumb color, volume, and texture compared with control bread, and
5% substitution is also acceptable to consumers. Thus, there is high potential of using toasted
soyflakes at a proper amount, such as 5%, in breadmaking in improving the nutritional value
with acceptable appearance, flavor and texture.

The regression and multiple regression indicate color correlations among raw
soybeans, raw soyflakes, and respective tofu made from soybeans and soyflakes. Thus, it is
possible to predict the tofu color from raw soybeans or raw soyflakes color. However, more
work needs to be done to establish mathematical models for predicting tofu color. More
samples should be included in the future study for more possible correlations, which may not
be observable in this study due to limited sample size.
APPENDIX A. LINE SCALE

Please taste the coded samples in each set the order presented, from left to right. Evaluate the attributes of each sample by placing a small vertical line across the horizontal line at the position that best describes what you perceive or taste (please put the code of sample on the respective lines you place on the horizontal line).

AROMA: smell the sample by lifting up one corner of the lid with eyes closed or without looking into the cup.

<table>
<thead>
<tr>
<th></th>
<th>Weak</th>
<th>Strong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toasted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beany</td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td>Rancid</td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td>Overall intensity</td>
<td>Weak</td>
<td>Strong</td>
</tr>
</tbody>
</table>

APPEARANCE (Color): take the lid off completely and observe the color.

<table>
<thead>
<tr>
<th></th>
<th>Light</th>
<th>Dark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yellow</td>
<td>Brown</td>
</tr>
</tbody>
</table>

FLAVOR: put the sample in your mouth. Expectorate the sample if you want to. Rinse your mouth with water and have a bite of cracker before evaluating the next sample.

<table>
<thead>
<tr>
<th></th>
<th>Weak</th>
<th>Strong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweetness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bitterness</td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td>Toasted</td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td></td>
<td>Weak</td>
<td>Strong</td>
</tr>
<tr>
<td>------------</td>
<td>------</td>
<td>--------</td>
</tr>
<tr>
<td>Beany</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rancid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEXTURE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mushy</td>
<td></td>
<td>Crispy</td>
</tr>
</tbody>
</table>

Comments (you can use the back of this sheet of paper):
APPENDIX B. INFORMED CONSENT DOCUMENT

Title of Study: Shelf life study of toasted MicroSoyflakes.

Investigators: Lester A. Wilson, Ph. D., Professor, Iowa State University, Department of Food Science and Human Nutrition, 2312 Food Sciences Building, Ames, IA 50011-1061. Phone: (515)-294-3889; Fax: (515)-294-8181; E-mail: lawilson@iastate.edu

Introduction: This study is to evaluate the flavor and texture of MicroSoyflakes at various toasted levels at different storage periods.

Description of procedures: Each of the total 9 sessions takes about 15 minutes. During this study, the following procedures will be followed: You will be asked if you are allergic to soy protein and other ingredients in the food products being tested. Then you will be asked to sign the consent form before the study starts. You will be served samples of toasted MicroSoyflakes and asked to evaluate the flavor and texture/mouthfeel of each product. The food products will be prepared using the standard procedures in CCUR pilot plant.

Risks: No risk is expected from these food products. You should not participate in this study if you are allergic to soy proteins, or any other ingredients in the foods that we will use. You will be given an ingredient list for each product prior to testing.

Benefits: This study will not benefit the participants directly but it is hoped that the information gained from this study will benefit society by the possible broad applications of MicroSoyflakes, which provide healthy and nutritious soy foods to consumers. 25 grams of soy protein a day, as part of a diet low in saturated fat and cholesterol, may reduce the risk of heart disease.

Costs and compensations: There will not be any costs for you to participate in this study. You will be compensated for participating in this study. You will be rewarded with the treat at the end of each sensory session and paid $30 at the end of the completed sessions.

Participant rights: Your participation in this study is complete voluntary and you may refuse to participate or withdraw from the study at any time. If you decide not to participate in the study or withdraw, it will not result in any penalty. You can also ask whenever you have questions.

Research injury: Emergency treatment of any injuries that may occur as a direct result of participation in this research is available at the Iowa State University Thomas B. Thielen Student Health Center, and/or referred to Mary Greeley Medical Center or another physician or medical facility at the location of the research activity. Compensation for any injuries will be paid if it is determined under the Iowa Tort Claims Act, Chapter 669 Iowa Code. Claims for compensation should be submitted on approved forms to the State Appeals Board and are available from the Iowa State University Office of Risk Management and Insurance.
Confidentiality: Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information. To ensure confidentiality to the extent permitted by law, the following measures will be taken: you will be assigned a unique code, which will be used on forms instead of your name. The record of the study will be kept with the student and the professor involved in the study. The results of the study will be kept secure by a password protected computer. Paper surveys will be destroyed at the end of the study. If the results are published, your identity will remain confidential.

Questions or problems: You are encouraged to ask questions at any time during this study. For further information about the study, please contact Dr. Lester A. Wilson at 294-3889 or Like Yan at 294-1873. If you have any questions about the rights of research subjects or research-related injury, please contact the Human Subjects Research Office, 2810 Beardsheer Hall, (515) 294-4566; austingr@iastate.edu or the Research Compliance Officer, Office of Research Compliance, 2810 Beardsheer Hall, (515) 294-3115; clament@iastate.edu

SUBJECT SIGNATURE

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered.

Subject’s Name (printed) ___________________________________________

(Subject’s Signature) ___________________________________________ (Date)

[Include the Parent/Guardian/Legally Authorized Representative signature line only if applicable to your study.]

(Signature of Parent/Guardian or Legally Authorized Representative) __________________________________________________________________________ (Date)

INVESTIGATOR STATEMENT

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.
(Signature of Person Obtaining Informed Consent)
<table>
<thead>
<tr>
<th>Sample code</th>
<th>Date</th>
<th>Overall appearance</th>
<th>Liking</th>
<th>Intensity/Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Dislike extremely</td>
<td>Neither Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dislike extremely</td>
<td>Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall flavor</td>
<td>Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dislike extremely</td>
<td>Neither Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall texture</td>
<td>Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dislike extremely</td>
<td>Neither Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dislike extremely</td>
<td>Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample code</td>
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<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample code</td>
<td>Like nor dislike</td>
<td>Light</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Date</th>
<th>Overall appearance</th>
<th>Liking</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Dislike extremely</td>
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<td>Light</td>
</tr>
<tr>
<td></td>
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<td>Light</td>
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<tr>
<td></td>
<td></td>
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<td>Like nor dislike</td>
<td>Light</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dislike extremely</td>
<td>Neither Like nor dislike</td>
<td>Light</td>
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<td></td>
<td></td>
<td>Dislike extremely</td>
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<td>Light</td>
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<tr>
<td></td>
<td></td>
<td>Overall texture</td>
<td>Like nor dislike</td>
<td>Light</td>
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<td></td>
<td></td>
<td>Dislike extremely</td>
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<td>Like nor dislike</td>
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<tr>
<td></td>
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<td>Sample code</td>
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<tr>
<td></td>
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## Sample code

<table>
<thead>
<tr>
<th>Liking</th>
<th>Intensity/Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dislike</td>
<td>Neither</td>
</tr>
</tbody>
</table>
| extremely | Like 
| nor dislike | extremely |

**Overall appearance**

- Dark

**Overall flavor**

- Dark

**Overall texture**

- Moist

---

**Overall, which sample do you like the most?**

**Why?**

**Which sample do you like the least?**

**Why?**

**Other comments:**
## APPENDIX D. COMPANION SOYBEANS AND SOYFLAKES

<table>
<thead>
<tr>
<th>Code</th>
<th>Grower</th>
<th>Location</th>
<th>Blend</th>
<th>Variety</th>
<th>Blend</th>
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<tr>
<td>X104Ja</td>
<td>Citurs Peterson/Morgan</td>
<td>Scranton/Jamaica/Correctionville</td>
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<td>Golden Country/Farm Advantage</td>
<td>75%/ 25%</td>
</tr>
<tr>
<td>X252Jb</td>
<td>Midwest Soya</td>
<td>Mason City</td>
<td>100%</td>
<td>Pioneer</td>
<td>100%</td>
</tr>
<tr>
<td>X147Jb</td>
<td>Rincker/Morgan</td>
<td>Ogden/Correctionville</td>
<td>70%/30%</td>
<td>Garst/Farm Advantage</td>
<td>70%/ 30%</td>
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<tr>
<td>X245Ja</td>
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<td>Mason City</td>
<td>100%</td>
<td>Vinton Scalpings</td>
<td>100%</td>
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<tr>
<td>X142Jb</td>
<td>Hefty</td>
<td>Bradgate</td>
<td>100%</td>
<td>Pioneer</td>
<td>100%</td>
</tr>
<tr>
<td>X252Ja</td>
<td>Midwest Soya/Nora Springs</td>
<td>Mason City</td>
<td>50%/50%</td>
<td>Pioneer/IA State</td>
<td>50%/</td>
</tr>
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<tr>
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<td>Lane/Blomgren-Brewer</td>
<td>Humboldt/Boone-Perry</td>
<td>60%/40%</td>
<td>IA State/Pr bnd-Asgrow/Asgrow</td>
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