EFFECT OF HYDRATED SODIUM CALCIUM ALUMINOSILICATE ON THE PHYSICAL PROPERTIES OF TWO DIFFERENT PEANUT BASED FOOD SYSTEMS.

By

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CHAPTER I

INTRODUCTION

In many developing countries, the supply of animal protein is inadequate to meet the protein needs of their rapidly growing population. This has resulted in research efforts directed toward the study of the food properties and potential utilization of protein from locally available food crops, especially from underutilized or relatively neglected high protein oilseeds and legumes (Giami *et al*., 2005). Also, the enrichment of cereal-based foods with oilseed protein has received considerable attention (Akubor and Badifu, 2004). Among oilseeds and legumes, peanuts (*Arachis hypogaea* L.) have a unique flavor that develops upon roasting and are also a good source (20-30%) of protein (Misra, 2004). Peanuts can be utilized in a variety of ways and can also be consumed directly. Thus, they occupy a unique position among oilseeds (Misra, 2004).

The use of peanuts in food is widespread (Palomar *et al*., 1994), including cookies and peanut paste. Cookies are baked products low in moisture and many of them contain a high percentage of sugar and fat (Adair *et al*., 2001). They were first introduced to the New World with Dutch and English settlers, but Americans have truly made them their own (Judy, 2004). Cookies have been suggested as a good use of composite flours due to their ready-to-eat form, wide consumption, relatively long shelf-life and good eating quality (McWatters *et al*., 2003; Giami *et al*., 2005). In many developing countries cookies are

widely accepted and consumed and, therefore, offer a valuable vehicle for supplementation with oilseed/legume flours for nutritional improvement (Giami *et al*., 2005). Thus protein enriched cookies look attractive for target areas, such as child-feeding programs, low income groups and disaster relief operations (Giami *et al*., 2005). Cookies with high sensory ratings have been produced from blends of wheat/cowpea, kinema and wheat, wheat/safflower, millet/pigeon pea, greengram, bengalgram, blackgram and wheat, raw rice and wheat, peanut, cowpea and wheat and soybean, chickpea or lupine with wheat (McWatters *et al*., 2003; Giami *et al*., 2005). Also, high protein cookies have been prepared from such composite flours such as wheat flour fortified with soy flour, cotton seed flour, sesame seed flour and pigeon pea flour (Akubor and Badifu, 2004).

One-half of the edible peanuts produced in the US are marketed as peanut butter and peanut spread. Peanut butter as defined by U.S. law, must contain at least 90% peanuts. Similar products which do not conform to the 90% rule are labeled as peanut spreads, many of which contain reduced fat and added vitamins and minerals. With the growing demand for reduced-calorie foods, novel peanut products are being developed (Clavero *et al.,* 2000).

A variety of foods, including peanut products may be contaminated with aflatoxins (Mayura *et al*., 1998). Aflatoxins are a structurally similar group of naturally occurring, harmful fungal byproducts and are strongly implicated in diseases and death of humans and animals (Bingham *et al.*, 2004). They are produced primarily by *Aspergillus flavus* and *Aspergillus parasiticus* molds. Among all the aflatoxins, aflatoxin B_1 (AfB_1) has generated

much concern due to its carcinogenicity (Mayura *et al*., 1998). Aflatoxin B_1 has been implicated as a factor in human liver cancer and classified as a Group 1 human carcinogen. The major source of exposure to aflatoxins is via the ingestion of contaminated food and feed. Thus, these poisons can be found as natural contaminants (sometimes in very high concentrations) in various foodstuffs, e.g., peanut butter and other peanut products, breakfast cereals, corn and cornmeal, dairy products, and some processed foods (Mayura *et al*., 1998). Various silicate clays are frequently added to animal feeds as enterosorbents to bind and reduce the bioavailability of mycotoxins. Phyllosilicate clays have been successfully added to animal feeds to bind aflatoxins in the gastrointestinal tract and subsequently prevent aflatoxicosis of farm animals (Wiles *et al*., 2004). In 2004, the US Food and Drug Administration approved use of the Novasil^{TM} brand of hydrated sodium calcium aluminosilicated (HSCAS) as an entersorbent for humans (personal communication, Dr Tim Phillips, Texas A&M University).

In the food and feed industries, silicates (e.g. calcium silicate) have traditionally been used as anticaking agents, i.e. to facilitate free flow (McWilliams, 2005). HSCAS is a common anticaking additive (at 0.5%) in animal feeds (Hinds *et al*., 2004). In the animal studies mentioned above, HSCAS was administered typically in slurry form or mixed with dietary components prior to feedings. Similar administering practices may not be aesthetically acceptable to humans, but incorporation of HSCAS into food products is an appropriate alternative (Hinds *et al*., 2004). However, because of the moisture binding properties of silicates, the potential effects of HSCAS on quality parameters of food products needs to be evaluated.

The general aim of this study was to evaluate the effect of hydrated sodium calcium aluminosilicate (HSCAS) on physical properties of several formulations of two different peanut based food systems namely, cookie stix and peanut paste. The term cookie stix is used to describe experimental cookies developed from a typical standard sugar cookie formulation. The cookie stix were narrow long cookies ranging in length from 5.0 to 5.2 cm, a width ranging from 2.0 to 2.1 cm and thickness ranging from 0.7 to 0.71 cm. A central ridge of 0.5 cm running length wise on the upper surface of the cookie was also present. Peanut paste is a common food product or ingredient worldwide, especially in developing countries. This study is part of a project funded by USAID – Peanut Collaborative Research Support Program (PCRSP), one objective of which is technology transfer to developing countries, such as Ghana, West Africa. Also, other collaborators in a related USAID-PCRSP are investigating the efficacy of HSCAS to bind aflatoxin when it is an ingredient in various processed peanut based products.

Objectives of the study

- To study the effects of HSCAS and peanut flour on the following properties of several formulations of cookie stix stored at 25°C and 35°C.
    (i) Texture (hardness and crunchiness)
    (ii) Total moisture (%)
    (iii) Water activity (A_w)
    (iv) Color (L value, chroma and hue angle)

- To study the effects of HSCAS and sugar on the following properties of several formulations of peanut paste stored at 25°C and 35°C.
    (i) Texture (firmness and adhesiveness)
    (ii) Water activity (A_w)
    (iii) Color (L value, chroma and hue angle)

Null hypotheses

Cookie stix

H1: Texture (hardness and crunchiness) will not be affected by addition of HSCAS and peanut flour.

H2: Total moisture will not be affected by addition of HSCAS and peanut flour.

H3: Water activity (A_w) will not be affected by addition of HSCAS and peanut flour.

H4: Color (L value, chroma and hue angle) will not be affected by addition of HSCAS and peanut flour.

Peanut paste

H1: Texture (firmness and adhesiveness) will not be affected by addition of HSCAS and sugar.

H2: Water activity (A_w) will not be affected by addition of HSCAS and sugar.

H3: Color (L value, chroma and hue angle) will not be affected by addition of HSCAS and sugar.

CHAPTER II

REVIEW OF LITERATURE

Overview of peanuts

Peanut (*Arachis hypogaea* L.) also called groundnut or earthnut (Olajide and Igbeka, 2003), is an ancient crop which was widely grown in Mexico, Central America and South America in pre-Colombian times (Stalker, 1997). Early Spanish and Portuguese explorers, however, were instrumental in distributing seeds of the domesticated species to the Old World. From Brazil the original two-seeded types were taken to Africa whereas three-seeded types originally from Peru were transported from the west coast of South America to China and islands in the western Pacific. In Europe, the Spanish varieties which were introduced in the late 1700s from Brazil, were primarily used for oil and human consumption. In North America the first successful introductions were small-seeded peanuts with a runner growth habit, and these introductions were probably from northern Brazil or the West Indies that were used as food supplies on ships carrying slaves from Africa to the New World (Stalker, 1997).

Peanut is grown around the world in tropical, sub-tropical and warm temperate climates. About 13.5 million ha are grown in Asia, 5.3 million ha in Africa, 1.2 million ha in the Americas, and 0.1 million ha in other parts of the world (Stalker, 1997). Because prices on the international commodity market favor the sale of peanuts as edible seeds,

most of the crop in the U.S. and South America is sold for consumption as food (Stalker, 1997). In addition to seeds, the foliage is an important fodder in regions where animals are used extensively on the farm, and the meal remaining after oil extraction is also an important source of animal feed (Stalker, 1997). About two-thirds of the total peanuts produced in the world, are utilized in the US, China and India (Misra, 2004). Peanuts are an important source of proteins and contribute considerably to the diets of humans and livestock (Olajide and Igbeka, 2003). They serve as an important oilseed, confectionary and livestock feed, particularly for small scale farmers in semi-arid regions of India and Africa (Craufurd *et al*., 2003) who are among the largest producers of the crop (Stalker, 1997). Throughout the world peanut is the third-most abundantly cultivated oilseed and contributes significantly toward the economy of some developing countries (Olajide and Igbeka, 2003). Several cereal and legume-based food products are made with peanut protein to overcome malnutrition in developing countries. The sensory attributes of peanut flour or meal on its own or when incorporated into food products have been found to be desirable (Singh and Singh, 1991).

The peanut seed has from 36 to 54% oil, and more than half of the global crop is grown as an oilseed. However, as major producers become self-sufficient for oil production, a larger percentage of the peanut seed crop is consumed directly by humans. In the United States approximately 60% of production is consumed as food (Stalker, 1997) by processing it for direct consumption as peanut butter, salted peanuts and confectionary. The peanut cake, a by-product of the crushing industry, is generally used as a livestock feed supplement (Misra, 2004).

In the US, peanuts are grown in nine states, roughly divided into two geographic regions, the Southeast (Goergia, Alabama, Florida, Virginia, North Carolina, South Carolina) and the southwest (Texas, Oklahoma, New Mexico) (Didzbalis *et al*., 2004). Most commercial varieties of peanuts are indeterminate plants, producing fruit over the entire growing period. This means that at harvest, pods are in all stages of maturity (Didzbalis *et al*., 2004) and the seed maturation is important to all aspects of the peanut industry (Young *et al.*, 2004). Changes in composition and cellular structure influence the processing quality of the seed (Young *et al*., 2004). Crop value is affected by the physiological and structural changes occurring during maturity. Thus, several studies have been conducted to establish a seed maturity index for peanuts to better understand the physiological and structural changes during maturation (Sanders, Shubert and Pattee, 1982). During postharvest curing, the moisture level of peanuts must be reduced from 30% in fresh dug peanuts to approximately 10% to allow for safe storage (Didzbalis *et al*., 2004).

Composition of peanuts

Peanuts are characterized by high oil and protein contents and low percentages of carbohydrates and ash (Ahmed and Young, 1982). Peanut kernels contain approximately 45% to 50% oil, 25% to 30% protein, 8% to 12% carbohydrate, 5% water, 3% fiber, and 2.5% ash (Madhaven, 2001). Since peanuts are increasingly utilized in preparing novel and improved food products, a comprehensive knowledge of their composition and flavor is desirable (Ahmed and Young, 1982).

Oil content and fatty acid composition

The fatty acid and lipid composition affect the quality and flavor of peanuts and their products (Hinds, 1995), and environment as well as genotype have been reported to influence the fatty acid composition of peanuts (Misra, 2004). The oxidative stability of lipids is influenced by the curing treatments. For example, metabolism of radioactive lipids during curing were observed to be higher when peanut seeds were stored at 50^{o}C than when they were stored at 22^{o}C (Sanders, Schubert and Pattee, 1982). The eight major fatty acids in peanuts are palmitic (hexadecanoic, 16:0), stearic (octadecanoic, 18:0), oleic (cis-9-octadecenoic, 18:1), linoleic (cis 9 cis -12 octadecadienoic, 18:2), arachidic (eicosanoic, 20:0), eicosenoic (cis-11-eicosenoic, 20:1), behenic (docosanoic, 22:0) and lignoceric (tetracosanoic, 24:0) acids. Palmitic, stearic, oleic and linoleic acids make up about 96% of peanut triacylglycerols (Ahmed and Young, 1982). Conflicting trends have been observed for changes in fatty acid profiles as seeds mature (Hinds, 1995).

Oleic acid, with only one double bond in its chain, belongs to the group of monounsaturated fatty acids (MUFAs) while linoleic acid with two double bonds, belongs to the group of polyunsaturated fatty acids (PUFAs). PUFAs are more susceptible to oxidation, and the oxidized products are known to cause an unpleasant odor and taste, and also promote atherosclerosis. Thus, the contents of oleic acid and linoleic acid for the most part, determine the quality of groundnut oil (Misra, 2004).

In a study by Yoshida *et al.* (2005), fatty acid distributions of triacylglycerols (TAGs) and phospholipids (PLs) isolated from total lipids in peanut seeds were

investigated. It was found that the predominant lipid component was TAGs, while PLs were present in lesser quantities. Other lipids such as steroyl esters, free fatty acids (FFAs), and sn-1,3- and sn-1,2-diacylglycerols (DAGs) were minor ones (Yoshida *et al*., 2005).

High oleic acid in peanuts has been associated with a low degree of lipid oxidation during storage, and a low incidence of oxidation has been associated with more desirable flavors following roasting (Casini *et al.*, 2003). The ratio of oleic acid to linoleic acids (O/L), and the tocopherol content are important features in determining peanut seed shelf life (Casini *et al.*, 2003). Thus, quality and stability characteristics associated with peanuts and peanut products can now be better maintained due to an adaptation of the high oleic acid (>80%) trait into several new peanut cultivars (Talcott *et al*., 2005). Research has indicated that high-oleic roasted peanut seeds have more stable roasted peanut attributes as long as after 6 weeks of storage at 22^{o}C, and their estimated shelf life is about twice longer than that of normal-oleic seeds (Pattee *et al.*, 2002). Studies have also shown that the consumption of high-oleic acid peanuts has potential health benefits, such as lowered total and LDL cholesterol in hypercholesterolemic postmenopausal women on a low total fat, low saturated fat and high monounsaturated fatty acid diet (O'Byrne *et al*., 1997). The concentration of oleic acid in high-oleic acid peanuts is similar to that of olive oil (Talcott *et al.*, 2005).

Carbohydrates

Mature peanut kernels are reported to contain 9.5-19% carbohydrates where starch and sucrose are the major constituents (Madhaven, 2001). However, from a quality point of

view only sucrose, reducing sugars (glucose and fructose) and flatus sugars (raffinose and stachyose) are considered important (Madhaven, 2001). Among carbohydrates, sucrose is considered to be the most important sugar of peanut, wherein it imparts the sweet flavor to raw peanuts (Madhaven, 2001). Also, carbohydrates have been shown to be contributing precursors to the compounds imparting the roasted peanut characteristic (Pattee *et al.*, 2000). Sugars, especially the monosaccharides (glucose and fructose) react with the free amino acids during roasting to impart the characteristic flavor of roasted peanuts and also impart the nutty flavor (Misra, 2004; Ahmed and Young, 1982). Peanut skin contains 49% carbohydrate and 19% fiber (Madhaven, 2001). The flavor of the roasted peanut seed is an important characteristic influencing consumer acceptance (Pattee *et al*., 2000).

Individual components of the peanut carbohydrate fraction are said to change during maturation as well as during curing. They also change with seed size and over storage time, decrease with higher soil temperatures, and are known to vary among a limited number of genotypes (Pattee *et al*., 2000). It has been observed that a higher level of monosaccharides is likely to contribute to discoloration of the cooked product that occurs due to excessive browning (Misra, 2004). Stachyose and raffinose are considered noxious because they have been reported to adversely affect the taste and cause flatulence (Misra, 2004).

Protein and free amino acids

Peanuts are a good source (20-30%) of protein (Misra, 2004). Peanut proteins are classified as albumins (water soluble) or globulins (saline soluble). The albumin fraction contains agglutinins, lectin-reactive glycoproteins, protease inhibitors, alpha-amylase

inhibitors, and phospholipases. The globulin fraction is subdivided into arachin and conarchin fractions (Madhaven, 2001).

Although the protein content of peanuts is not given much importance for assessing the quality of the kernels, a high protein content is considered an added advantage from a nutrition perspective. The kernels contain a small quantity (0.20-0.50%) of free amino acids (Misra, 2004). As has been stated earlier, during roasting the free amino acids react with sugars especially the monosaccharides, and impart the characteristic color and nutty flavor of roasted groundnuts. Among the free amino acids, aspartic acid, glutamic acid, glutamine, asparagine, histidine and phenylalanine are associated with the production of the typical flavor of groundnut while threonine and tyrosine have been shown to be associated with development of atypical flavor (Misra, 2004).

Moisture

Cured peanuts have a moisture content of 5-7% which is considered ideal for processing. As the moisture content decreases, the chances of the seeds splitting during mechanical blanching increases, but on the other hand as the moisture content increases the chances of mold growth increase (Misra, 2004).

Minerals and Vitamins

Roasted peanuts have a higher mineral content than raw peanuts (Ahmed and Young, 1982). Peanuts also contain more potassium than sodium, and are good sources of potassium, phosphorus and magnesium. Peanuts have a negligible amount of vitamin A.

They have alpha, gamma and delta tocopherol, with gamma tocopherol being in highest concentrations. Thiamine occurs in peanut seeds in concentrations of about 1.0 mg/100g, while in the peanut seed testa its concentration is in excess of 3.8mg/100g (Ahmed and Young, 1982).

Flavor of peanuts

Traditional consumption of peanuts as whole nuts and peanut butter is based on the use of roasted peanut seeds (Sobolev, 2001). Peanuts have a pleasant and unique flavor that develops upon roasting, and the flavor of roasted peanuts is the integrated effect of genotype, production and handling, and storage and processing operations (Misra, 2004).

Several hundred compounds that contribute to the flavor have been identified in roasted peanuts (Ahmed and Young, 1982). It was found that the roasting period significantly influenced the strength of the odor and flavor of peanuts. Amino acids and carbohydrates are the precursors of the roasted peanut flavor (Ahmed and Young, 1982). They consist mainly of pyrazines, ketones, aldehydes, pyrroles, furans, terpenes, aromatic hydrocarbons, phenols and alcohols (Hinds *et al.*, 2005). In boiled peanuts, an HPLC analysis showed that the major volatile component of boiled peanut extract seemed to be vanillin (3-methoxy-4-hydroxybenzaldehyde) (Sobolev, 2001). A variety of descriptive words, including terms such as roasted groundnut, underoast, overroast, sweet, bitter salt, earthy, molasses, tongue/throatburn, painty, fruity, sour, nutty, astringent, woody/hulls/skins, mold, stale, and petroleum are used to describe the peanut flavor (Misra, 2004; Sanders *et al*., 1989).

Antioxidant benefits of peanuts

Research has established that there is an inverse relationship between dietary intake of antioxidant-rich foods and the incidence of human diseases (Yen *et al*., 2005). Therefore, studies on dietary intake of antioxidative compounds and the assay of the natural antioxidant source have attracted much attention (Yen *et al*., 2005). Peanut is a principal agricultural plant in the world and its antioxidative activity has been investigated. Studies have indicated that marked antioxidant activity and antimutagenic effect are found in peanut hulls, and the antioxidative component in hulls was identified as luteolin (Yen *et al*., 2005). Peanut kernels and peanut seed testa have also been shown to have antioxidant properties (Yen *et al*., 2005).

Phytoalexins are a group of low molecular weight secondary metabolites produced by plants as a defense response to biotic and abiotic stimuli including fungal infection, mechanical damage, and UV irradiation (Lee *et al*., 2004). Resveratrol (trans-3,5,4'-trihydroxystilbene) is one of the major stilbene phytoalexins found in various families of plants, and, peanuts, grapes and their products are considered the most important dietary sources of resveratrol (Sanders, *et al*., 2000). Its association with reduced cardiovascular disease and reduced cancer risk has provoked a lot of interest possibly due to its anti-proliferative and antioxidative activities (Lee *et al*., 2004).

In one study, resveratrol was identified as an excellent chemopreventive substance, based on its safety and efficacy in animal studies (Stewart *et al*., 2003). It was also associated with reduced risk of cardiovascular disease by inhibiting or altering platelet

aggregation and coagulation, or modulating lipoprotein metabolism (Nepote *et al*., 2005). The presence of resveratrol in peanuts and related products is most often identified by high-performance liquid chromatography (Rudolf *et al*., 2005).

Recently, some work has been done to study antioxidant compounds obtained from Argentinean peanut skins (Nepote *et al*., 2005). In those studies, the content of phenolic compounds was found to be between 0.115 and 0.149 gg^{-1}. The ethanoic extracts exhibited high radical-scavenging and antioxidant activity, as demonstrated in sunflower oil (Nepote *et al*., 2005). Proanthocyanidins have been described as the most important phenolic and antioxidant compounds in peanut skins (Nepote *et al*., 2005). Peanut skins are used to treat chronic haemorrhage and bronchitis in Chinese traditional medicine. Six A-type proanthocyanidins and flavonoids have been isolated form the water-soluble phenolic fraction of the skin of the mature seed of peanut (Lou *et al*., 2004).

Tocopherols, derivatives of vitamin E, are lipid soluble natural antioxidants produced only by plants. Peanuts contain approximately 26-60 mg tocopherols/100g, of which 12-25 mg is alpha tocopherols, 10-34 mg is beta tocopherol and 0.6-2.5 mg is gamma tocopherol (Misra, 2004). Tocopherols contribute significantly to prolonging the shelf-life of products containing whole peanut or peanut oil, and have been found to provide maximum stability at a concentration of 0.05% (Misra, 2004). Tocopherol content of kernels does not correlate with oil content, fatty acid composition or kernel mass. However, it has been found that refining of peanut oil results in considerable loss of tocopherol content. Rancidity is a problem in food safety and also reduces the shelf life and the nutritional quality of food

products (Hwang *et al*., 2001). Lipid oxidation can be effectively prevented using antioxidants. However, since some synthetic antioxidants, i.e. butylated hydroxyanisol (BHA) and butylated hydroxytoulene (BHT), have been suspected to be responsible for liver damage and carcinogenesis in laboratory animals, efforts have been made to look for potent natural antioxidants (Hwang *et al*., 2001)

Peanut consumption and improved diet quality

The health benefits associated with nuts are thought to reflect their nutritional profile including their nutrient density, fatty acid profile and presence of bioactive compounds (Griel *et al*., 2004). Peanuts are often classed with other nuts for the purpose of dietary studies, however, they are actually legumes and grow underground. But, they do have many characteristics of both (tree) nuts and pulses and as such are quite unique. They have been and remain an important staple food for many Asian, African and American populations, where they make a significant nutritional contribution to the diet (Higgs, 2002).

Peanuts are a rich source of B-vitamins, vitamin E, magnesium, copper and phosphorus (Higgs, 2002). Peanut and peanut products enhance the nutrient profile of the diet. Inclusion of this energy dense food can be done in a manner that does not result in weight gain, provided that energy intake does not exceed energy expended over time (Higgs, 2002). Consumer awareness about the energy content and nutrient value of peanuts and how they can be incorporated in the diet as a strategy for substituting unsaturated fats

for saturated fats can improve the nutrient, and especially the micronutrient profile of the diet (Higgs, 2002).

Peanuts and their role in coronary heart disease

It is now widely recognized and supported by both metabolic and epidemiological studies, that it is the type of fat that influences cholesterol levels, not the total fat level (Higgs, 2002). Replacing saturated fat with unsaturated fat is more effective at lowering the risk of coronary heart disease (CHD) than simply reducing total fat intake. The beneficial effects of increasing the monounsaturated fatty acid (MUFA) intake have been recently recognized and it is agreed upon that a more effective health strategy for reducing CHD risk may be to replace saturated fatty acids (SFA) with MUFAs as this may prove more efficacious in achieving the target of less than 10 per cent energy as SFA. Resveratrol and B-sitosterol found in peanuts have been associated with decreased risk of CHD and reduced cancer risk (Higgs, 2002).

Various epidemiological, prospective and clinical studies have illustrated that regular nut consumers have a reduced risk of heart disease. Numerous studies (Fraser *et al*., 1992; Hu *et al*., 1998; Kris-Etherton *et al*., 1999) have reported a positive correlation between frequent peanut consumption and a reduced risk of cardiovascular disease. The oil present in peanuts is high in monounsaturated fats that are associated with reduced cardiovascular diseases. For example, diets that had peanut oil or peanut butter providing 34-36% of the total fat lowered total cholesterol by 10% and LDL cholesterol by 14% and decreased CVD risk by 16-21% compared with a low fat diet (Kris-Etherton, 1999). Also, research supports

a positive role for nuts in the battle against cancer, obesity and type II diabetes (Higgs, 2002). Numerous studies have demonstrated that tree nuts and peanuts beneficially affect plasma lipids and lipoproteins, that is, they reduce total cholesterol (TC), low density lipoprotein cholesterol (LDL-C) and triglycerides without reducing high density lipoprotein (HDL) cholesterol (Higgs, 2002).

Peanut consumption and reduced risk for type 2 diabetes

Type 2 Diabetes affects approximately 16 million people in the United States and 135 million people worldwide, and the number of people with diabetes will reach an estimated 300 million worldwide by 2025 (Jiang *et al*., 2002). Because management of diabetes and its complications such as cardiovascular disease, amputations, blindness, and renal failure imposes enormous medical and economic burdens, primary prevention has become a public health imperative (Jiang *et al*., 2002). Recent studies have shown that diet and lifestyle are important means of preventing type 2 diabetes (Jiang *et al*., 2002). Evidence indicates that specific types of dietary fat rather than total fat (as percentage of energy) intake predict risk of type 2 diabetes. Peanuts contain 44% to 56% fat (Ahmed and Young, 1982), with 48% of it being monounsaturated and 33% of it being polyunsaturated fatty acids (Higgs, 2002), and this lipid profile may be beneficial for insulin and glucose homeostasis (Jiang *et al.*, 2002). Several studies have shown that a higher intake of monounsaturated and polyunsaturated fat improves insulin sensitivity. A higher intake of polyunsaturated fat is associated with a lower risk of type 2 diabetes, whereas a higher intake of saturated fat and *trans*-fat adversely affects glucose metabolism and insulin resistance, and thereby may increase the risk of type 2 diabetes. Other components of nuts

such as fiber and magnesium decrease insulin demand and resistance, and have been inversely associated with risk of type 2 diabetes (Jiang *et al*., 2002).

Consumer acceptability of peanuts from different origins

Consumer preferences vary for peanuts produced in different countries (Young *et al*., 2005). Peanuts are an important commodity both within the United States and abroad, and approximately one million tons of peanuts are consumed annually in the United States alone (Young *et al.*, 2005). The world export of peanuts is approximately one million metric tons (shelled basis) (Young *et al*., 2005). Flavor is a significant factor for determining peanut quality and consumer acceptability. Volatile compounds present in the peanuts are responsible for the aroma and flavor of roasted peanuts, and over 300 of such compounds are present in peanuts (Young *et al*., 2005). Differences in variety, environment, and handling practices result in a range of flavor profiles in peanuts from various origins (Young *et al*., 2005). Undesirable peanut flavors are a function of curing temperature, exposure time to excessive temperature, moisture content, size of the peanut and kernel maturity stage (Ahmed and Young, 1982). Also, extended storage time increases peanut off-flavor development and decreases roasted peanut flavor. Currently, the major peanut world market exporters are the United States, China and Argentina. Although, United States peanuts represent approximately 10% of world peanut production, the United States has become one of the leading world exporters, accounting for about one-fourth of the world peanut trade (Young *et al*., 2005). Young *et al*. (2005) also reported that the peanut production origin had an impact on the flavor characteristics with respect to descriptive sensory attributes and consumer preferences.

Peanut products

Several peanut products exist on the market e.g., roasted peanuts, peanut candies, beverages, boiled peanuts and snacks, but peanut butter and spread are by far the most popular use of peanuts. Peanut proteins are also used for their functional properties (emulsifying, foaming) or for their nutritional properties in several food products. They are used for human nutrition in developing countries to supplement cereals, beverages and skimmed milk (Mouecoucou *et al*., 2004)

Peanut butter, paste and spread

In the U.S., 50% of the peanuts produced are consumed as peanut butter (Santerre *et al*., 1994). Peanut butter as defined by U.S. law must contain at least 90% peanuts. Similar products which do not conform to the 90% rule are labeled as peanut spreads, many of which contain reduced fat and added vitamins and minerals (Clavero *et al*., 2000).

Peanut butter production in the U.S. increased from 742 million pounds in 1990 to 745 million pounds in 1998 (Aryana *et al*., 2003). It is a staple in the American diet for its flavor and convenience (Yeh *et al*., 2003). Peanut butter is manufactured through a series of processing steps such as shelling, blanching, dry roasting and fine grinding (Woodroof, 1983). It is during the grinding stage that a stabilizer, generally hydrogenated fat, is added (Gills and Resurreccion, 2000). It is microbiologically stable at ambient temperature due to low (<2%) moisture content (Woodroof, 1983; Yeh *et al*., 2002).

Peanut butter stabilized with hydrogenated fat is firmer in texture than unstabilized or natural peanut butter (Gills and Resurreccion, 2000), and peanut butter stabilized with palm oil (Hinds *et al*., 1994). Natural peanut butter is a popular product among some consumers and it does not contain a stabilizer, has a less firm texture and flows more easily (Aryana *et al*., 2003). Texture attributes such as stickiness have been identified as the key quality attributes of peanut butter (Lee and Ressurreccion, 2001). Although approximately 50% of peanuts harvested in the U.S. are used to manufacture peanut butter, there is a surplus of peanut butter on the market due to a decline in peanut butter consumption (Jolly *et al*., 2005). Thus, this can be used in making other commonly consumed products. Hinds (2003) reported that when peanut butter was incorported in muffins, their tenderness increased as the levels of peanut butter was increased.

Yeh *et al*. (2002) determined changes in the physiochemical and sensory characteristics of peanut spreads fortified with protein, vitamins and minerals, and stored at 4, 23 or 40 ^{o}C for 3 months. They found that differences in the texture profile with storage temperatures were detected by instrumental analysis, but, no differences were detected by trained panelists. Also, they reported that water soluble vitamins were more stable than vitamin A. Peanut butter is popularly consumed by children, middle-aged and elderly persons of both sexes (Yeh *et al*., 2002). Further, in many developing countries such as the semi-arid and tropical regions of Africa, considerable amounts of peanuts are consumed in the form of a spreadable peanut paste prepared traditionally (Agbo *et al*., 1992). However, since peanut kernels contain about 80% unsaturated fatty acids, they are prone to oxidative and hydrolytic changes which could in turn affect the quality and flavor. Muego-

Gnanasekharan and Resurreccion (1992) determined the physiochemical and sensory characteristics of peanut paste stored at 30, 40 and 50^{o} C and indicated that peanut paste is shelf stable and can withstand warm ambient temperatures. They also mentioned that the shelf life of peanut paste may be extended by suppressing lipid oxidation, through degassing, vacuum packaging and the addition of an antioxidant or chelating agent.

Work done by Santos and Resurreccion (1989), has shown that a bland light colored paste made from peanuts can be used as a basic ingredient in cheese flavored spreads, which if used in combination with chocolate and fruit flavors could have potential applications in commercial bakery and snack products. These products besides possessing the nutritional benefits of peanut butter could also help in increasing the utilization of peanuts in countries where peanut butter is not widely consumed. Further, it is also important to note that the functional properties of peanut paste can be affected by various treatment methods. McWatters and Cherry (1975) have found that emulsification and foaming capacities of peanut paste were improved when peanut paste was heated. However, increase in the moisture content also occurred during heating, and the paste firmness decreased.

Peanut cookies

A resemblance to familiar food reduces initial negative responses to a new food. Thus, peanut flour can be incorporated into a familiar food such as a cookie, thereby making it more acceptable to various segments of the population. (Adair *et al*., 2001).

Many cookies contain a high percentage of sugar and fat. If the sweetness in the cookie is maintained, however, consumers will tolerate some deviations from the standard recipe in both texture and flavor. Reduced-fat peanut butter cookies have not been well received (Adair *et al*., 2001). Swanson and Munsayac (1999) reported that it was difficult to emulate the quality parameters of full fat peanut butter cookies by substituting part of the fat in peanut butter with fruit purees. Peanut butter cookie recipes usually require 2 sources of fat: that in the peanut butter, and additional fat as butter or shortening (Adair *et al*., 2001). Fat replacers mimic some, but not all, of the qualities imparted by fat. In cookies which tend to be high in fat and low in moisture, it is probably unrealistic to expect reduced–fat products that are indistinguishable from their full fat counterparts. However, since 1989, the number of persons consuming 'healthy' cookies has increased indicating that consumers have either sacrificed some quality attributes or changed their expectations (Swanson, 1998). For these consumers, changes in standard product expectations may increase acceptability of reduced-fat products. It can also be inferred that children, who may not have consumed the traditional full fat product, may find these reduced-fat products more acceptable than adults who are longtime consumers of the full-fat products (Swanson, 1998).

The effect of varying levels of defatted peanut, soybean, and field pea flours on the quality and baking characteristics of sugar cookies was studied (McWatters, 1978). These flours replaced 10, 20, and 30% of the wheat flour in sugar cookies, and the findings indicated that peanut flour or field pea flour could be successfully used to replace wheat flour. The baking performance and dough handling properties of these flours were

satisfactory. However, soyflour doughs at 20 and 30% wheat flour replacement were difficult to shape and handle as they were drier and more crumbly (McWatters, 1978). Palomar *et al.* (1994) tried to optimize the formulation for cookies made with toasted peanuts and sweet potato flakes using response surface methodology. They used varying levels of crushed toasted peanuts and sweet potato flakes to see the acceptability of sensory properties such as color and texture and also to determine if there was a correlation between the physical properties and consumer acceptance of the different formulations. They concluded that there is a potential for making an acceptable cookie with enhanced nutritional benefits. In accordance with recent recommendations to decrease intake of dietary fat and cholesterol, some consumers have indicated a desire for cholesterol-free baked products. Because egg yolk contains considerable cholesterol and fat, recipes using egg whites or egg-white-based commercial or home-prepared substitutes have been promoted using peanut butter and sugar cookies made with egg substitute (Totheroh, 1994).

Peanut candy

Candy is a very popular food product, ranking third among the top ten food categories in the United States in 1998, and first within all snack categories with retail sales topping $23 billion (Mckee *et al*., 2003). In 1998, Americans consumed more than six billion pounds of candy, and home preparation of candy still remains popular although most candy is purchased. Brittles are non-crystalline candies that are cooked to a high enough temperature to give a hard candy that solidifies before crystallization can occur. Although brittles can be made with or without a variety of nuts, peanut brittle is one of the most familiar brittle-type candies (Mckee *et al*., 2003). Peanut brittles containing roasted

peanuts were found to have more peanut and caramel aromas that those made with raw peanuts (Mckee *et al*., 2003). For the confectionary industry, fading of the characteristic roasted peanut flavor and the development of off-flavors is a concern, and the overall quality of peanut confections could be affected by interactions between antioxidant, sugar, moisture and storage time (Abegaz *et al*., 2004).

Hinds *et al*. (2003) evaluated a honey-roasted peanut product developed in Haiti, flavored with ginger and anise, and the quality and consumer acceptability of the Haiti product was compared with a traditional US-manufactured brand. The results demonstrated variations in consumer acceptability based on age and gender. In another study the acceptability of sensory properties of a peanut chocolate bar was optimized using response surface methodology. The results indicated that the use of dark-roasted peanuts provided more acceptable peanut-chocolate bars than the light-roasted peanuts (San-Juan *et al*., 2005).

Peanut beverages

Beverages from locally available raw materials of plant origin such as peanuts and soybean have been developed to cater to the short supply of milk in various countries. A beverage was developed from an extract from peanut solids by the addition of sugar, emulsifier, cacao powder and flavor with the aim of determining the physiochemical, microbiological, sensory and nutritional features (Rustom *et al*., 1996). The results indicated that the beverage was commercially sterile, and that it had good sensory and nutritional characteristics. It was also suggested that since this beverage was lactose free, it

had potential use as a milk substitute for lactose intolerant individuals (Rustom *et al*., 1996).

Beverages developed from oilseeds usually have beany or green off-flavors, suspension instability and chalky mouthfeel. The need for a better flavor and mouthfeel led to the development of a beverage using finely ground, partially defatted roasted peanuts as the main ingredient. The beverage contained no animal milk and had a pleasant roasted peanut flavor (Hinds *et al.*, 1997). This study observed the effects of two different heat processing protocols on total solids, suspension stability, visual stability, viscosity and color. It was concluded that the physical and sensory properties of kettle-pasteurized beverages (< 100 ^{o} C) were better than the bottle processed beverages (111^{o} C) (Hinds *et al*., 1997). A new chocolate-flavored, protein-based beverage was developed to evaluate its nutritional, physical and sensory attributes with the aim of obtaining the best formulation. The results of the study indicated that the beverage was desirable and that it had higher consumer rating that a commercially available beverage with respect to appearance, color and sweetness (Deshpande, *et al*., 2005).

Snack peanuts

Available snack products are limitless, and the market is wide open for new ideas and innovations (Prinyawiwatkul *et al*., 1993). Various technologies such as extrusion are commonly employed by processors to improve an existing product category or to create new product formulations (Prinyawiwatkul *et al*., 1993). Extrusion cooking has been used to produce a wide range of foods including snacks, ready-to-eat (RTE) cereals,

confectioneries, texturized meat substitutes, extruded crispbreads, and pet food products. These foods are usually calorie dense but otherwise low in nutritional value. However, since convenience and snack foods are becoming very popular, it would be desirable to design snacks that are more nutritious, complete foods (Suknark *et al*., 1997). Flavor innovation is also important in the success of new snack products in the marketplace and is one of the main selling points in achieving consumer acceptance. Peanut and other oilseed flours have been used into various extruded products to create desirable characteristics. Formulation and process development play a crucial role in developing an acceptable snack food. It is ideal that products should be produced easily with consistent quality, should be economical and should meet the necessary standards (Prinyawiwatkul *et al*., 1993).

Approximately 25 percent of the domestic edible peanut use in the United States comprises of snack peanuts, and its consumption has varied significantly since 1978. Various influencing factors such as health, production shortfalls, and economic factors in peanut manufacturing sectors contributed to declining trends in the early 1990s. As the issues that caused declines in consumption were addressed, an increase in consumption was accomplished in 1995. However, there is a growing concern about the sluggish domestic demand for snack peanuts because a continuous decline in consumption implies a shrinking peanut industry (Rimal, 2002).

Value added products from peanuts

Peanuts are of interest as a potential component of biopolymeric films because of their high protein (22-23%) content (Lui *et al*., 2004). Defatted peanut meal or peanut

press-cake (by-product from oil manufacture) may be textured by extrusion processing, and used as a meat extender or meat analog (Hinds *et al*., 2003). The potential use of textured peanut as a meat substitute is because of its low level of volatile flavor compounds. These compounds will contribute to an overall bland taste with no off-flavors (Hinds *et al*., 2005). Peanut has also found uses as a substrate source for biodegradable films, because of its high protein content. Besides, peanut films have desirable properties such as low oxygen permeability and a bland flavor (Jangchud and Chinnan, 1999). Also, if alternative uses were found for protein from the seeds unsuitable for human consumption, it would increase the value-added aspect of this crop (Lui *et al*., 2004).

Role of moisture in flavor changes of model peanut confections during storage

Commercial peanut products with relatively high moisture include a combination of peanut butter and jelly in a jar, low fat peanut spread, chocolate peanut butter flavored milk, peanut butter in ice cream, and yogurt with peanut flavored clusters. The confectionary industry is concerned about the fading of the characteristic peanut flavor and the accompanied off-flavor development in peanut products. Roasted peanut products with high moisture content can develop an objectionable soggy nut flavor (Woodroof, 1983). Peanut butters with 2.5 and 5.0 g/100g added moisture were observed to develop less roasted aroma and roasted flavor, compared with samples without added moisture during 29 days of storage at 25^{o}C (Abegaz *et al*., 2004).

The reasons for ‘flavor-fade’ are not clear, nor is the role of moisture or the levels at which water enhances flavor loss. Prevention or reduction of ‘flavor-fade’ requires

understanding the relationship between carbonyl-amine and lipid oxidation reactions. The volatile compounds in peanuts are produced as a result of non-enzymatic carbonyl-amine and lipid oxidation reactions (Abegaz *et al*., 2004). The development of rancidity and other off-flavors is important to the flavor as peanut butter is approximately 50g fat/100g. The oxidation of polyunsaturated fatty acids produce monohydroperoxides which are precursors of volatile aldehydes such as nonanal, octanal, decanal, and hexanal. Peanut butter products can develop off-flavors that are responsible for painty, cardboard, and oxidized flavors (Abegaz *et al*., 2004).

Water Activity (A_w)

Water activity (A_w) is the measure of the availability of water in a food. It is defined as the water vapor pressure of a solution divided by the vapor pressure of pure water at the same temperature (Gould and Gould, 1988). When substances such as sugar and salt are dissolved in water they reduce the number of unattached water molecules and this way reduce the A_w of the water. The extent to which the A_w is reduced depends on the concentration of these dissolved substances (Gould and Gould, 1988). A_w is an important factor influencing the preservation of foods (Leistner, 1994). Microbiological spoilage by bacteria, yeast and molds is a concern in food products with water activity > 0.60 (McWilliams, 2005). Clavero *et al*. (2000) reported that the growth of *Clostridium botulinum* with toxin formation could occur in peanut spread at $A_w \geq 0.96$ under aerobic conditions along with increased populations of other molds and yeasts.

The A_w can also affect the physical and sensory properties of foods. Balasubrahmanyam and Datta (1994) reported that at 0.325 A_w in cookies, the moisture content is more stable and less likely to migrate. They also reported that lipid oxidation tends to be lowest at this level. Crunchy food products can loose the crunchy sensation when the water content increases, and this occurs during storage of food products with a crust (Luyten *et al*., 2004). For baked or extruded products, an A_w of 0.5 corresponds to a moisture content of 8-10% on a dry basis. It was found that for extruded rice crisps the crispness magnitude sharply declined for a A_w range of 0.4 to 0.55 (Heidenreich *et al*., 2004). Crunchiness and crispness are perceived by consumers as indicators of freshness and good quality, while sogginess and gumminess caused by increased moistness may disqualify the product. Water content correlated with A_w affects the crunchiness and crispness of food products (Marzec and Lewicki, 2006).

Peanuts and aflatoxins

Aflatoxins are produced by several *Aspergillus* species, and are potent carcinogenic and mutagenic secondary metabolites (Somashekar *et al*., 2004). Food commodities are usually contaminated by a range of different fungi during stages of growth, harvesting and storage. Contamination of food and feedstuffs by *Aspergillus* species and their toxic metabolites is a serious problem as they have serious adverse implications on animal and human health, and cause economic losses for international trade, particularly that of developing countries (Somashekar *et al*, 2004 ; Barros *et al*., 2005).

Investigation on the occurrence of aflatoxin in high-risk commodities, maize and peanut/groundnut, continues to be a major part of surveillance programs in various parts of the world (Somashekar *et al*., 2004). Epidemiological studies have related the incidence of liver cancer in humans with the consumption of aflatoxins through contaminated food (Somashekar *et al*., 2004). Studies on laboratory animals have shown that aflatoxins are potent liver carcinogens in animals, and there is evidence that they are also human carcinogens, with aflatoxin B1 being the most potent (Abdulkadar *et al*., 2002; Bleasa *et al*., 2003). Aflatoxin has been implicated as an aetiological factor in human primary liver cell cancer in various high-risks areas of Africa and Asia (Fong and Chan, 1981). Aflatoxin B_1 has been shown to induce liver cancer in a wide range of animals and at doses lower than any other hepatocarcinogen. A 9% incidence of liver cancer in Fischer rats exposed continuously to 1ppb of aflatoxin B_1 has been reported (Fong and Chan, 1981).

Aflatoxin contamination of peanuts can occur in the field (preharvest) when severe late-season drought stress occurs and during storage (postharvest) when improper conditions of moisture and temperature exist (Dorner *et al*., 2003). Peanuts are often invaded before harvest by *Aspergillus flavus*. However, extensive growth of *Aspergillus flavus* and aflatoxin production occurred in peanuts with an A_w of 0.97 stored at 25^{o}C (Ellis *et al*., 1994). *A. flavus* produces aflatoxins, potent natural carcinogens, and cyclopiazonic acid (CPA), which is toxic to variety of animals and has been implicated in human poisoning (Pildain *et al*., 2004). Data from different geographical areas demonstrate a great variability in the mycotoxin producing potential of *A. flavus*. It has been suggested that strains with different aflatoxin-producing ability may interact with host genotypes to

influence rate of aflatoxin production. *A. flavus* can be divided into two groups of strains, L and S. The S strain, produces high levels of aflatoxins and numerous small sclerotia that are, on average, <400 micrometers in diameter. This isolate has been referred to as atypical and also named *A. flavus var parvisclerotigenus*. The L strain produces fewer, larger sclerotia that are >400 micrometers in diameter and, on an average, less aflatoxin (Pildain *et al*, 2004). Typically, L strains produce only B aflatoxins or no aflatoxins at all, while S strains produce large quantities of either B or B and G aflatoxins (Pildain *et al*., 2004). Contamination of foods and feeds by the aflatoxin-producing species of *Aspergillus flavus* and *A. paraciticus* cannot be completely avoided and may lead to significant economic losses and health risks. Reduction of aflatoxin in peanut and peanut products is important because these products are prominent in international trade (Yong and Cousin, 2001).

Efforts to restrict exposure to aflatoxins have been made by governmental agencies and the peanut industry since an awareness of the toxin's existence and hazard developed (Dichter, 1984). The Food and Drug Administration (FDA) estimates that the average concentration of aflatoxins, found in consumer peanuts and peanut products in the U.S.A. is 2 ppb (Dichter, 1984). The current action level (highest permissible level) for aflatoxin in finished peanut products sold for human consumption is 20 ppb, a technically 'temporary' tolerance level which has been in effect since 1969 (Dichter, 1984). In 1974, the FDA proposed a tolerance level for aflatoxin of 15 ppb in peanut products, a level that the agency believed could be easily met by a high percentage of the industry. At the present time the 20-ppb level remains in effect in the U. S. and it is not clear why the 15-ppb level was not made into a formal rule (Dichter, 1984). Postharvest moldiness of peanuts is a

production constraint in Ghana due to lack of effective storage facilities (Awuah and Kpodo, 1996). However, in Ghana, there are no regulatory standards for tolerance levels of aflatoxins, although the permitted levels in Europe are 15 ppb (Otsuki *et al*., 2001).

Silicate and aflatoxins

A variety of physical, chemical and biological approaches have been reported in literature to counteract the mycotoxin problem (Ramos and Hernandez, 1996). However, aflatoxin extraction or detoxification has proven practical for only few feed ingredients and therefore a cost-effective feed ingredient, capable of detoxifying low level aflatoxin contamination without deleterious side effects, would represent a significant advancement in animal and human health (Ellis *et al*., 2000).

One of the more encouraging approaches in solving the mycotoxin problem is the addition of non-nutritive sorptive materials to feedstuffs with the consequent reduction of the gastrointestinal absorption of these fungal metabolites. In vitro studies have shown that several sorptive materials can form highly stable complexes with some mycotoxins, like aflatoxins, while dietary additions of zeolite, bentonite, kaolin, bleaching powders and a specific hydrated sodium calcium aluminosilicate (HSCAS) have been shown to reduce the in vivo toxic effects in farm animals of several mycotoxins, such as aflatoxins (Ramos and Hernandez, 1996).

A variety of silicate clays are frequently added to animal feeds to bind and reduce the bioavailability of mycotoxins in the gastrointestinal tract (Wiles *et al*., 2004). HSCAS, a

phyllosilicate clay performed better than other sorbents. HSCAS was shown to tightly bind more than 80% of AfB_1 in solution. In vivo studies incorporating HSCAS in the diets of Leghorn and broiler chicks significantly prevented the deleterious effects of aflatoxins. Addition of 0.5% HSCAS significantly decreased the growth inhibitory effect from exposure to 7.5 mg AfB_1/kg body weight (Sarr *et al*., 1995). It has also been observed that 0.3% of HSCAS in rat diets significantly decreased metabolic concentrations of AfB_1 (Personal communication with Timothy Phillips, 2005). The in vivo adsorption of AfB_1 in the gastrointestinal tract of rats by HSCAS was confirmed in metabolism studies (Mayura *et al*., 1998). The concentration of AfM_1 (the major urinary metabolite of aflatoxin was significantly reduced in animals treated with HSCAS plus AfB_1. This finding suggests strong binding of AfB_1 by HSCAS resulting in decreased bioavailability of AfB_1 in the gastrointestinal tract. These results are in agreement with previous studies (Mayura *et al*., 1998).

A human study was conducted in western Texas with the FDA's approval to verify the safety of HSCAS. Persons participating in the study consumed HSCAS capsules (0.6% of the diet consumed) 3 times a day for a month. Physiological tests were performed routinely and no adverse effects were reported. It is projected that the maximum amount required for human consumption would be between 0.25-0.3% (Personal communication with Timothy Phillips, 2005). However, it is important to not that HSCAS loses most of its binding ability when heated above 200^oC for 30 minutes or more (Grant and Phillips, 1998).

Response surface methodology

Response Surface Methodology (RSM) is a collection of experimental strategies, mathematical methods and statistical inferences increasingly used to determine the effects of several variables, for the purpose of optimizing various processes (De Faveri *et al*., 2004). It consists of a group of mathematical and statistical procedures that can be used to study relationships between one or more responses and a number of factors (Murphy *et al*., 2004). Most applications deal with the study of the effects of two or more factors. In general, factorial designs are more efficient for this purpose than the traditional method of studying one variable at a time (De Faveri *et al*., 2004).

RSM usually contains three stages (1) design of experiments, (2) response surface modeling regression, and (3) optimization. The main advantage of RSM is the reduced number of experimental trials needed to evaluate multiple parameters and their interactions (Chen, 2005). For the most part, RSM relates product properties by using regression equations that describe interrelations between input parameters and product properties. Some good examples of the appropriate applications of this technique in textured products are the optimization of complex products or properties or many process variables (Singh *et al*., 2004).

The traditional practice of varying one variable at a time does not allow evaluating the combined effects of all the factors involved in the process and is very time consuming. These restrictions can be overcome by the use of a statistical experimental design combined with RSM. This technique allows evaluating the mutual effects of several affecting factors at different levels and determining a wide region in which the obtained results are valid (De

Faveri, 2004). This statistical technique has been extensively applied in many areas such as biotechnology, microbiology (Zhao *et al*., 2005) and food science (Chen *et al*., 2005; Asare *et al*., 2004; Singh *et al*., 2004; Hinds, 2003; Hinds *et al*. 1994; Palomar *et al*., 1994).

CHAPTER III

METHODOLOGY

Materials and methods for Cookie Stix

Raw materials: Defatted peanut flour containing 25-30% protein and 12% fat (dry basis), light roast, was purchased from Golden Peanut Company, Alpharetta, GA., and was stored at 4 degrees C until use. Hydrated sodium calcium aluminosilicate (HSCAS), Novasil^{TM} was donated by Trouw Nutrition USA, Highland, Illinois. The spices and other ingredients were purchased from a local grocery store.

Cookie stix Experimental design

The design points were determined using a central composite design of peanut flour (at 0, 15, 50, 85, and 100%, replacing all purpose flour), and HSCAS (at 0, 0.05, 0.15, 0.25 and 0.3% weight of dry ingredients) (Myers and Montgomery, 2002) (Table 1). Cookie stix containing 0% peanut flour and 0% HSCAS was used as a control against which the influence of peanut flour and HSCAS on the various formulations of cookie stix could be compared.

Table 1. Experimental Design for Peanut flour and HSCAS in Cookie stix.

Formulation #	Code #	X1	HSCAS (%)	X2	Pf (%)
1	015	-1	0.05	-1	15
2	069	+1	0.25	-1	15
3	104	-1	0.05	+1	85
4	110	+1	0.25	+1	85
5	127	- √2	0.0	0	50
6	150	+ √2	0.3	0	50
7	289	0	0.15	- √2	0
8	486	0	0.15	+ √2	100
9	510	- √2	0	- √2	0
10	695	0	0.15	0	50
11	779	0	0.15	0	50

X1 = HSCAS (hydrated sodium calcium aluminosilicate)

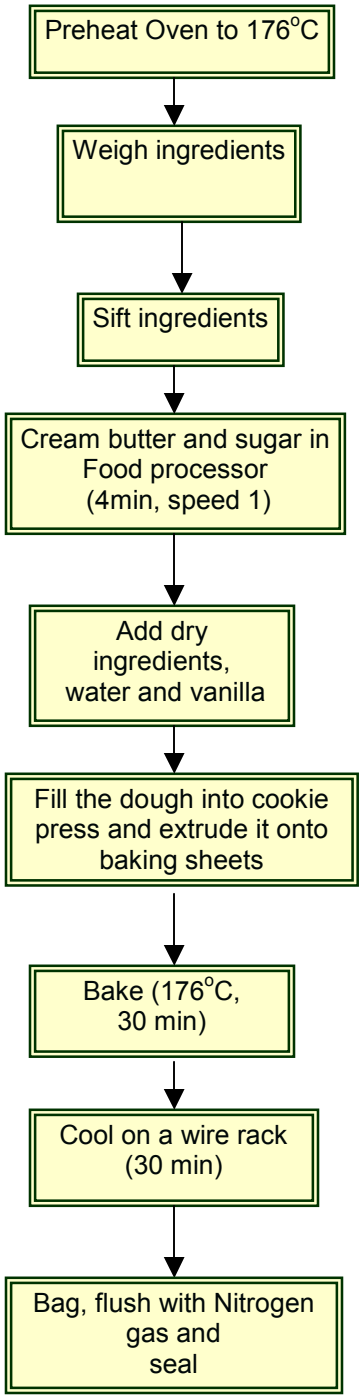
X2 = Peanut flour

Pf = Peanut flour

Cookie stix preparation

Ingredients used to prepare cookie stix are listed in Appendix A. Based on the experimental design, HSCAS was added to the dry ingredients prior to mixing (Fig. 1). The cookie dough was prepared using a Hamilton Beach Big Mouth 14 cup food processor (450 Watts, Model 70590, Washington, North Carolina), and the cookies were extruded using a Villaware Power Cookie Press (Model No. 5375, Cleaveland, Ohio) fitted with the T dye. The oven was preheated to 176^{o}C, the dry ingredients were weighed and sifted. The butter and sugar were then creamed in the food processor for 4 minutes at speed # 1. The sifted dry ingredients, water and vanilla essence were added and the mixture was blended till it formed a dough. The dough was then filled in a cookie press and extruded using the T dye onto baking sheets and the cookies (5.0 to 5.2 cm long, 2.0 to 2.1 cm wide and 0.7 to 0.71 cm high) were baked at 176^{o}C for 30 minutes. They were then cooled on a wire rack for 30 minutes, placed in bags (11.4cm x 5.2cm x 2.0cm made with Black and Decker BG100, food sealer replacement bags - made of 5-ply plastic impermeable to moisture and air), flushed with nitrogen gas and sealed using a Black and Decker food sealer (Towson, Maryland). Cookies were held at 25^{o}C and 35^{o}C, and their properties were evaluated after 1, 7 and 14 days of storage. Storage temperatures of 25^{o}C and 35^{o}C were selected to simulate typical storage temperatures for these products in U.S. and Ghana respectively.

Figure 1. Preparation of Cookie Stix



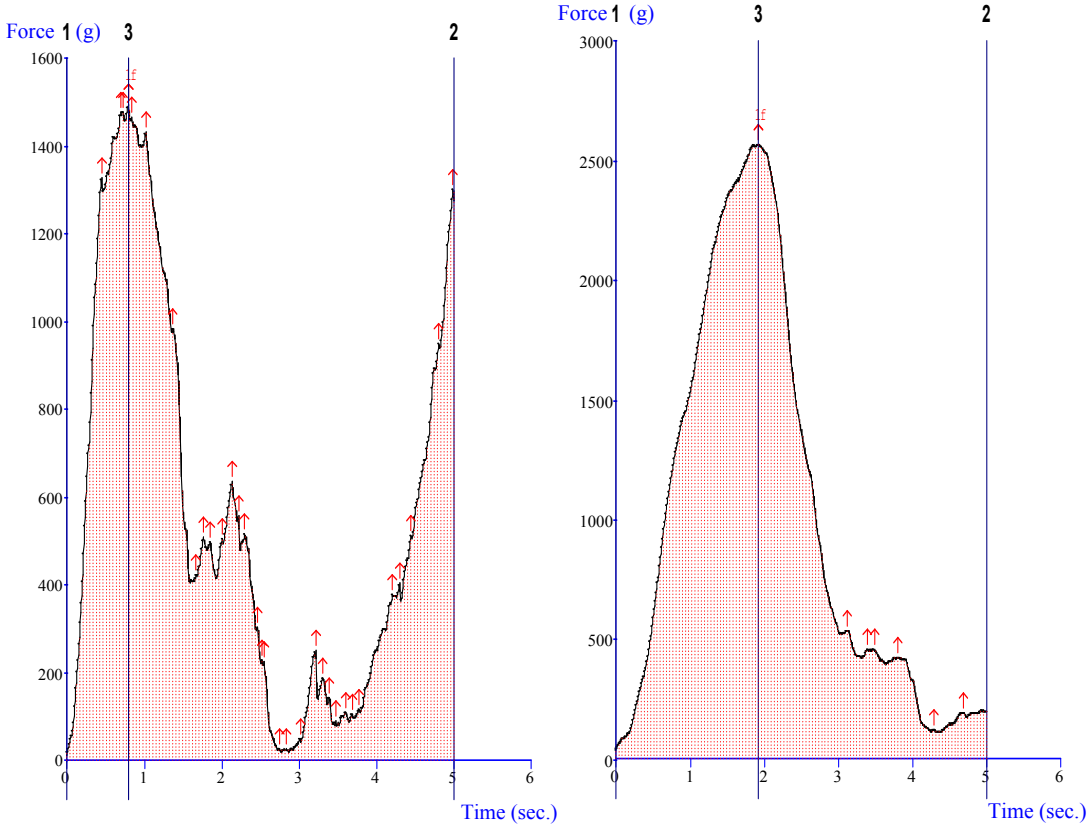
Evaluation of Cookie Stix

Color evaluation: Six pieces were randomly selected from each formulation, three each at 25 ^{o}C and 35 ^{o}C for 1, 7, and 14 days and then analyzed for color. Color was measured using a Minolta Chroma Meter Reflectance System (Model CR-200/CR-210 version 3.0, Minolta, Japan) set in the CIE L* C* h^{o} mode using a C light source at 2^{o} observer angle. In the CIE system, hue is the color descriptor and is measured in a 360 degree angle where the first quadrant 0-90 degrees represents red to yellow, the second quadrant 90-180 degrees represents yellow to green, the third quadrant 180-270 degrees represents green to blue, and the fourth quadrant 270-360 degrees represents blue to red. Chroma, as defined by the CIE system, is the intensity of the hue, and the L-value measures the degree of lightness and darkness on a grey scale where 0 represents black and 100 represents white. Calibration was based on a standard tile with the following color space chromaticity co-ordinates. Y=94.3, X=0.3134, and Y=0.3207 (L*= 97.75, h^{o}= 104.0, and C= 2.38). Measurements were taken on 6 separate randomly selected pieces of cookies (three each from 25 ^{o}C and 35 ^{o}C) at 1, 7 and 14 days to obtain a set of color values. When measuring color three shots were taken randomly per cookie and used to obtain 1 data point.

Texture: Texture of cookies was measured using a TA-XT2i Texture Analyser (Texture Technologies Corp., Scarsdale, New York) fitted with a TA-52 (2mm diameter) probe, 25 kg load cell, plus Texture Expert Exceed Software. The probe penetrated the cookie stix to a depth of 4mm at a test speed of 0.8 mm/s. Six randomly selected pieces of cookies, three each per treatment from 25 ^{o}C and 35 ^{o}C were selected for texture

evaluation. Each single piece of cookie was centered beneath the probe and hardness was evaluated and interpreted as the maximum shear force (g) required by the probe to penetrate the cookies. Crunchiness was calculated by dividing the linear distance (linear distance of the penetration curve) by the F Count, which represents the number of resistant forces the probe encountered while it was penetrating the cookie. The lower the crunch factor the crunchier was the cookie. Typical graphs obtained for hardness and crunchiness of the cookies are displayed in Figure 2.

Figure 2. Typical Graph of Cookie Stix Texture (hardness and crunchiness)



Cookie Stix Code 289, 25C, Dy 14

Hardness = 1493 g force

Linear distance of penetration curve = 61.8 mm
F-Count = 32

Crunch factor = linear distance/F-count = 61.8/32 = 1.9

The lower the crunch factor, the crunchier is the cookie.

Cookie Stix Code 695, 25C, Dy 14

Hardness = 2564 g force

Linear distance of penetration curve = 54.2 mm
F-Count = 7

Crunch factor = linear distance/F-count = 54.2/7 = 7.7

The lower the crunch factor, the crunchier is the cookie.

Moisture Content (%): Six pieces were randomly selected from each formulation, three each from 25^{o}C and 35^{o}C storage temperature, for determining the moisture content using Denver Instruments IR-30 Moisture Analyzer (Arvada, Colorado). The initial temperature of instrument was set at 95^{o}C. Measurements were taken on separate randomly selected pieces of cookies at 1, 7 and 14 days to obtain a set of moisture content values.

Water Activity (A_w): Six pieces were randomly selected from each formulation, three each from 25^{o}C and 35^{o}C storage temperature, for determining the water activity (Rotronic Instrument Corp., Aw QUICK water activity meter, Huntington, New York). Measurements were taken on separate randomly selected pieces of cookies at 1, 7 and 14 days to obtain a set of water activity values.

Statistical Analysis: Data were analysed using SAS Statistical Software, (SAS version 9.1, SAS Institute, NC, 2003). Analysis of variance (ANOVA) was performed using the general linear models (GLM) procedure. A quadratic response surface model was fitted into the data using Response Surface Regression Analysis (PROC RSREG) to determine the behavior of the response variables in relation to the independent variables studied. Arcsine transformations (A_w, moisture (%) and L value) and log transformations (hue, chroma, hardness and crunchiness) were computed and analyzed in the response surface model to improve the fit of the data. The data from the equations were then inverse transformed to plot the graphs. Not all temperature/day combinations had a quadratic effect or interaction (HSCAS and peanut flour), but the saturated model was fit to all

combinations. Grid points were generated for HSCAS and peanut flour combinations so that predictions could be made at these values.

Materials and methods for Peanut Paste

Raw materials: All natural peanut paste (100%) was donated by Seabrook Ingredients, Edenton, North Carolina, and HSCAS was donated by Trouw Nutrition USA, Highland, Illinois. The paste was stored at 4 degrees C until use. The sugar was purchased from a local grocery store.

Peanut Paste Experimental design

The design plots were determined using a central composite design of sugar (at 0, 0.9, 3, 5.1, and 6%, weight of paste) and HSCAS (at 0, 0.05, 0.15, 0.25 and 0.3%, weight of paste were used (Myers and Montfomery, 2002) (Table 2). Paste containing 0% sugar and 0% HSCAS was used as a control against which the influence of sugar and HSCAS on the various formulations of paste could be compared.

Table 2. Experimental Design for Sugar and HSCAS in Peanut paste.

Formulation #	Code #	X1	HSCAS %	X2	Sugar %
1	015	0	0.15	0	3.0
2	047	+1	0.25	+1	5.1
3	058	-1	0.05	+1	5.1
4	141	-1	0.05	-1	0.9
5	209	0	0.15	+ √2	6.0
6	219	- √2	0	- √2	0
7	494	+√2	0.3	0	3.0
8	591	0	0.15	- √2	0
9	625	- √2	0	0	3.0
10	706	+1	0.25	-1	0.9
11	882	0	0.15	0	0.0

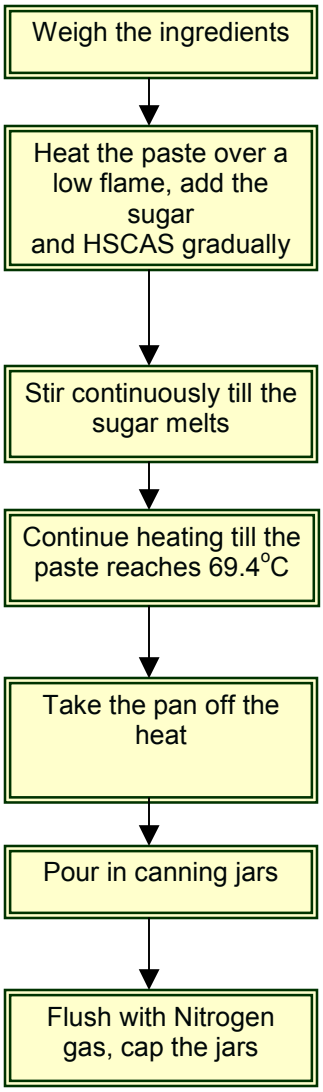
X1 = HSCAS (hydrated sodium calcium aluminosilicate)

X2 = Sugar

Peanut paste preparation

Five test levels of sugar and five test levels of HSCAS were used in the paste formulations. Based on the experimental design, HSCAS was added to the peanut paste along with the sugar with constant stirring (Fig. 2). The paste was heated on a low flame over an industrial cooking range and the temperature of the paste was monitored periodically using an Atkins Temptec Accu Tuff 340 thermocouple. The paste was heated till the temperature reached 69.4^{o}C. It was then taken off the flame, filled into canning jars (Kerr, 8 oz jelly jars), and flushed with Nitrogen gas for 60 seconds, then stored at 25^{o}C and 35^{o}C until further analysis. Cookies were held at 25^{o}C and 35^{o}C, and their properties were evaluated after 1, 7 and 14 days of storage. Storage temperatures of 25^{o}C and 35^{o}C were selected to simulate typical storage temperatures for these products in U.S. and Ghana respectively.

Figure 3. Preparation of Peanut Paste

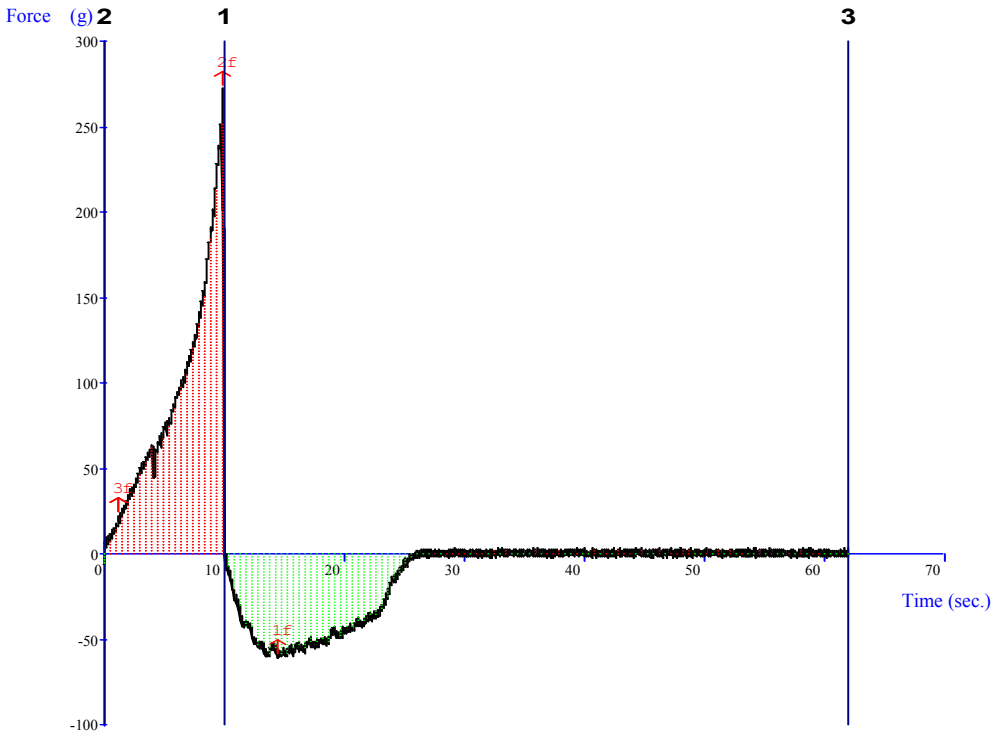


Evaluation of the Peanut Paste

Color: Six samples were randomly selected from each formulation, three each at 25 ^{o}C and 35^{o}C storage temperature, for color evaluation. Color was measured using a Minolta Chroma Meter Reflectance System (Model CR-200/CR-210 version 3.0, Minolta, Japan) set in the CIE L* C* h^{o} mode using a C light source at 2^{o} observer angle using a procedure similar to that used for cookie stix. Measurements were taken on 6 separate randomly selected samples (three each at 25^{o}C and 35^{o}C) at 1, 7 and 14 days to obtain a set of color values.

Texture: Texture of the peanut paste was measured using a TA-XT2i Texture Analyser (Texture Technologies Corp., Scarsdale, New York) fitted with a TA-3, 25mm diameter Cylinder Perspex probe, 25 kg load cell, plus Texture Expert Exceed Software using a penetration depth of 10mm and a test speed of 1mm/sec. Six randomly selected samples of paste, three each from 25^{o}C and 35^{o}C per treatment were selected for texture evaluation. Each sample was centered beneath the probe and firmness and adhesiveness were evaluated. Firmness was interpreted as the maximum force (g) required by the probe to penetrate the paste. Adhesiveness was interpreted as the work done for the probe to pull away from the paste. Figure 4 shows a typical graph of texture (firmness and adhesiveness) of the paste.

Figure 4. Typical Graph of Peanut Paste Texture (firmness and adhesiveness)



Firmness (g) = maximum positive force (2f) required to penetrate paste to depth of 10mm.

Adhesiveness (g.s) = work done to pull probe out of paste (represented by area beneath the horizontal axis).

Water Activity (A_w): Six samples were randomly selected from each formulation, three each at at 25 ^{o} C and 35 ^{o} C, for determining the water activity (Rotronic Instrument Corp., Aw QUICK water activity meter, Huntington, NY). Measurements were taken on separate randomly selected samples of paste at 1, 7 and 14 days to obtain a set of water activity values.

Statistical Analysis: Data were analysed using SAS Statistical Software, (SAS version 9.1, SAS Institute, NC, 2003). Analysis of variance (ANOVA) was performed using the general linear models (GLM) procedure. A quadratic response surface model was fitted into the data using Response Surface Regression Analysis (PROC RSREG) to determine the behavior of the response variables in relation to the independent variables studied. For all temperature and storage day combinations, the predicted values did not fall in the range of the original data. Thus, it was necessary to transform the data to achieve a model fit. Arcsine transformations of the data were computed and analyzed in the response surface model for A_w, L value, chroma, hue, firmness and adhesiveness. The data from the equations were then inverse transformed to plot the graphs. Not all temperature/day combinations had a quadratic effect or interaction (HSCAS and sugar), but the saturated model was fit to all combinations. Grid points were generated for HSCAS and sugar combinations so that predictions could be made at these values.

CHAPTER IV

RESULTS AND DISCUSSION

Cookie stix

Cookie stix were prepared and stored at two temperature levels, namely 25^{o}C and 35^{o}C for 1, 7 and 14 days. The response variables evaluated included A_w, moisture (%), L value, chroma, hue, hardness and crunchiness. The results and observations for the various storage temperatures and times are listed below.

Analysis of Variance (ANOVA)

Results of the Analysis of Variance are presented in Appendix C. For cookie stix treatments held at 25^{o}C on storage days 1 and 7, all variables were significantly affected by the formulation variables (Table 5). However, when the cookie stix were held at 25^{o}C for 14 days, all the dependent variables except crunchiness were significantly influenced by the formulation variables. When cookie stix were stored at 35^{o}C for days 1, 7 and 14 all the dependent variables tested were significantly affected by the formulation variables.

Moisture (%)

On day 1 at 25^{o}C, the moisture content increased as the percentage of peanut flour increased and decreased slightly as the percentage of HSCAS increased (Figure 5a). On

day 7 at the same temperature, the moisture percentage was lowest at 0% HSCAS and 0% peanut flour (Figure 5b). The moisture percentage increased as the percentages of HSCAS and peanut flour increased. On day 14 at 25^{o}C, the moisture content decreased slighlty with an increase in the percentage of HSCAS, but increased with an increase in the percentage of peanut flour (Figure 5c).

On day 1 at 35^{o}C, the moisture level was lowest at 0% peanut flour and 0% HSCAS, it increased with an increase in the percentage of peanut flour, but decreased after about 0.15% HSCAS (Figure 6a). On day 7, the moisture content increased as the percentages of peanut flour and HSCAS increased (Figure 6b). On day 14 at 35^{o}C, the moisture content was lowest at 0% HSCAS and 0% peanut flour (Figure 6c). It increased with an increase in the peanut flour up to 60% and then decreased again. It increased with an increase in the percentage of HSCAS (Figure 6c). Kurikuri, a fried peanut based snack indigenous to Ghana, stored at 10^{o}C, had moisture percentage decreasing as the percentage of HSCAS increased up to 0.0625 % (Hinds and Ellis, 2003).

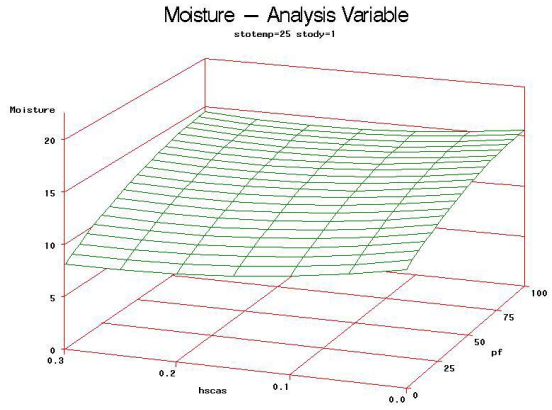
Baked products typically have moisture contents of 8-10% on a dry basis (Heidenreich *et al*., 2004). The moisture contents of some commercially available cookies which we evaluated ranged from 4.41 to 6.13 %. The moisture content of cookie stix ranged from 2.93 (for the control) to 19.07 % (for cookie stix containing 100% peanut flour), with an average of 9.78%. Moisture migration in food products can make them soggy. The moisture content in food products is most stable at a A_w of 0.325 and this A_w corresponds to a moisture content of 3.2% at 30^{o}C (Balasubrahmanyam and Datta, 1994).

In our study, a A_w of 0.3 corresponded to a moisture content of 3.1% at 35 ^oC (Appendix C).

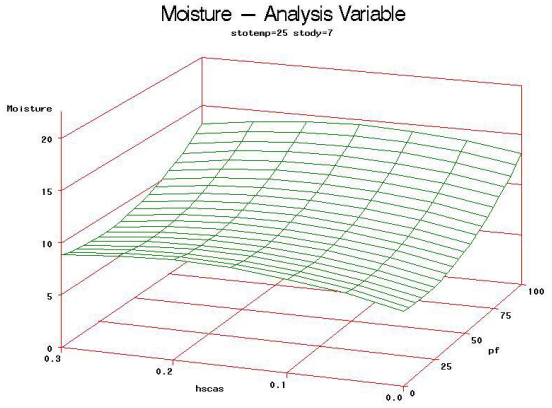
Significant changes in moisture content due to effects of replication were observed in extruded sorghum and peanut bars. This change was not characteristic for the storage time (Anderson and Jones, 1999). In our study, significant differences between moisture content of replicated data points (formulations containing 50% peanut flour and 0.15% of HSCAS) were also observed (Appendix C). It was also observed that there were variations in the moisture content with respect to storage times and temperatures (Figures 5 and 6). Cookies stored at 25^{o}C had higher moisture contents (7 to 14%), compared to those stored at 35^{o}C (6 to 12.1%) (Figures 5 and 6). For both storage temperatures, the control had the least moisture content (3.1 to 4.2%), while cookie stix containing 100% peanut flour and 0.15% HSCAS had the highest moisture contents (~15 to 18%) on day 7 at 25^{o}C. Formulations containing peanut flour had more water added to facilitate ease of dough formation and would have contributed to the higher moisture contents of these treatments. This trend was also observed on days 1 and 7 at 35^{o}C, however, on day 14, the moisture content drops to about 5.5% for the same formulation (Appendix C). Finally, it is important to say that the packaging material used to seal the cookies was impermeable to air and moisture and no condensation was observed for any storage day and storage temperature.

Figure 5. Predicted surface for Moisture (%) of Cookie Stix at 25^{o}C for storage days 1(a), 7(b) and 14 (c)

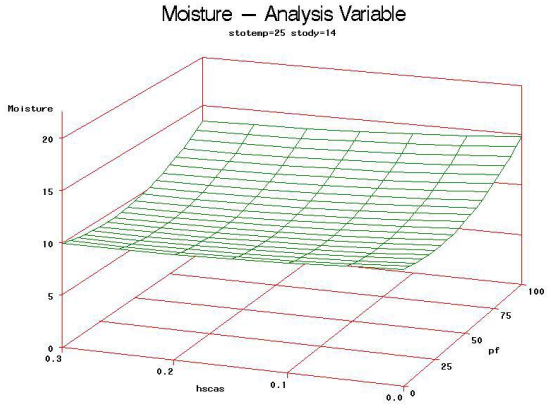
a.



b.



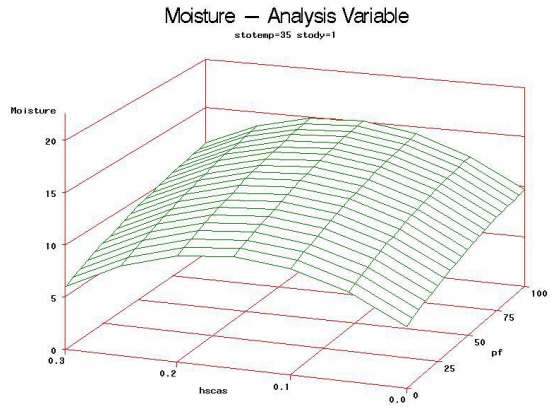
c.



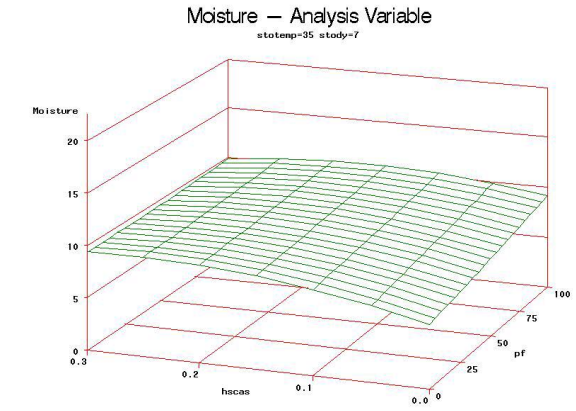
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 6. Predicted surface for Moisture (%) of Cookie Stix at 35^{o}C for storage days 1(a), 7(b) and 14 (c)

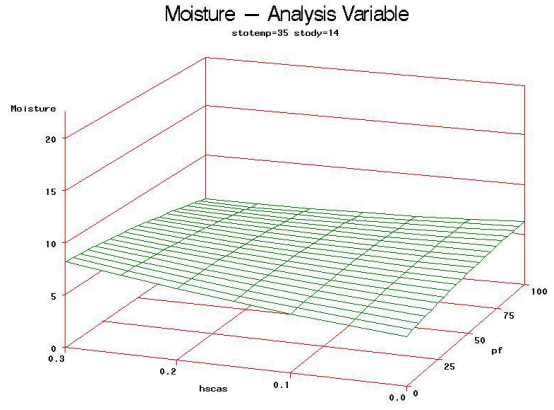
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Water activity (A_w)

For most formulations and storage periods, the A_w decreased as the percentage of HSCAS increased, and increased as the percentage of peanut flour increased. On day 1 at 25°C, (Fig. 7a) the A_w decreased as the percentage of HSCAS increased, but increased as the percentage of peanut flour increased (Figures 7a). On day 7 at 25°C, the A_w at 0.0% peanut flour and 0.0% HSCAS is the lowest (<0.5) (Figure 7b). It increased to 0.8 with an increase in HSCAS upto 0.15% and then decreased again as the percentage of HSCAS increased. A_w increased with an increase in peanut flour. On day 14 at 25°C, formulations containing more than 0.2% HSCAS had the lowest A_w (Figure 7c). A_w increased with an increase in the percentage of peanut flour up to 50% and then decreased.

On day 1 at 35°C, the control cookie stix (0% HSCAS and 0% peanut flour) had the least A_w (Figure 8a). As the percentages of HSCAS and peanut flour increased, the A_w increased. Later, however, for the highest level of HSCAS and peanut flour, a slight decrease is observed. On day 7 at 35°C, the highest A_w was observed with 80% peanut flour and above (Figure 8 b). Overall, the A_w increased as the percentage of peanut flour increased and increased only slightly with increasing HSCAS levels. On day 14 at 35°C, the A_w increased with an increase in the peanut flour (Figure 8c). It also increased with an increase in HSCAS upto 0.15% and then decreased.

Thus, it can be inferred from the above observations that at 25°C, the A_w decreased as the percentage of HSCAS increased. However, at 35°C, the A_w increased as the

percentages of HSCAS and peanut flour increased for days 1 and 7, but, on day 14 it decreased as the percentage of HSCAS increased.

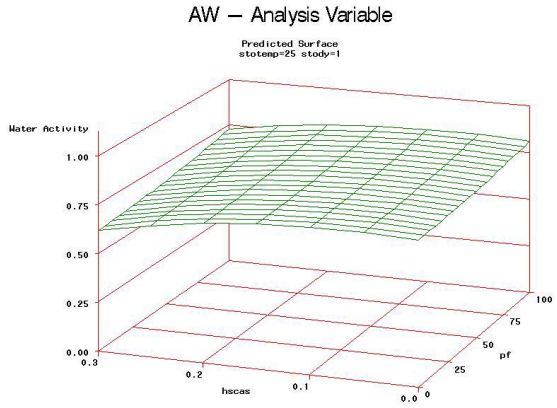
It is evident from literature that for baked products, an A_w of 0.50 corresponds to a moisture content of 8-10% on a dry basis (Heidenreich *et al*., 2004). Microbiological spoilage by bacteria, yeast and molds is a concern in food products with water activity >0.6 (McWilliams, 2005). Cookies have been classified by Smith *et al*. (2004) as low moisture bakery products with A_w values ranging from 0.2 to 0.3. However, in our study the means of A_w for most of the formulations ranged from 0.3 to 0.7. We also evaluated the A_w of some commercially available cookies and found that their A_w ranged from 0.3 to 0.5 (Appendix E). As an anticaking agent, HSCAS may attract unbound water in a food, thus altering their A_w which in turn will influence the shelf-life of the food product (Kilcast and Subramaniam, 2000). For our study, we can state that since an increase in HSCAS resulted in a decrease in A_w for most formulations and storage periods, HSCAS may play a role in prolonging the shelf life of the product. Also, it was observed that the means of formulations with 0.25% HSCAS when combined with 15% peanut flour, and 0.15% HSCAS when combined with 50% peanut flour had fairly low water activities in the range of 0.3 to 0.5%. Kurikuri stored at 10^oC also had a lower A_w (0.3) when it contained 0.25 % HSCAS compared with lower levels (0.05 – 0.06%) HSCAS (Hinds and Ellis, 2003).

Moisture % of the cookie stix corelated significantly ($P<0.05$) with A_w 0.4 to 0.9 (Pearson's correlation coefficient) for all temperature-storage day combintions. Treatments that contained higher moisture also had a higher A_w. Like the moisture % of cookie stix, the

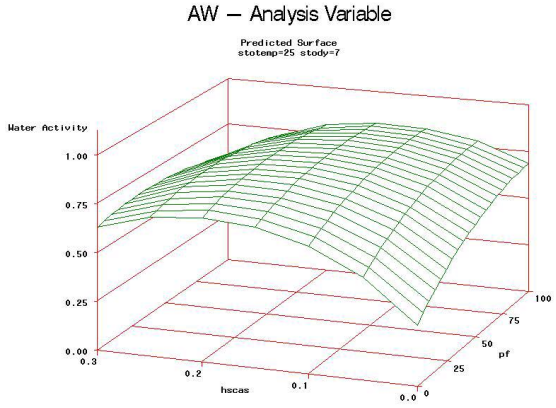
A_w is lowest for the control (0.1 to 0.6%). This was observed for most temperature and storage day combinations (Figures 7 and 8 and Appendix C). Further, lower values were also observed at 35^{o}C than at 25^{o}C (Figures 7 and 8 and Appendix C). Like the moisture content the A_w decreased with an increase in storage time (Figures 7c and 8c). However, on day 14 at both temperatures HSCAS by itself seemed to have a more profound effect on A_w than was seen with respect to total moisture (Figures 7 and 8), suggesting that HSCAS still had available sites for binding water on day 14.

Figure 7. Predicted surface for A_w of Cookie Stix at 25°C for storage days 1(a), 7(b) and 14 (c)

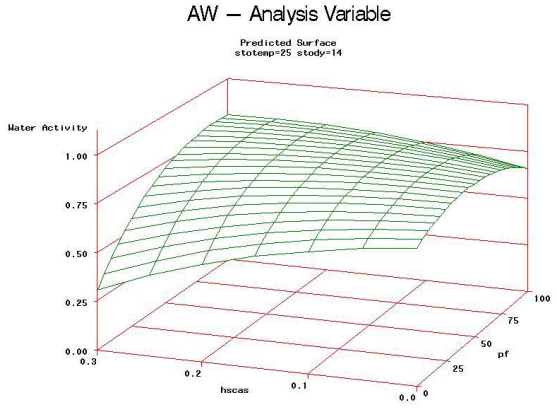
a.



b.



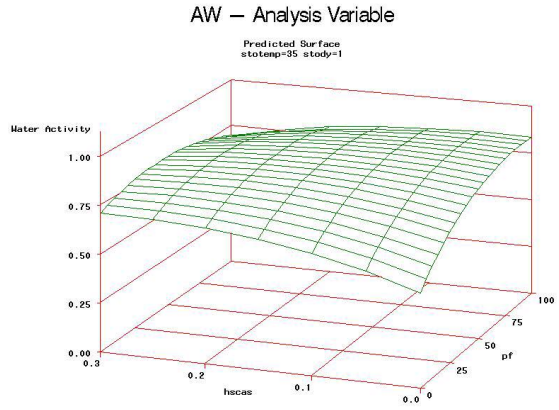
c.



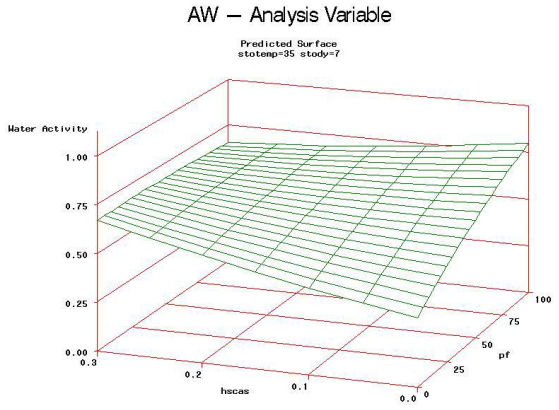
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 8. Predicted surface for A_w of Cookie Stix at 35°C for storage days 1(a), 7(b) and 14 (c)

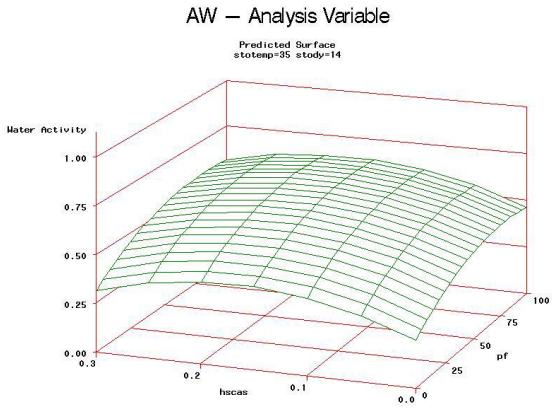
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

L value

The L value does not change with an increase in HSCAS, however, the L value decreased with an increase in peanut flour on day 1 at 25^{o}C (Figure 9a). On day 7 at the same temperature, the L value does not change much with and increase in HSCAS, however, it decreased with an increase in the percentage of peanut flour (Figure 9b). The L value was highest at 0% HSCAS and 0% peanut flour indicating that these cookies had the lightest color. On day 14 at 25^{o}C, the L value decreased as the percentage of peanut flour increased (Figure 9c).

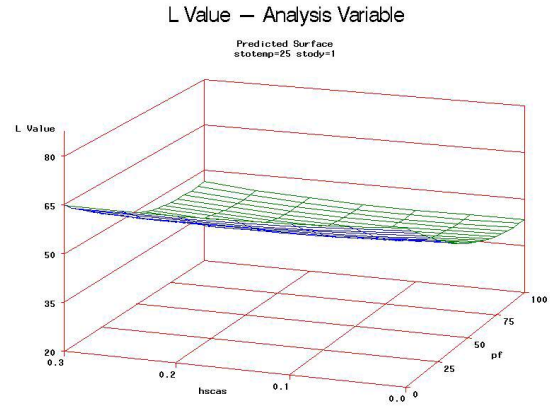
On day 1 at 35^{o}C, the L value decreased with an increase in the percentage of peanut flour (Figure 10a). It is not affected much by HSCAS. On day 7, the L value does not change much with HSCAS, but decreased with and increase in the percentage of peanut flour (Figure 10 b). On day 14 at 35^{o}C the L value increased very slightly as the percentage of HSCAS increased but decreased as the percentage of peanut flour increase and thus cookies became darker 9 (Figure 10c).

L values were significantly affected by levels of peanut flour in the cookie stix and the mean values ranged from 33.0 to 69.0 (Appendix C). This was expected because peanut flour is darker than all-purpose flour. Commercial cookies which we evaluated had L values ranging from 50.0 to 76.0 (Appendix E) and some of the L values of our cookie stix fell within that range. However, it is important to note that, during baking, the monosaccharides in the peanut flour might react with the amino acids in a possible maillard reaction, and thus contributes to lower the L values of the experimental cookie stix.

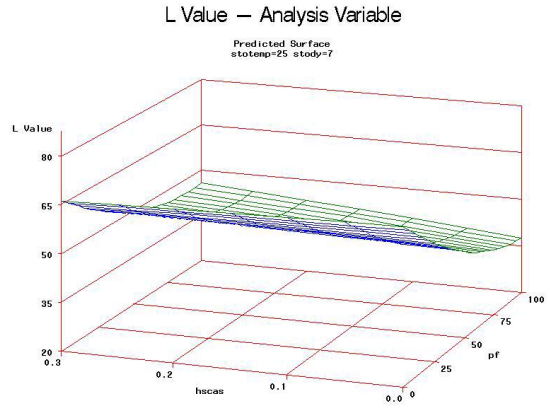
Anderson and Jones (1999) reported that in extruded sorghum and peanut bars the lightness decreased as the storage time increased. However, not much difference was seen in the L value of our cookiestix with respect to storage times and temperature. In kurikuri stored at 10^{o}C, the L value decreased as the percentage of HSCAS increased from 0.005% to 0.25% (Hinds and Ellis, 2003). However, HSCAS levels did not significantly affect L value of the cookie stix.

Figure 9. Predicted surface for L value of Cookie Stix at 25^{o}C for storage days 1(a), 7(b) and 14 (c)

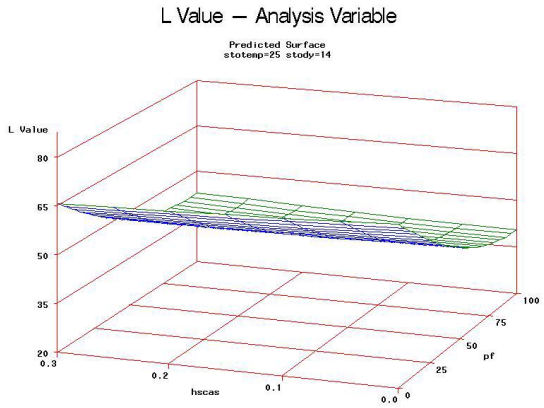
a.



b.



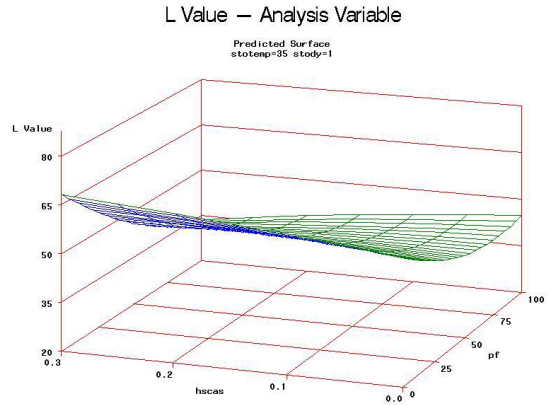
c.



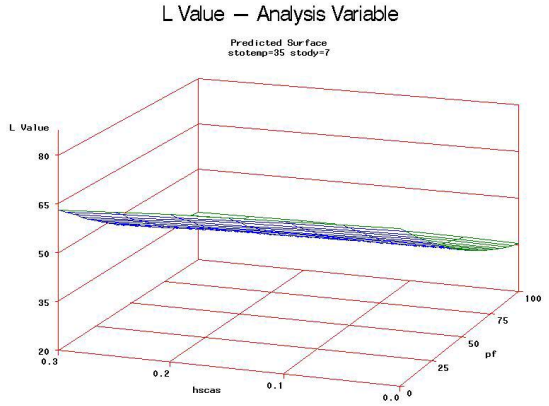
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 10. Predicted surface for L value of Cookie Stix at 35°C for storage days 1(a), 7(b) and 14 (c)

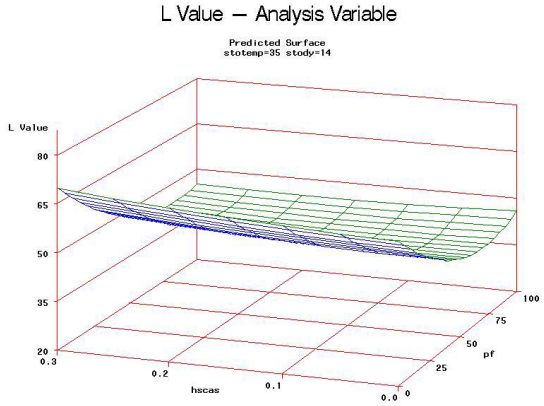
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Hue angle

On day 1 at 25°C, the hue angle decreased as the percentage and peanut flour increased i.e., the cookies became more brown (Figure 11a). On day 7 at the same temperature storage, the hue angle was highest at 0.3% HSCAS and 0% peanut flour, indicating that these were the least brown cookies (Figure 11b). It was not affected much by HSCAS but decreased with an increase in the percentage of peanut flour. On day 14 at 25°C, the hue decreased as the percentage of peanut flour increased. It was not affected by HSCAS (Figure 11c).

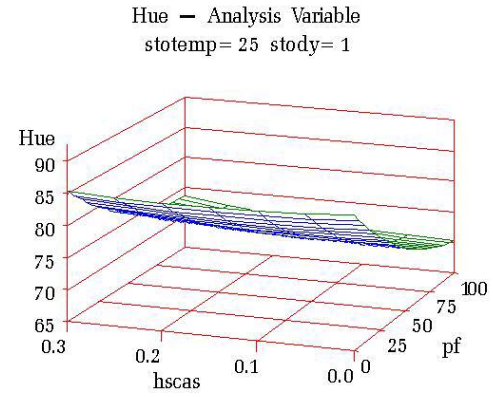
On day 1 at 35°C, the hue angle increased slightly as the percentage of HSCAS increased for low levels of peanut flour (Figure 12a). It decreased with an increase in the percentage of peanut flour indicating that cookies became more brown. On day 7 at 35°C, the hue angle decreased with an increase in the percentage of peanut flour, it does not change much with HSCAS (Figure 12b). On day 14 at 35°C, the hue angle decreased as the percentage of peanut flour increased. It does not change much with HSCAS (Figure 12 c).

Peanut flour was the main factor affecting the hue of cookie stix, and the cookie stix changed hue from tan to brown as the peanut flour was increased. The hue angle for cookie stix ranged from 66.2 to 86.0 (Appendix C) which is very similar to the hue angle of commercial cookies we evaluated (65.7 to 86.8) (Appendix E). Extremely small variations in the hue angle are seen with respect to storage temperature and times. There was no particular formulation which was affected by storage temperature and time.

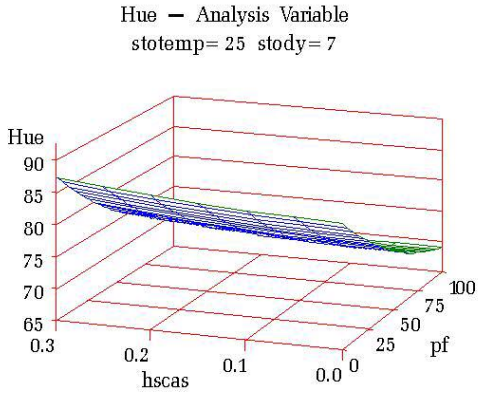
The color of peanut products can vary based on the formulation. It was observed in muffins containing peanut flour and peanut butter, the outer surface became browner as the percentage of peanut flour increased, while an increase in peanut butter gave rise to a more intense hue. It was also reported that as the peanut flour and peanut butter concentrations were increased the internal crumb color, became darker and more intensely brown (Hinds, 2003). Anderson and Jones (1999) reported that in extruded sorghum and peanut bars the hue angle changed from greenish yellow to orange yellow, as the storage time increased. In kurikuri stored at 10^{o}C, the hue angle increased as the percentage of HSCAS increased from 0.005% to 0.25% (Hinds and Ellis, 2003).

Figure 11. Predicted surface for Hue angle of Cookie Stix at 25°C for storage days 1(a), 7(b) and 14 (c)

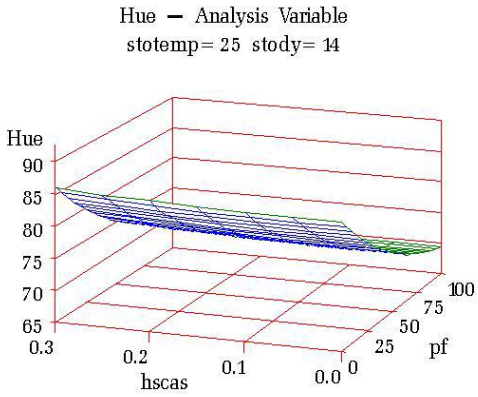
a.



b.



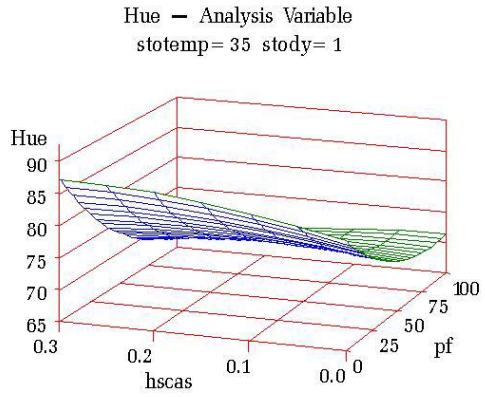
c.



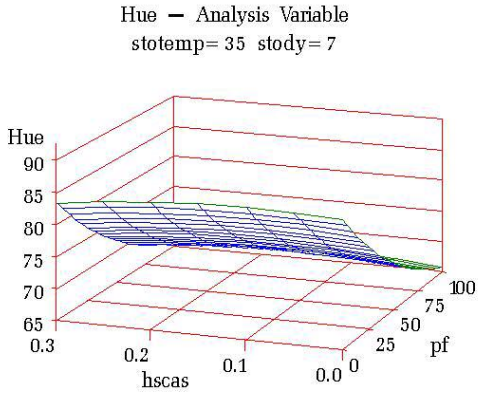
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 12. Predicted surface for Hue angle of Cookie Stix at 35°C for storage days 1(a), 7(b) and 14 (c)

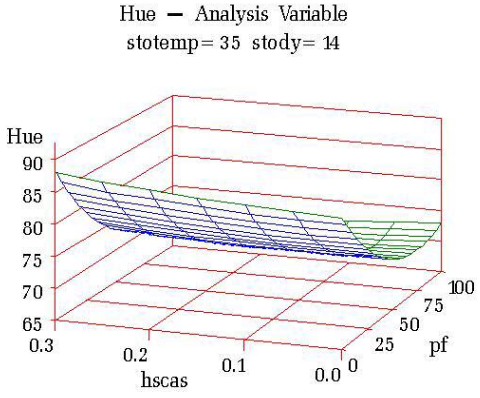
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Chroma

The chroma increased with an increase in peanut flour on day 1 at 25^{o}C (Figure 13a) indicating the color became more intense. On day 7 at the same temperature, the chroma is lowest for 0% HSCAS and 0% peanut flour (Figure 13b). It did not change with respect to HSCAS, but increased with an increase in the percentage and peanut flour. On day 14 at 25^{o}C, the chroma is lowest at 0% HSCAS and 0% peanut flour, it increased with an increase in peanut flour, but no change is observed with respect to HSCAS (Figure 13c).

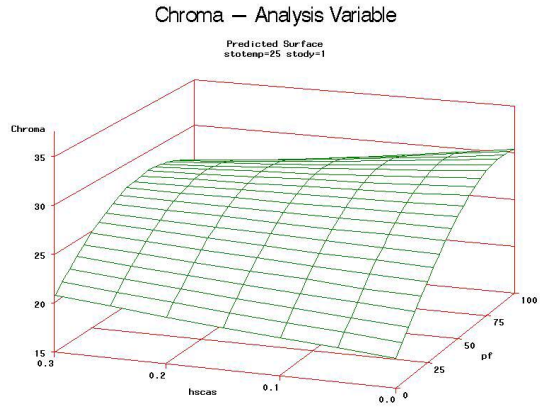
On day 1 at 35^{o}C, the chroma increased indicating that the color of the cookies became more intense as the percentage of peanut flour increased (Figure 14a). It decreased slightly at 0.15% HSCAS and then increased again. On day 7, at the same temperature, chroma increased as the percentage of peanut flour increased (Figure 14b). On day 14 at 35^{o}C, the chroma is lowest at 0% peanut flour and 0% HSCAS. It increased as the percentage of peanut flour increased (Figure 14c).

Peanut flour was the main factor influencing chroma of the cookie stix. Their color became more intense as the peanut flour percentage was increased. With respect to storage times and temperatures, the chroma of cookie stix stored at 25^{o}C was slightly lower than values at 35^{o}C (Figures 13 and 14). Also, on day 1 at 25^{o}C, a slightly sharp increase in chroma with decreased HSCAS was observed (Figure 13a), which was not seen with other storage conditions. Anderson and Jones (1999) reported that in extruded sorghum and peanut bars the chroma increased as the storage time increased. In kurikuri stored at 10^{o}C,

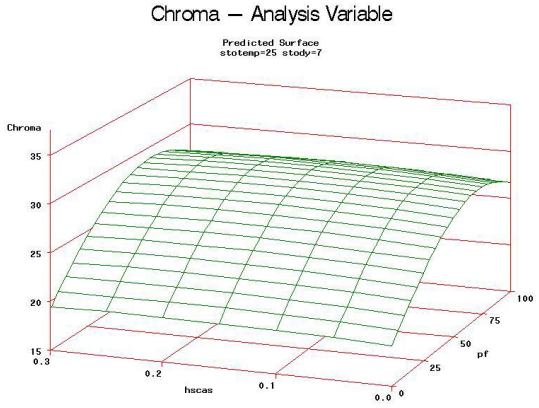
the chroma decreased as the percentage of HSCAS increased from 0.005% to 0.25% (Hinds and Ellis, 2003).

Figure 13. Predicted surface for Chroma of Cookie Stix at 25°C for storage days 1(a), 7(b) and 14 (c)

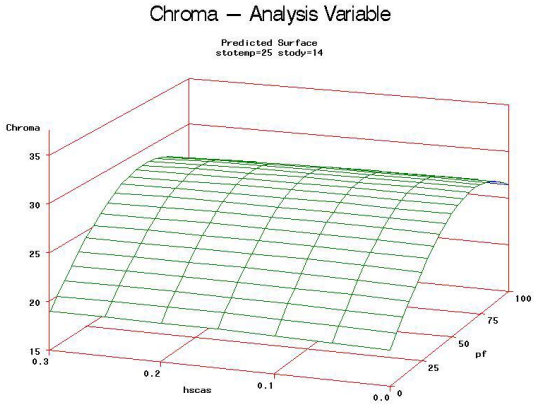
a.



b.



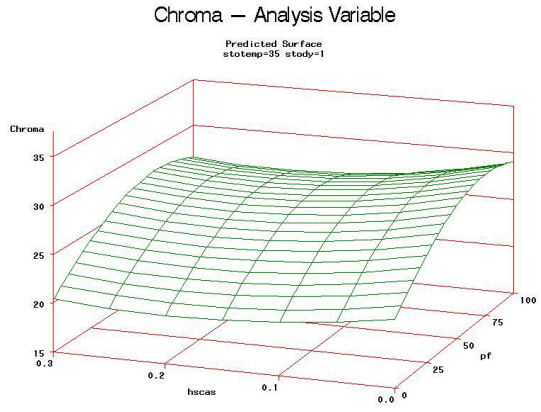
c.



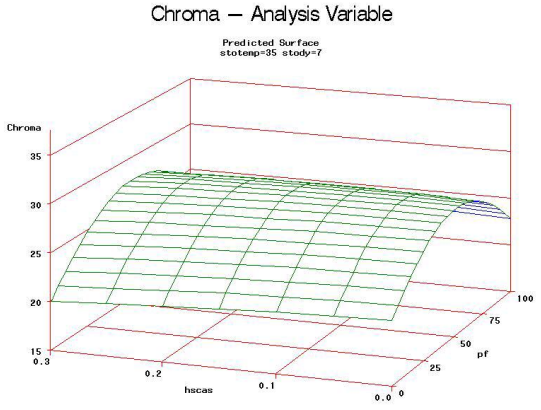
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 14. Predicted surface for Chroma of Cookie Stix at 35°C for storage days 1(a), 7(b) and 14 (c)

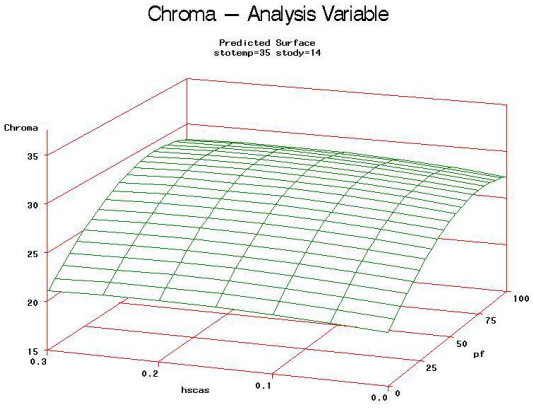
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Hardness

Hardness increased with an increase in HSCAS, and decreased with an increase in the percentage of peanut flour on day 1 at 25°C (Figure 15a). On day 7 at the same temperature, the hardness was highest at 0.3% HSCAS and 100% peanut flour (Figure 15 b). The hardness is lowest at 0% HSCAS and 50% peanut flour. On day 14 at 25°C, the hardness increased and then decreased with an increase in HSCAS (Figure 15c). Lowest levels are seen at 0.05% and 0.3% HSCAS for all levels peanut flour (Figure 15c).

The hardness on day 1 at 35°C is highest for all levels of HSCAS at 0% peanut flour (Figure 16a). Cookie hardness decreased with an increase in the percentage of peanut flour. On day 7 at 35°C, cookie stix were softest when peanut flour was 25 or 100%, especially at 3% HSCAS (Figure 16b). The hardness on day 14 at 35°C, increased as the percentage of peanut flour increased (Figure 16c). However, the hardest cookies, on day 14, contained 0% HSCAS.

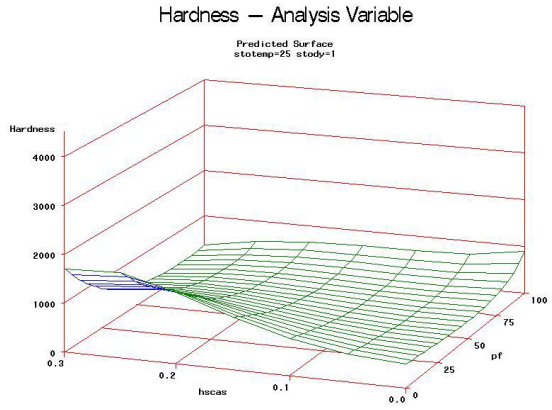
For HSCAS-supplemented kurikuri it was observed that at two months of storage, the hardness increased with an increase in HSCAS up to 0.0625% and then decreased when the HSCAS was increased to 0.25% (Hinds and Ellis, 2003). At six months of storage, however, the hardness decreased with an increase in HSCAS up to 0.0625% and then increased when the HSCAS was increased to 0.25%.

The storage times and temperatures had an influence on the hardness of cookie stix. The values for hardness were higher at 35°C, than at 25°C (Figures 15 and 16). Further, the

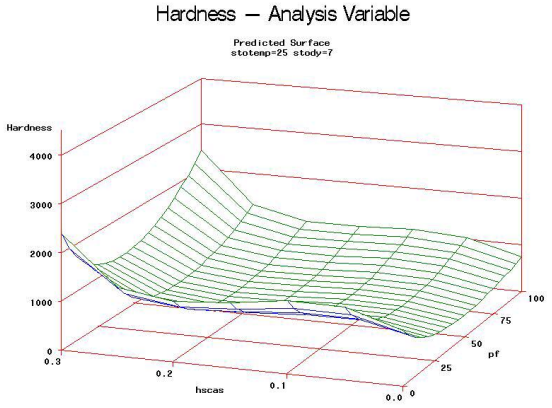
cookie stix were hardest on day 14, at 35^{o}C (Figure 16c). To some extent the values for hardness are comparable to that of kurikuri on day 14 at at 25^{o}C (Figure 15c) and on day 7 at at 35^{o}C (Figure 16b), where the hardness decreased when HSCAS was increased to 0.25%. Further, the mean values for hardness for cookie stix ranged from 326.5 to 4653.2 g (shear force) (Appendix C). This range was comparable to that of commercial cookies (Appendix F) where the hardness ranged from 238.6 to 3985.8 g (shear force).

Figure 15. Predicted surface for Hardness of Cookie Stix at 25°C for storage days
1(a), 7(b) and 14 (c)

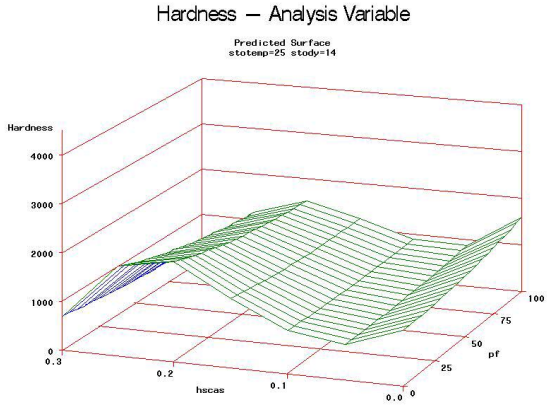
a.



b.



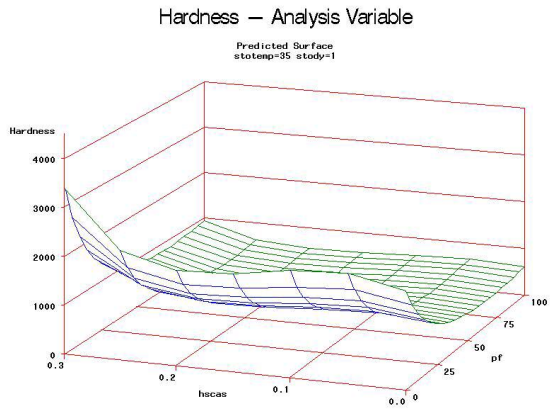
c.



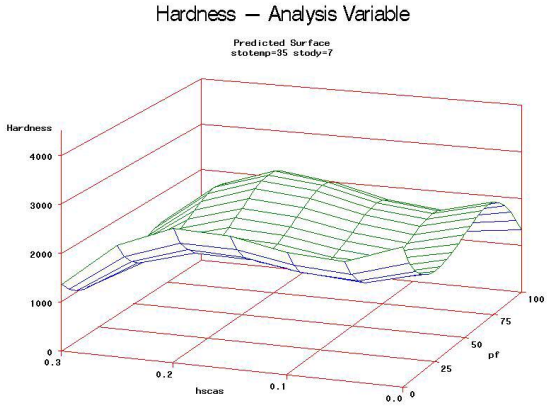
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 16. Predicted surface for Hardness of Cookie Stix at 35°C for storage days
1(a), 7(b) and 14 (c)

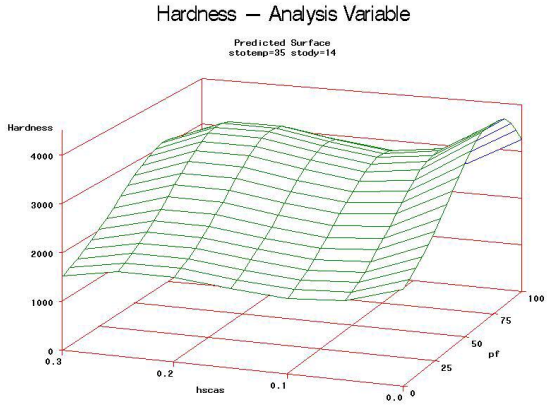
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Crunchiness

On day 1 at 25°C cookie stix were the most crunchy when they contained ≥ 0.2% of HSCAS (Figure 17a). Crunchiness on day 7 at the same storage temperature is more at 0.3% and 0.0% HSCAS when peanut flour is less than 25% (Figure 17b). The crunchiness decreased as the percentage of peanut flour increased. On day 14 as well, at 25°C, the crunchiness decreased as the percentage of peanut flour increased. The crunchiness was highest above 0.25% HSCAS for 0% peanut flour (Figure 17c).

At 35°C on day 1 storage the crunchiness was highest above 0.15% HSCAS and at 0% peanut flour (Figure 18a). The crunchiness decreased as the percentage of peanut flour increased upto 70% and then began to increase slightly. On day 7 at the same temperature, the crunchiness is highest at 0 and 100% peanut flour and above 0.15% HSCAS (Figure 18b). At 35°C on day 14, the crunchiness was highest at ≥ 0.275% HSCAS and 0% peanut flour (Figure 18c). Cookies were the least crubchy when they contained approximately 80% peanut flour and 0.18 to 0.20% HSCAS.

In HSCAS-supplemented kurikuri it was observed that at two months of storage, the crunchiness was highest when HSCAS was 0.0625% (Hinds *et al*., 2004). It decreased to a level similar to that of the control when the HSCAS was increased to 0.25%. At six months of storage, however, the crunchiness decreased with an increase in HSCAS up to 0.0625% and then remained at the same level when the HSCAS was increased to 0.25% (Hinds *et al*., 2004).

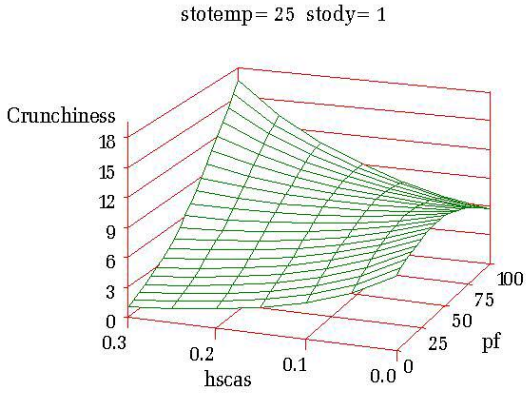
Cookie stix stored at day 7 were the most crunchy for both storage temperatures (Figures 17b and 18b). Cookie stix stored at day 1 were the least crunchy for both storage temperatures (Figures 17a and 18a). On day 14 cookies stored at 25^{o}C (Figure 17c), were more crunchy than those stored at 35^{o}C (Figure 18c). This trend differed from that of kurikuri i.e., the crunchiness decreased as HSCAS was increased to 0.25% (Hinds *et al*., 2004). With cookiestix the highest crunchiness was recorded at 0.3% HSCAS and 0-15% peanut flour for all storage times and temperatures. Further, the mean crunchiness for cookie stix ranged from 1.7 to 11.8 (Appendix C) and this was comparable to commercially available cookies which had crunchiness ranging from 1.95 to 10.36 (Appendix F).

Marzec and Lewecki, (2006) reported A_w could affect textural parameters, for example, wafers lost their crunchiness at A_w ranges from 0.33 to 0.591. For cookie stix it was observed for all storage days and both storage temperatures the crunchiness increased as the A_w decreased (Figures 7, 8, 17 and 18).

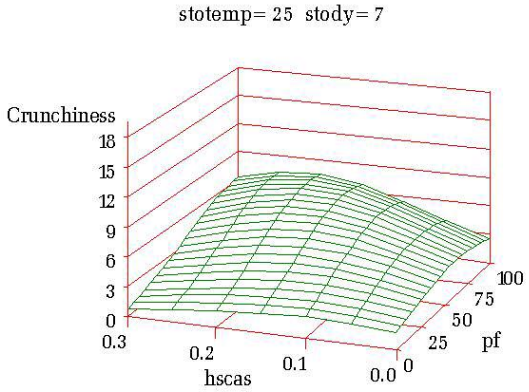
Figure 17. Predicted surface for Crunchiness of Cookie Stix at 25°C for storage days

1(a), 7(b) and 14 (c)

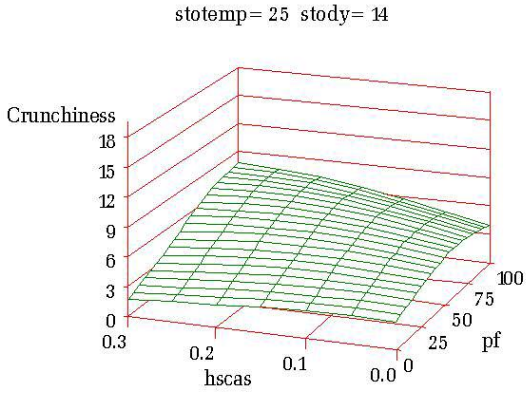
a.



b.



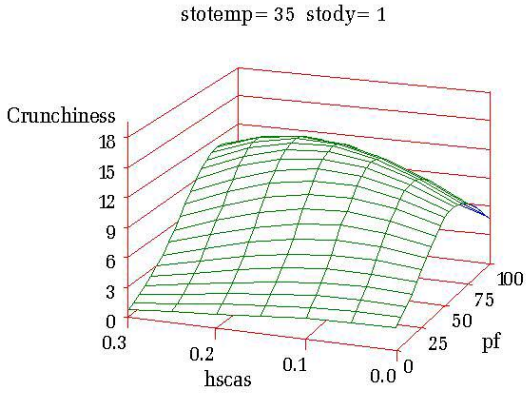
c.



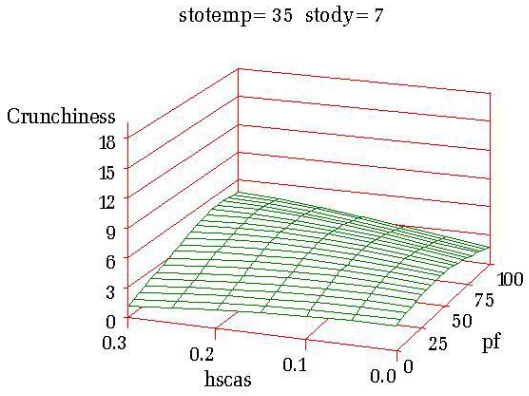
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)
***The lower the crunchiness value, the more crunchy is the cookie stix.**

Figure 18. Predicted surface for Crunchiness of Cookie Stix at 35°C for storage days
1(a), 7(b) and 14 (c)

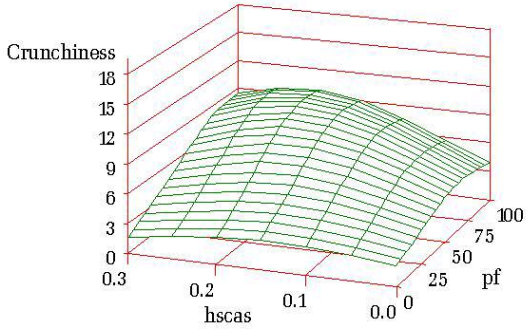
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)
***The lower the crunchiness value, the more crunchy is the cookie stix.**

Peanut paste

Peanut paste was prepared and stored at two different temperature levels, namely, 25°C and 35°C for 1, 7 and 14 days. The response variables evaluated included A_w, L value, chroma, hue, adhesiveness and firmness. The results and observations for the various storage temperatures and times are presented below.

Analysis of Variance (ANOVA)

Results from ANOVA are in Appendix C. For peanut paste treatments held at 25°C on storage day 1, the A_w, L value and chroma were significantly affected by the formulation variables (Table 5). On day 7, only A_w and hue angle were significantly affected by the formulation variables. When the peanut paste was held at 25°C for 14 days, A_w, hue angle and adhesiveness were significantly affected by the formulation variables.

When peanut paste was stored at 35°C for days 1, A_w, chroma and hue angle were significantly affected by the formulation variables. On day 7, A_w, L value, chroma and hue angle were significantly affected by the formulation variables. On day 14, A_w, hue angle, adhesiveness and firmness were significantly affected by the formulation variables.

Water activity (A_w)

At 25°C on day 1, the A_w does not change much with respect to both HSCAS and sugar (Figure 19a). The A_w was lowest (0.18) at 0.25% HSCAS and at 6% sugar. On day 7 at 25°C, as well, the A_w does not change much with respect to the HSCAS and sugar (Figure 19b). Like day 1 at 25°C, the A_w was lowest (0.26) at 0.25% HSCAS and at 6%

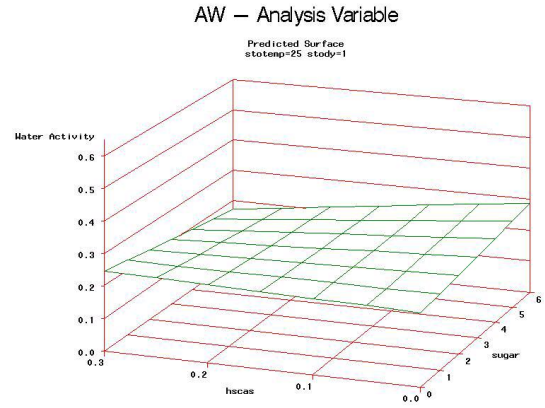
sugar. On day 14 at 25°C, the A_w increased as the HSCAS and sugar increased, reaching a maximum (0.5) at 0.3% HSCAS and 0.6% sugar (Fogure 19c). Further, the overall A_w on day 14 was slightly higher compared to day 1 and 7 storage at 25°C.

At 35°C on day 1, the highest A_w (0.28) was observed at 0% HSCAS and 6% sugar (Figure 20a). The A_w was lowest (0.18) at 0.3% HSCAS and 6% sugar. On day 7 at the same temperature, the A_w was slightly higher (0.26 to 0.4) compared to that of day 1 (Figure 20b). It increased with an increase in HSCAS, at high sugar level but decreased with HSCAS at low sugar. At 35°C on day 14, the A_w was slightly higher compared to that of days 1 and 7 (Figure 20c). Like day 14 at 25°C, A_w peaked (0.55) with 0.3% HSCAS and 6% sugar.

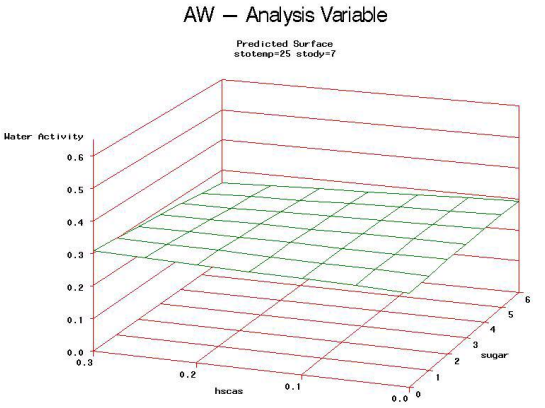
The average A_w for all the various peanut paste formulations we prepared ranged from 0.18 to 0.55, indicative that it should not be affected by microbial growth. Muego-Gnanasekharan and Resurreccion (1992) mentioned that the A_w of peanut paste was 0.44 which is comparable to the paste we analysed. On days 1 and 7 for both storage temperatures the A_w decreased as the concentrations of both HSCAS and sugar increased together (Figures 19a, 19b, 20a and 20b). However, on day 14, the A_w increased as the concentrations of HSCAS and sugar jointly increased. Thus it could be possible that sugar and HSCAS may bind more water on days 1 and 7 compared to day 14. Also, it may be suggested that HSCAS and sugar may interact with each other as the storage time increases to give rise to this anomaly. Further, HSCAS seems to bind more water at 25°C than at 35°C.

Figure 19. Predicted surface for A_w of Peanut Paste at 25°C for storage days 1(a), 7(b) and 14 (c)

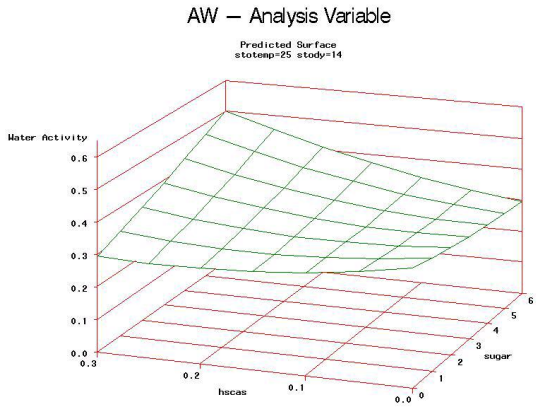
a.



b.



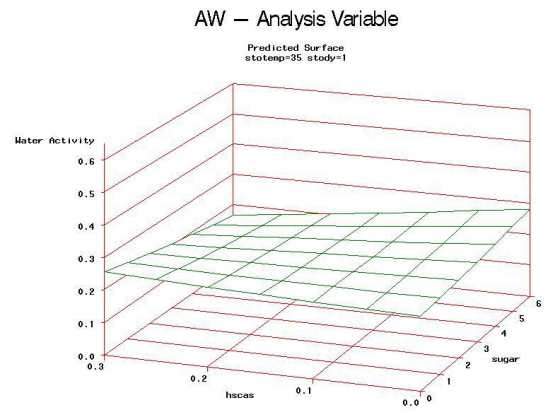
c.



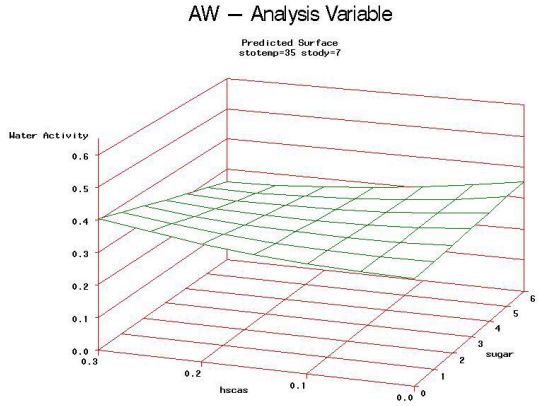
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 20. Predicted surface for A_w of Peanut Paste at 35°C for storage days 1(a), 7(b) and 14 (c)

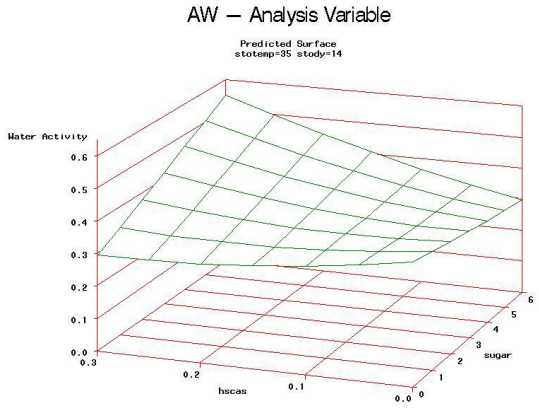
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

L value

The L value ranged from 53 to 59, and did not change much with respect to the HSCAS and sugar at 25^{o}C on day 1 (Figure 21a). The lowest L value on day 1 was observed with 0.15% HSCAS and 3% sugar. On day 7 at 25^{o}C, the L value decreased slightly as the percentages of HSCAS or sugar increased individually (Figure 21b). However, the L value increased slightly as the percentages of both HSCAS and sugar increased together, thus indicating an interaction between HSCAS and sugar that affects the L value. Further, on day 14 at 25^{o}C, the L value does not change much (52 to 59) with respect to HSCAS and sugar (Figure 21c).

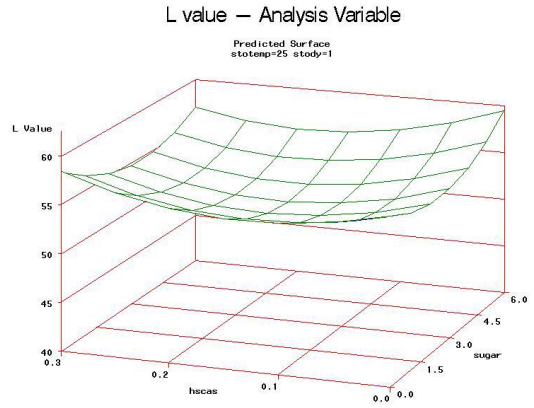
On day 1 at 35^{o}C, the L value was not affected by changes in HSCAS and sugar levels (Figure 22a). On day 7 at 35^{o}C, the L value decreased as HSCAS increased, for low levels of sugar (Figure 22b). On day 14 at 35^{o}C, the L value did not change much with respect to HSCAS and sugar increases (Figure 22c). However, the L value decreased slightly as the percentages of both HSCAS and sugar decreased, thus indicating an interaction between HSCAS and sugar that affects the L value.

Hinds *et al* (2002) evaluated the color of peanut butter and mambas (a Hatian peanut butter type product). The L value means of the mambas were not significantly different fron that of a U.S. made peanut butter. Further, the mambas containing sugar (Sucre mambas) had a lower mean for L value (57.6 $\pm$ 0.74) compared to the plain mambas. The mean L values observed for most of the peanut formulations we prepared were not different with respect to storage temperatures and times (48.6 to 56.4 at 25^{o}C and 51.0 to

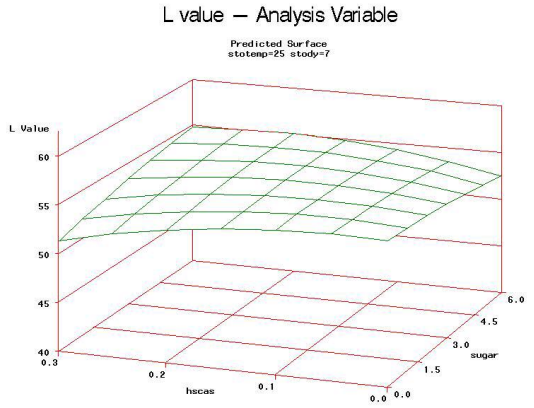
56.4 at 35^{o}C) (Appendix D). Shelf life studies to evaluate the physiochemical and sensory characteristics of peanut paste stored at different temperatures and storage times have revealed that lowest L values were recorded at 0 storage days (Muego-Gnanasekharan and Resurreccion, 1992). Singh *et al*. (2000) reported that peanut paste with higher moisture levels (~8%) had a lighter color. The moisture range of our peanut paste on day one was lower (~1.2%) and detailed monitoring of moisture of the paste was not carried out.

Figure 21. Predicted surface for L value of Peanut Paste at 25^{o}C for storage days 1(a), 7(b) and 14 (c)

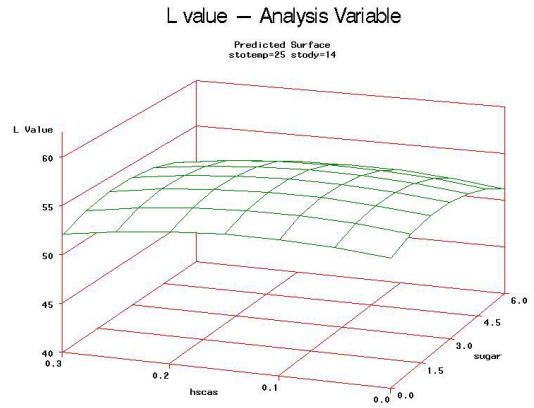
a.



b.



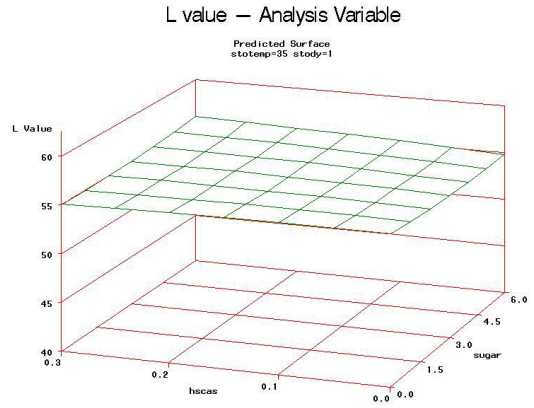
c.



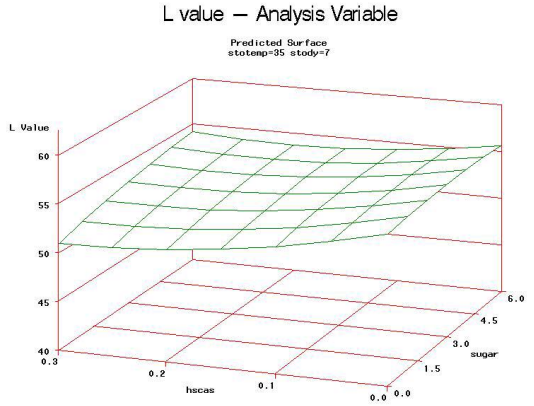
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 22. Predicted surface for L value of Peanut Paste at 35^{o}C for storage days 1(a), 7(b) and 14 (c)

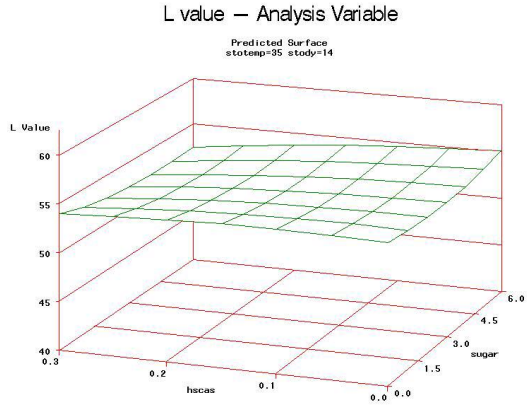
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Hue angle

The hue angle does not change with respect to HSCAS and sugar at 25^{o}C on day 1 (Figure 23a). On day 7 at 25^{o}C, the hue angle increased slightly (71 to 73) with an increase in HSCAS and sugar (23b). A similar trend is observed on day 14 at 25^{o}C and the lowest value was observed at 0.15% HSCAS and 3% sugar for this day and storage temperature (23c).

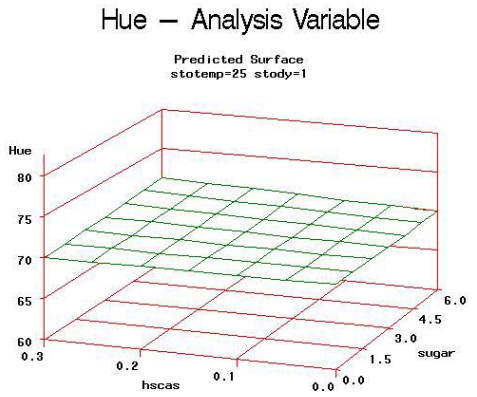
On day 1 at 35^{o}C, the hue angle increased slightly (69 to 71) with an increase in the percentage HSCAS (Figure 24a). On day 7 at 35^{o}C, the hue angle increased slightly with an increase in the percentages of HSCAS and sugar (Figure 24b). Further, on day 14 the hue angle increased slightly with an increase in the percentages of HSCAS and sugar for this temperature range (Figure 24c).

Except for paste stored at 25^{o}C, day 1, all mean hue angle values observed for the peanut formulations we prepared were significantly different with respect to storage temperatures and times (Appendix D). The hue angle ranged from 69.8 to 74.4 at 25^{o}C and from 68.9 to 75.4 at 35^{o}C (Appendix D). Also on days 14 at both temperatures, the the paste was slightly darker brown (Figure 23c and 24c) indicating that storage time was the main factor affecting the hue angle of the paste. It may also be suggested that the sugar and amino acids in the paste may interact in a Maillard reaction to contribute to the darker color when stored for longer periods of time. Muego-Gnanasekharan and Resurreccion (1992) reported that the hue angle of paste decreased with an increase in storage time when stored at 50^{o}C. Hinds *et al* (2002) reported that the hue angle of mambas prepared in Haiti were

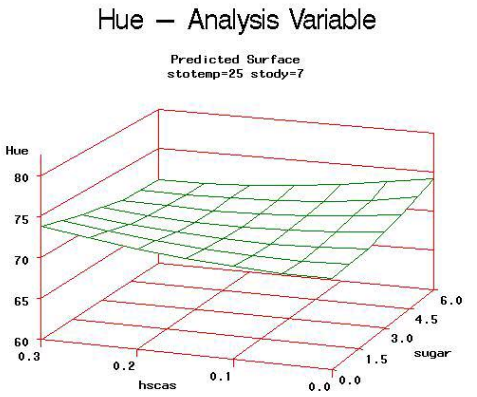
not significantly different from that of peanut butter prepared in the U.S., although sugar (%) in the products ranged from 4.7 to 11.6%.

Figure 23. Predicted surface for Hue angle of Peanut Paste at 25^{o}C for storage days 1(a), 7(b) and 14 (c)

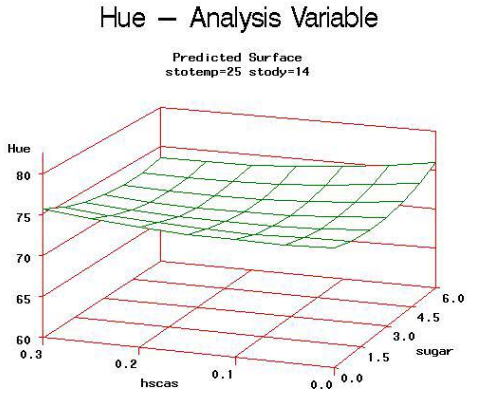
a.



b.



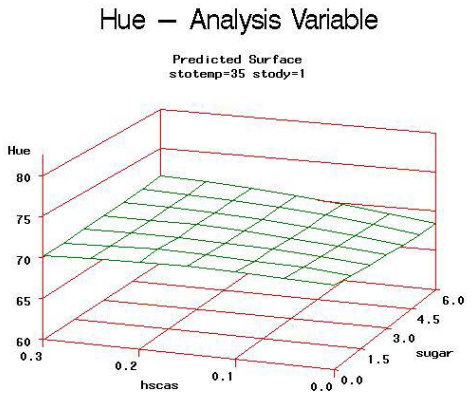
c.



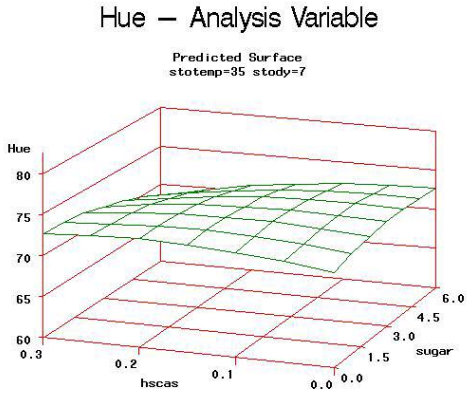
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 24. Predicted surface for Hue angle of Peanut Paste at 35°C for storage days 1(a), 7(b) and 14 (c)

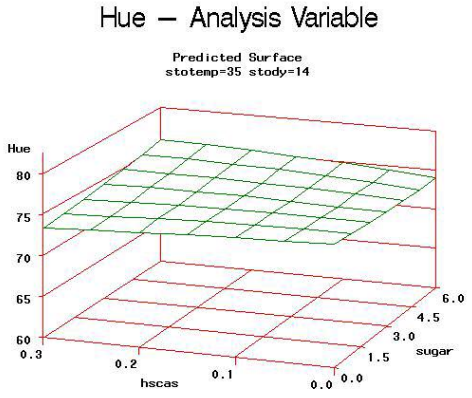
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Chroma

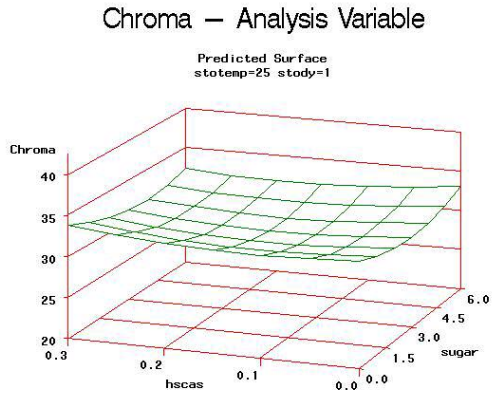
At 25°C on day 1, the chroma decreased slightly as the percentage of HSCAS and sugar increases upto 0.15% and 0.3% respectively, and then increased (Figure 25a). On day 7 at the same temperature, the chroma increased slightly as the percentage of HSCAS increased (Figure 25b). On day 14 at 25°C, the chroma did not change with respect to HSCAS, but decreased slightly as the percentage of sugar decreased (Figure 25c).

At 35°C on day 1, the chroma increased slightly with an increase in HSCAS percentage, and it decreased as the percentage of sugar increased when HSCAS was low (Figure 26a). However, it did show a slight increase when the percentages of both the formulation variables increased. At 35°C on day 7, the chroma was lowest when the percentage of HSCAS was 0.15% (Figure 26b). It also peaked at high percentages of both HSCAS and sugar (Figure 26b). At 35°C on day 14, the chroma decreased slightly as the percentage of sugar decreased (Figure 26c). Hinds *et al* (2002) reported that the chroma of mambas containg sugar (sucre mambas) had lower values (29.5) compared to the values (31.0) of plain mambas containing no sugar but were not significantly different from that of peanut butter prepared in the U.S.

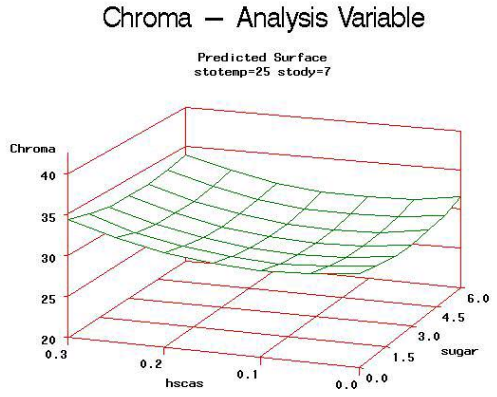
The means values for chroma for the peanut paste we prepared did show significant differences with respect to storage temperatures and times (Appendix D).

Figure 25. Predicted surface for Chroma of Peanut Paste at 25°C for storage days 1(a), 7(b) and 14 (c)

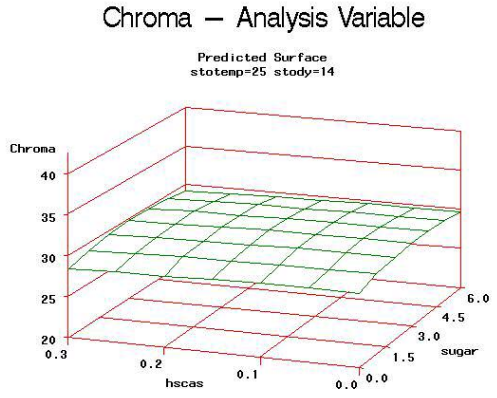
a.



b.



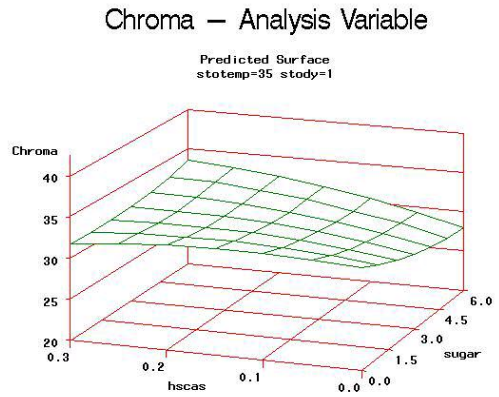
c.



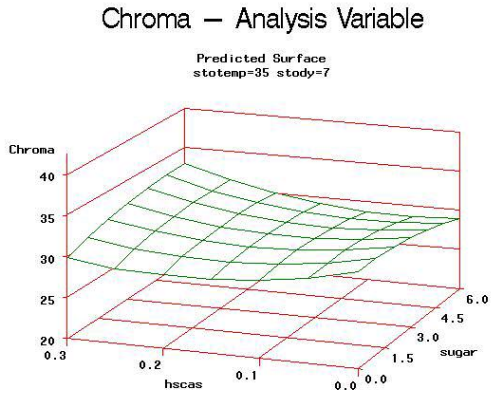
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 26. Predicted surface for Chroma of Peanut Paste at 35°C for storage days 1(a), 7(b) and 14 (c)

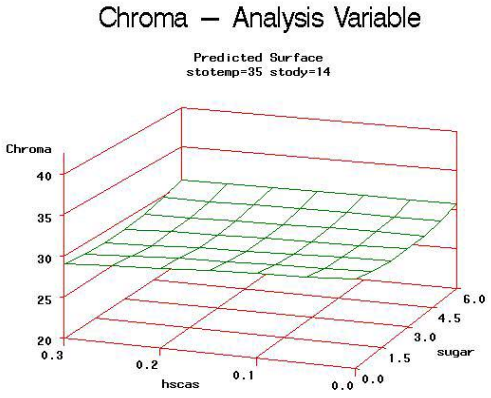
a.



b.



c **.**



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Firmness

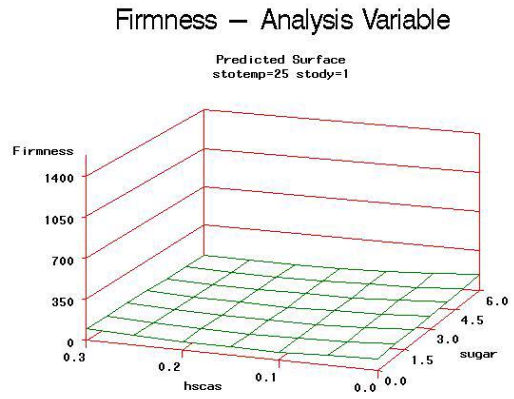
At 25°C on day 1, the firmness decreased slightly when the percentage of HSCAS was increased upto 0.15%, increased (80 to 120 g) as the percentage of sugar increased (Figure 27a). On day 7 at the same temperature, the firmness was the least when the percentage of HSCAS was 0.15% (Figure 27b). The firmness did not change much with respect to sugar. Overall the firmness readings were slightly higher (99.6 to 188.5 g) than that of day 1 storage (65.1 to 93.2) at 25°C (Appendix D). On day 14 at 25°C, the firmness decreased as the percentage of HSCAS increased up to 0.15% and then increased as the percentage of HSCAS increased (Figure 27c). The firmness decreased slightly as the percentage of sugar up to 0.5%, and then increased. The highest value was observed at 0.3% HSCAS and 6% sugar and the lowest value was observed at 0.15% HSCAS and 1.5% sugar.

On day 1 at 35°C, the firmness did not change much with respect to HSCAS and sugar (Figure 28a). On day 7 at the same temperature, firmness increased slightly with an increase in the sugar concentration beyond 3% for higher HSCAS levels (Figure 28b). On day 14 at 35°C, the firmness was affected significantly when the percentages of HSCAS and sugar both increased (Figure 28c). Highest values (~ 1200 g) were observed at 0.3% HSCAS and 6% sugar. Overall, the firmness was the highest compared to that of days 1 and 7. The peanut paste treatments contained no stabilizers. Thus, the increase in firmness with increased storage time could have arisen from settling/separation of the paste components.

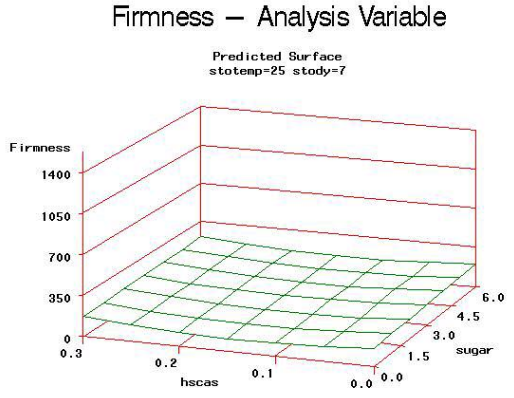
Singh *et al*. (2000) reported that as the quantities of water and starch based fat replacer were increased in the formulation of a reduced fat (> 50% reduction) peanut paste, the firmness significantly reduced. In another study the functional properties of peanut paste were observed related to moist heat treatment. The results revealed that paste firmness decreased as the moisture uptake of peanuts increased during heat processing (McWatters and Cherry, 1975). Hinds *et al* (2002) reported that the mean values of firmness of mambas prepared in Haiti were not significantly different from that of peanut butter prepared in the U.S. Further, the firmness of their mambas prepared with sugar was lower (4.4 g) compared to the plain mambas (5.6 g). For the peanut paste we prepared, the mean firmness scores were significantly different only when the paste was stored at 35^{o}C for 14 days.

Figure 27. Predicted surface for Firmness of Peanut Paste at 25°C for storage days 1(a), 7(b) and 14 (c)

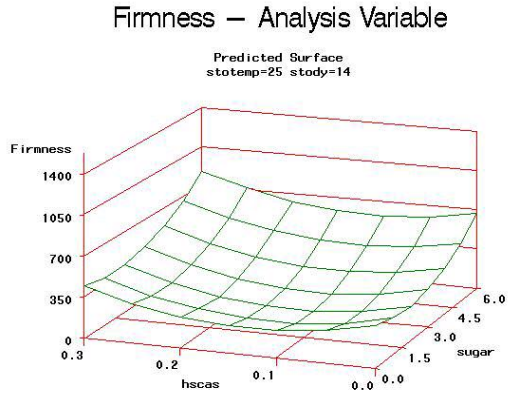
a.



b.



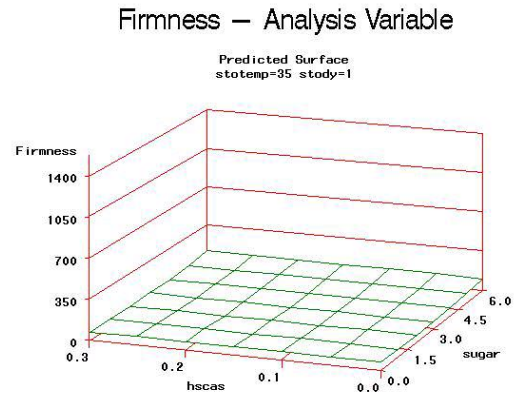
c.



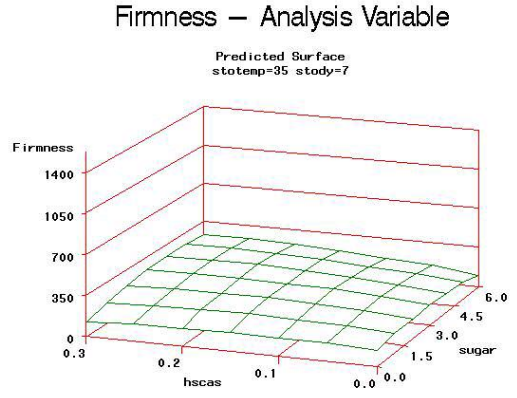
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 28. Predicted surface for Firmness of Peanut Paste at 35°C for storage days 1(a), 7(b) and 14 (c)

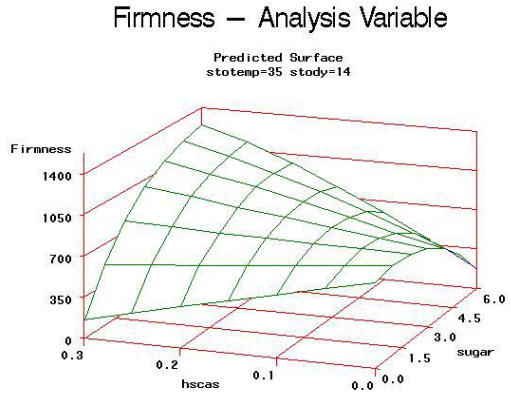
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Adhesiveness

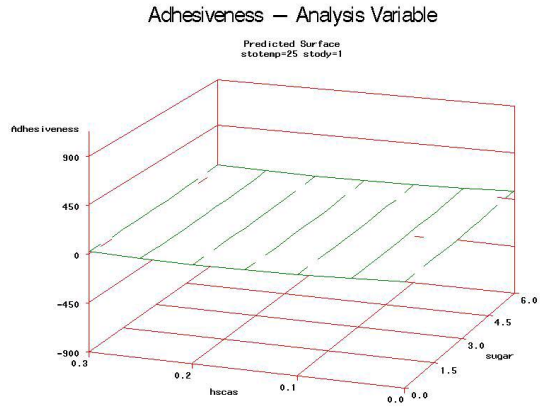
The adhesiveness does not change with respect to the HSCAS and sugar at 25^{o}C on day 1 (Appendix D) and on day 7 (Appendix D). However, the values (173.6 to 233.8 g*mm) on day 7 were slightly higher that those of day 1 (65.1 to 124.6 g*mm). On day 14, the adhesiveness increased as sugar increased, and was highest (600 g*mm) at 6% sugar (Figure 29c). Overall, the adhesiveness readings (264.6 to 682.2 g*mm) at this temperature were higher than that of days 1 (65.1 to 124.6 g*mm) and 7 (173.6 to 233.8 g*mm). It was also observed that adhesiveness readings on day 14 at 25^{o}C were slightly higher than day 14 at 35^{o}C (Figures 29c and 30c). Therefore, it could be possible that with an increase in storage time, the adhesiveness might increase with an increase in storage temperature.

At 35^{o}C on day 1, and day 7 the adhesiveness does not change with respect to the HSCAS and sugar (Figures 30a and 30b). However, the adhesiveness readings on day 7 (209.1 to 277.8 g*mm) were slightly higher than that of day 1 (59.7 to 118.5 g*mm) storage at 35^{o}C (Appendix D). At 35^{o}C on day 14, the adhesiveness is slightly high (~420) at 0% HSCAS and 0% sugar, then it decreases slightly ($\leq$ 300) as the percentages of both HSCAS and sugar increase (Figure 30c).

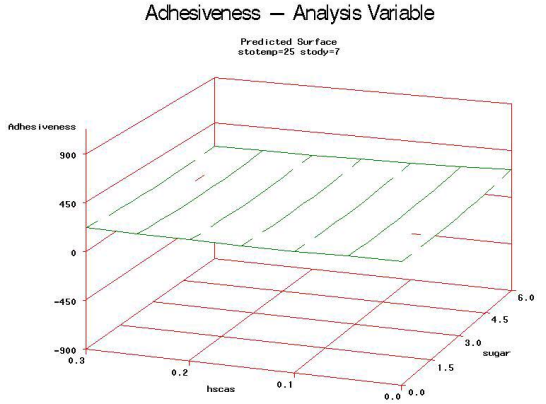
Hinds *et al* (2002) reported that there was a significant difference in the mean values of adhesiveness for Haitian mambas compared to the U.S peanut butter. There was no significant difference in the adhesiveness between the Sucre mambas and the Plain mambas. For the peanut paste we prepared the mean adhesiveness scores were significantly different only when the paste was stored at 35^{o}C for 14 days.

Figure 29. Predicted surface for Adhesiveness of Peanut Paste at 25°C for storage days 1(a), 7(b) and 14 (c)

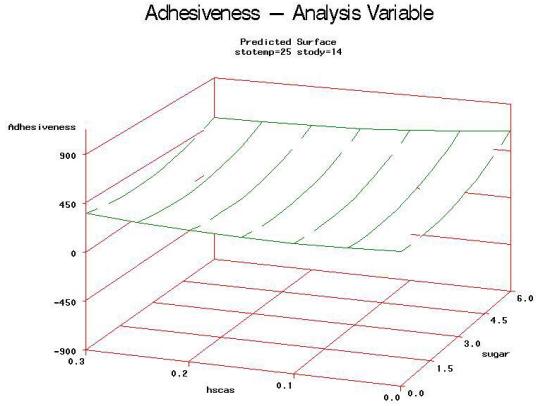
a.



b.



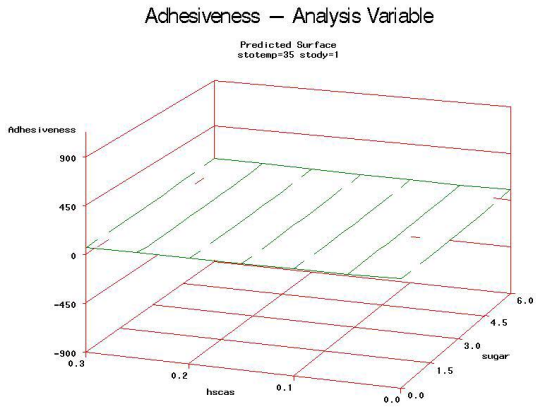
c.



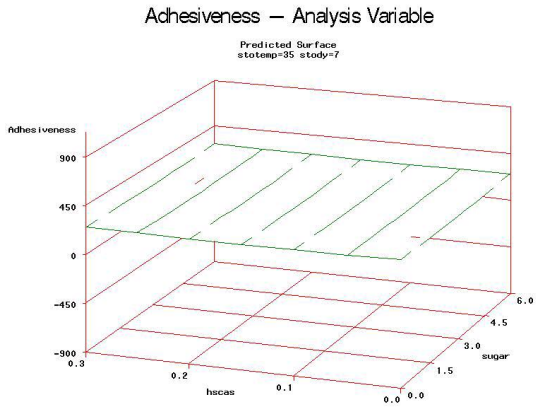
Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

Figure 30. Predicted surface for Adhesiveness of Peanut Paste at 35^{o}C for storage days 1(a), 7(b) and 14 (c)

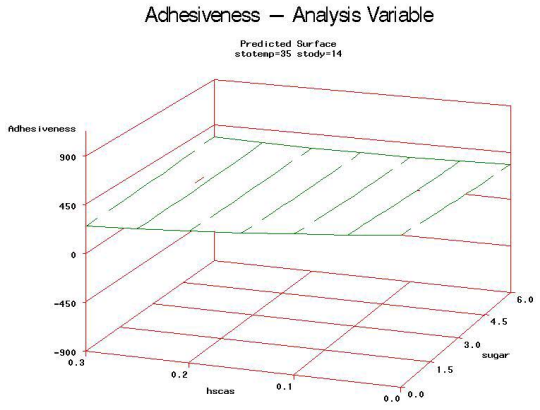
a.



b.



c.



Stotemp = Storage temperature; Stody = Storage day; hscas = hydrated sodium calcium aluminosilicate (%); pf= peanut flour (%)

CHAPTER V

CONCLUSIONS

Peanuts and their products can be used to create a variety of value added functional foods. In this study the effect of HSCAS and peanut flour and HSCAS and sugar on the physical properties of cookie stix and peanut paste were evaluated. Response surface methodology was used to determine the behavior of the response variables in relation to the independent variables studied.

Cookie Stix

The results for the cookie stix indicated that varying levels of HSCAS and peanut flour did affect the dependent variables especially the crunchiness and water activity (A_w). Further, differences were also observed when the product was stored at different storage temperatures, namely 25^o C and 35^o C and also for different storage periods, namely 1, 7 and 14 days. The effects of HSCAS and peanut flour on the response variable are listed below.

Texture

The crunchiness of cookie stix decreased as the percentage of peanut flour increased and increased as the percentage of HSCAS increased. The cookie stix

containing 0.15% HSCAS and 0% peanut flour, or 0.25% HSCAS and 15% peanut flour were the most crunchy. The hardness also decreased with an increase in peanut flour. It increased with an increase in HSCAS. Some of the values observed for hardness were comparable to those of commercially available cookies .

Total moisture (%)

The moisture content decreased as the concentration of HSCAS increased and increased as the percentage of peanut flour increased. The moisture content also decreased with an increase in storage time. Further, cookie stix stored at 35^{o}C had comparatively lower values for moisture (%) compared to those stored at 25^{o} C. For example cookie stix stored at 35^{o}C for 14 days had moisture contents ranging from 3% to 7%, while cookie stix stored at 25^{o}C for 14 days had moisture contents ranging from 6% to 16%.

Water activity (A_w)

The control cookie stix (0% HSCAS and 0% peanut flour) had the least A_w, however, increasing the concentrations of HSCAS and peanut flour did seem to affect the water activity of the product. The A_w decreased with an increasing concentration of HSCAS, but generally increased as the percentage of peanut flour increased. The A_w also decreased with an increase in storage time. Further, cookie stix stored at 35^{o}C had lower values (0.2-0.8) of A_w compared to those stored at 25^{o}C (0.6-0.8). Cookie stix containing 15 to 50 % peanut flour and 0.15 to 0.3% HSCAS had $A_w \leq 0.6$, and thus could be expected to have a longer shelf life than the other formulations.

Color (L value, chroma and hue angle)

Generally cookie stix were darker, and had a more intense brown color with increased peanut flour. The L value decreased with an increase in the peanut flour. It did not change much with respect to the HSCAS. The hue angle decreased with an increase in HSCAS and peanut flour. The chroma increased with an increase in both HSCAS and peanut flour.

Peanut Paste

The results for the peanut paste also indicated that varying levels of HSCAS and sugar did affect the dependent variables especially the firmness, adhesiveness and water activity (A_w). Further, differences were also observed when the product was stored at different storage temperatures, namely 25^o C and 35^o C and also for different storage periods, namely 1, 7 and 14 days. The effects of HSCAS and sugar on the response variable are listed below.

Texture

The firmness increased as the concentrations of sugar and HSCAS both increased. A greater increase was observed on day 14 for both 25^oC and 35^oC storage temperatures. Similar trends were observed with the adhesiveness.

Water activity (A_w)

The A_w increased as the concentrations of both sugar and HSCAS increased. However, the increase was more marked at 14 days of storage at both the temperature levels.

Color (L value, chroma and hue angle)

L value, chroma and hue angle showed varying trends as the concentrations of HSCAS and sugar increased. Hue angle and L value increased with an increase in sugar and HSCAS when the paste was stored at 35^{o}C indicating that the paste became slightly darker brown in color.

Significance and Recommendations

For cookie stix it was observed that HSCAS (at 0.25%) decreased the A_w and thus could have potential for prolonging the shelf life of the product. It also increased the crunchiness which is a desirable quality parameter for cookies. It also affected the color of the product, however, color effects are not an indicator of adverse quality because consumers are accustomed to seeing cookies with a wide range of color.

For the peanut paste the adhesiveness was significantly affected only on day 14 storage for both temperature ranges. The firmness was significantly affected only when the paste was stored at 35^{o}C on day 14 storage.

Based on the findings of this study it can be recommended that HSCAS and peanut flour can be successfully used in the formulation of cookies. Observations made based on the means of different response variables has shown that formulations containing 0.25% HSCAS and 0.15% peanut flour could be used to make cookie stix with variables similar to those of commercially available cookies. Also, the cookie stix could also be stored at temperature ranges of 25^{o}C and 35^{o}C without any adverse affect on the product. Storage at 35^{o}C is important for tropical / developing countries e.g. Ghana where food products are typically stored at ambient temperatures (~35^{o}C).

For the peanut paste it was observed that HSCAS and sugar did not adversely affect the textural attributes of the paste for most formulations and storage times. However, the

A_w increased with an increase in sugar and HSCAS, and also with storage time, but A_w levels were still with a range (0.2 – 0.4) that would not facilitate microbial growth.

Finally, since no adverse effects were observed with the incorporation of HSCAS, a sensory evaluation to determine the acceptability of similar products should be conducted in Ghana, where aflatoxin contamination is a challenge.

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APPENDICES

Appendix A. Cookie stix formulations

	% Dry wt	Weight of Ingredients in grams										
Batch code		**015**	**069**	**104**	**110**	**127**	**150**	**289**	**486**	**510**	**695**	**779**
Butter	24.8	113	113	113	113	113	113	113	113	113	113	113
Baking pd	0.15	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Vanilla		2	2	2	2	2	2	2	2	2	2	2
Cinnamon	0.46	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Salt	0.4	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Nutmeg	0.12	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Peanut Fl	Varies	43.3	43.3	245	245.1	144.2	144.2	0	288.4	0	144.2	144.2
AP Fl	Varies	245	245	43.3	43.26	144.2	144.2	288.4	0	288.4	144.2	144.2
Water	Varies	135	135	195	195	160	160	130	210	130	160	160
Sugar	10.8	49.1	49.1	49.1	49.1	49.1	49.1	49.1	49.1	49.1	49.1	49.1
HSCAS	Varies	0.23	1.14	0.23	1.139	0	1.367	0.683	0.683	0	0.683	0.683

HSCAS = hydrated sodium calcium aluminosilicate.

Appendix B. Peanut paste formulations

Formulation #	Code	HSCAS %	Sugar %	HSCAS (g)	Sugar (g)
1	015	0.15	3	2.4	48
2	047	0.25	5.1	4	81.6
3	058	0.05	5.1	0.8	81.6
4	141	0.05	0.9	0.8	14.4
5	209	0.15	6	2.4	96
6	219	0	0	0	0
7	494	0.3	3	4.8	48
8	591	0.15	0	2.4	0
9	625	0	3	0	48
10	706	0.25	0.9	4	14.4
11	882	0.15	3	2.4	48

HSCAS = hydrated sodium calcium aluminosilicate.

Appendix C. Effect of independent variables on physical properties (means[τ]+ s.d.) of Cookie stix…(contd on pages 125, 126, 127, 128, 129, 130)

Formulation					Outer surface color[α]		
[ττ] HSCAS PF …(%).....	ST[Φ] °C	SD[σ]	A w	Moisture (%)	L value	Chroma	Hue
0.05 15.0	25 °C	1	0.7±0.01 hijk	11.6± 1.70 fghi	62.1±1.57 defghi	24.2±0.33 pqrst	81.3±0.52 defg
0.25 15.0	25 °C	1	0.6±0.05 st	7.6±0.45 qrst	60.3±3.42 efghi	24.8±0.73 pqrs	81.1±0.25 defg
0.05 85.0	25 °C	1	0.8±0.03 cb	11.8±1.92 fghi	47.1±2.90 lmno	30.7±1.77 a	72.0±0.71 pqrst
0.25 85.0	25 °C	1	0.6±0.03 rq	9.38±2.25 lmnop	46.5±1.77 mnopq	29.4±1.27 abcd	73.7±0.84 lmno
0.00 50.0	25 °C	1	0.7±0.05 mnop	15.3±1.21 cd	45.6±1.41 mnopqr	26.7±0.93 efghijklmno	74.6±0.52 jkl
0.30 50.0	25 °C	1	0.7±0.01 ijklm	15.6±2.05 cd	47.4±1.74 lmno	25.8±0.92 hijklmnop	76.3±0.46 h
0.15 0.00	25 °C	1	0.7±0.03 jklm	9.13±1.23 lmnopq	62.5±4.09 defgh	17.8±0.59 xyz	85.2±0.35 abc
0.15 100	25 °C	1	0.8±0.04 ab	18.4±0.99 a	40.2±2.30 tuvw	27.2±1.17 efghijklm	70.4±0.47 uvw
0 0.00	25 °C	1	0.7±0.06 hijk	10.5±1.88 hijkl	68.1±2.54 abc	17.3±0.60 z	85.5±0.98 abc
0.15 50.0	25 °C	1	0.7±0.05 lmno	9.7±1.66 jklmno	48.6±2.39 lm	26.8±0.84 efghijklmn	75.8±0.57 hij
0.15 50.0	25 °C	1	0.8±0.02 bcd	15.4±0.82 dc	46.7±1.66 mnop	26.6±0.81 efghijklmno	74.0±0.55 lmn
0.05 15.0	25 °C	7	0.7±0.00 lmno	10.7±0.50 hijkl	61.0±0.98 efghi	24.4±0.34 qrst	80.9±0.55 efg
0.25 15.0	25 °C	7	0.6±0.01 opq	7.8±0.36 pqrs	57.4±4.83 ij	22.6±1.50 tu	82.5±0.57 d
0.05 85.0	25 °C	7	0.7±0.00 fghij	10.6±0.24 hijkl	44.6±3.19 mnopqrstu	29.5±1.53 abcd	71.7±0.67 qrstu
0.25 85.0	25 °C	7	0.7±0.04 efghi	12.6±1.23 fg	44.6±2.38 mnopqrstu	28.3±0.35 bcdef	72.5±1.17 nopqrs
0 50.0	25 °C	7	0.6±0.01 st	9.5±1.02 klmno	43.2±4.82 mnopqrstu	26.0±2.01 ghijklmnopq	73.3±1.05 lmnop
0.3 50.0	25 °C	7	0.6±0.01 opq	9.2±0.59 lmnop	51.5±2.20 kl	28.3±1.25 bcdef	76.0±0.21 hi
0.15 0.00	25 °C	7	0.7±0.01 fghij	10.7±0.10 hijkl	68.4±3.45 ab	18.9±0.46 wxy	85.6±0.70 abc
0.15 100	25 °C	7	0.8±0.01 bcd	15.1±0.34 dc	38.7±3.09 vw	26.8±1.55 fghijklmn	67.6±0.67 x
0 0.00	25 °C	7	0.1±0.01 b	4.2±0.83 xyz	68.3±2.15 abc	18.8±1.86 xyz	84.2±0.95 c
0.15 50.0	25 °C	7	0.7±0.00 efgh	5.4±0.28 vwxy	48.5±0.53 lm	27.5±0.53 defghijk	75.6±0.12 hijk
0.15 50.0	25 °C	7	0.7±0.01 defgh	11.3±0.80 ghij	48.4±1.95 lm	27.9±0.42 cdefgh	74.0±0.60 lmn

0.05	15.0	25 °C	14	0.7±0.00 nop	9.61±0.29 klmno	59.8±3.48 ghi	24.7±0.43 opqrs	80.7±0.20 efg
0.25	15.0	25 °C	14	0.5±0.00	9.05±0.16 lmnopq	58.1±2.78 hij	23.1±0.57 rst	82.1±0.74 de
0.05	85.0	25 °C	14	0.7±0.00 mno	10.3±0.13 hijklmn	43.3±1.92 mnopqrstu	28.0±0.60 bcdefg	71.6±1.30 qrstu
0.25	85.0	25 °C	14	0.7±0.01 defgh	10.4±0.08 hijkl	44.4±0.88 mnopqrstu	28.6±0.59 bcde	73.0±0.76 mnopq
0	50.0	25 °C	14	0.8±0.01 bc	12.6±0.74 fg	47.9±1.01 lmn	27.5±0.68 defghijk	73.9±0.12 lmno
0.3	50.0	25 °C	14	0.7±0.00 ijklm	10.2±0.10 hijklmn	47.1±2.36 lmno	26.9±0.94 efghijklmn	73.7±0.38 lmno
0.15	0.00	25 °C	14	0.5±0.00 ut	10.5±0.04 hijkl	68.6±1.82 ab	18.1±0.99 xyz	85.3±0.20 abc
0.15	100	25 °C	14	0.8±0.01 bcde	16.1±0.57 bc	38.3±1.33 w	26.3±0.47 fghijklmno	67.5±1.25 xy
0	0.00	25 °C	14	0.6±0.00 pq	10.4±0.14 hijklm	69.0±2.61 a	17.7±0.83 xyz	84.5±1.13 bc
0.15	50.0	25 °C	14	0.7±0.00 ghijk	6.4±0.22 stuv	48.9±1.62 lm	27.3±1.21 defghijkl	74.8±0.56 ijkl
0.15	50.0	25 °C	14	0.8±0.01 ab	13.1±0.12 ef	46.0±0.56 mnopqr	26.6±0.58 efghijklmno	73.6±0.50 lmno
0.05	15.0	35 °C	1	0.7±0.02 mnopq	9.1±0.33 pqlmno	62.3±2.21 defgh	25.5±0.93 klmnopq	80.2±0.26 g
0.25	15.0	35 °C	1	0.7±0.02 nopq	7.2±0.23 rstu	64.3±2.34 cdefg	25.2±0.24 lmnopqr	81.9±0.46 def
0.05	85.0	35 °C	1	0.7±0.00 cdefgh	11.0±1.65 ghijk	45.2±1.00 mnopqrs	30.0±0.91 abc	71.4±0.44 stuv
0.25	85.0	35 °C	1	0.7±0.03 hijkl	10.5±1.11 hijkl	39.9±0.71 uvw	26.5±0.61 efghijklmno	69.8±1.15 w
0	50.0	35 °C	1	0.8±0.01 ab	8.8±0.98 mnopqr	41.7±1.88 qrstuvw	25.6±1.30 ijklmno	72.7±0.45 nopqrs
0.3	50.0	35 °C	1	0.8±0.01 ab	11.9±0.49 fghi	42.6±2.7 opqrstuv	25.4±1.73 klmnopq	72.7±0.81 nopqrs
0.15	0.00	35 °C	1	0.7±0.04 klmn	11.92±1.05 fghi	58.3±2.1 hij	16.9±0.79 z	85.8±0.10 ab
0.15	100	35 °C	1	0.8±0.01 a	17.1±0.95 ab	38.6±2.59 vw	26.2±1.33 fghijklmnopq	69.8±0.44 w
0	0.00	35 °C	1	0.4±0.04 x	5.4±0.68 vwxy	57.5±3.4 ij	22.9±2.23 st	81.1±2.01 defg
015	50.0	35 °C	1	0.8±0.03 cdefgh	12.6±1.15 fg	47.1±3.87 lmno	27.5±1.78 defghijk	74.4±0.31 klm
015	50.0	35 °C	1	0.8±0.02 bcdef	14.3±0.50 de	43.2±2.76 mnopqrstu	25.7±1.92 ijklmnopq	72.8±0.82 nopqrs
0.05	15.0	35 °C	7	0.6±0.01 st	11.3±0.97 ghij	60.2±3.02 fghi	26.2±0.72 fghijklmnopq	79.9±0.46 g
0.25	15.0	35 °C	7	0.5±0.01 w	6.7±0.09 stuv	60.2±1.73 fghi	26.0±1.06 ghijklmnopq	80.6±0.47 fg
0.05	85.0	35 °C	7	0.7±0.02 pq	7.6±0.29 qrst	38.0±1.77 w	25.2±1.35 lmnopqr	67.2±1.31 xy

0.25	85.0	35 °C	7	0.6±0.02 s	8.8±0.55 mnopqr	42.1±3.28 pqrstuvw	27.8±1.52 defghi	69.6±1.34 w
0	50.0	35 °C	7	0.7±0.00 pq	9.3±0.32 lmnop	48.5±3.90 lm	28.7±1.66 bcde	73.8±0.53 lmno
0.3	50.0	35 °C	7	0.8±0.01 fghij	12.0±0.55 fgh	40.8±1.33 stuvw	25.1±0.54 nopqr	70.1±0.40 wv
0.15	0.00	35 °C	7	0.6±0.00 rs	11.2±0.41 ghijk	64.9±2.04 abcde	19.6±0.92 vwx	86.0±0.82 a
0.15	100	35 °C	7	0.8±0.01 hijkl	12.6±0.44 fg	33.7±2.28 x	23.1±0.65 rst	66.2±0.95 y
0.00	0.00	35 °C	7	0.2±0.00 b	2.6±0.51 a	66.3±2.96 abcd	20.9±0.95 u	84.3±1.06 bc
0.15	50.0	35 °C	7	0.3±0.00 y	5.7±0.37 uvwx	45.1±2.40 mnopqrst	27.8±0.79 fghijklm	73.0±0.20 mnopqr
0.15	50.0	35 °C	7	0.7±0.01 jklm	10.3±0.50 ijklmn	46.2±3.13 mnopqr	27.7±1.57 fghij	72.6±0.35 mnopqrs
0.05	15.0	35 °C	14	0.2±0.00 a	6.3±0.48 stuvw	55.3±1.63 jk	25.0±0.50 nopqr	81.2±1.35 defg
0.25	15.0	35 °C	14	0.3±0.00 yz	4.8±0.26 wxy	61.4±1.82 efghi	24.5±1.36 pqrst	82.4±0.76 d
0.05	85.0	35 °C	14	0.5±0.00 v	6.1±0.23 tuvw	41.5±1.72 rstuvw	26.8±0.66 fghijklmno	71.7±1.10 qrstu
0.25	85.0	35 °C	14	0.5±0.01 v	5.7±0.37 uvwx	43.8±2.57 mnopqrstu	28.6±0.85 bcde	70.7±0.81 tuvw
0	50.0	35 °C	14	0.5±0.01 w	6.4±0.44 stuv	44.8±0.62 mnopqrst	27.7±0.73 fghij	72.0±0.10 pqrst
0.3	50.0	35 °C	14	0.6±0.01 rs	8.7±0.83 nopqr	46.4±0.45 mnopq	27.7±0.72 defghij	73.0±0.21 mnopqr
0.15	0.00	35 °C	14	0.6±0.01 uv	8.5±0.47 opqr	64.9±0.95 abcdef	20.4±0.71 vw	84.7±1.05 abc
0.15	100	35 °C	14	0.7±0.01 pq	5.5±0.55 wxyv	45.1±2.70 mnopqrst	30.1±1.73 ab	71.5±1.59 rstuv
0	0.00	35 °C	14	0.3±0.00 z	3.1±0.16 az	63.8±1.72 cdefg	19.7±0.83 vwx	85.2±1.16 abc
0.15	50.0	35 °C	14	0.6±0.00 s	4.1±0.19 zy	44.1±2.76 mnopqrstu	26.5±1.19 fghijklmnop	72.8±0.72 nopqrs
0.15	50.0	35 °C	14	0.7±0.01 rq	7.0±0.48 stuv	46.4±1.98 mnopq	28.4±0.65 bcdef	72.5±0.38 opqrs

Formulation			Texture	
[τ] HSCAS PF	ST[Φ]	SD[σ]	Hardness	Crunchiness[α]
…(%).....	[o]C		g (shear force)	
0.05 15.0	25 [o]C	1	583.4±290.30 vwx	4.1±1.01 fghijklm
0.25 15.0	25 [o]C	1	1364.3±366.17 jklmnopqrstuv	2.2±0.78 lm
0.05 85.0	25 [o]C	1	568.1±299.45 vwx	7.9±3.56 abcdefghijkl
0.25 85.0	25 [o]C	1	506.5±196.86 vwx	9.6±3.68 abcdefg
0.00 50.0	25 [o]C	1	326.5±48.88 x	9.0±1.77 abcdefghijk
0.30 50.0	25 [o]C	1	428.0±255.00 wx	7.3±2.76 abcdefghijklm
0.15 0.00	25 [o]C	1	1022.7±432.93 nopqrstuvwx	3.3±2.66 hijklm
0.15 100	25 [o]C	1	689.6±360.62 stuvwx	10.5±4.32 abcde
0 0.00	25 [o]C	1	519.2±325.83 vwx	9.5±0.35 abcdefgh
0.15 50.0	25 [o]C	1	898.7±569.8 qrstuvwx	7.64±5.08 abcdefghijklm
0.15 50.0	25 [o]C	1	252.0±35.9 x	10.5±0.19 abcde
0.05 15.0	25 [o]C	7	1469.8±310.7 jklmnopqrstuv	2.9±0.49 lmk
0.25 15.0	25 [o]C	7	1169.3±354.45 mnopqrstuvw	1.7±0.46 lm
0.05 85.0	25 [o]C	7	1074.7±36.4 nopqrstuvwx	7.8±5.86 abcdefghijkl
0.25 85.0	25 [o]C	7	1690.7±110.25 hijklmnopqrs	6.73±4.56 abcdefghijkl
0 50.0	25 [o]C	7	827.8±837.6 qrstuvw	2.4±1.19 ml
0.3 50.0	25 [o]C	7	936.9±432.4 pqrstuvw	4.8±0.46 defghijklm
0.15 0.00	25 [o]C	7	1157.9±132.84 mnopqrstuvwx	1.8±0.05 lm
0.15 100	25 [o]C	7	758.7±167.4 rstuvw	6.4±0.52 abcdefghijkl
0 0.00	25 [o]C	7	892.9±185.7 pqrstuvw	2.2±0.87 lm
0.15 50.0	25 [o]C	7	664.9±23.35 tuvwx	5.0±1.03 defghijklm
0.15 50.0	25 [o]C	7	397.4±134.22 wx	9.3±3.14 abcdefghi

0.05	15.0	25 °C	14	1208.3±156.60 lmnopqrstuvw	4.8±3.09 defghijklm
0.25	15.0	25 °C	14	1637.2±128.71 ijklmnopqrst	3.0±0.97 lm
0.05	85.0	25 °C	14	860.1±340.55 qrstuvwx	4.2±1.53 fghijkl
0.25	85.0	25 °C	14	2087.0±566.3 fghijklm	6.1±2.90 bcdefghijklm
0	50.0	25 °C	14	1645.7±175.20 lmnopqrs	5.9±3.17 bcdefghijklm
0.3	50.0	25 °C	14	383.5±42.91 wx	5.9±0.59 bcdefghijklm
0.15	0.00	25 °C	14	1802.7±133.88 fghijklmnopq	2.4±0.55 lm
0.15	100	25 °C	14	956.73±82.12 opqrstuvwx	10.2±4.87 abcdef
0	0.00	25 °C	14	684.0±189.65 tuvwx	2.8±1.38 lm
0.15	50.0	25 °C	14	1875.7±373.9 hijklmnop	6.1±2.37 bcdefghijklm
0.15	50.0	25 °C	14	471.7±98.2 vwx	6.6±4.60 abcdefghijklm
0.05	15.0	35 °C	1	1706.4±501.41 hijklmnopq	4.5±2.38 efghijklm
0.25	15.0	35 °C	1	1601.7±0.85 lmnopqrstu	1.5±0.28 m
0.05	85.0	35 °C	1	796.5±185.71 rstuvwx	9.9±5.04 abcdef
0.25	85.0	35 °C	1	769.0±14.42 rstuvwx	12.3±0.11 a
0	50.0	35 °C	1	449.3±68.36 wx	11.0±0.05 abcde
0.3	50.0	35 °C	1	715.4±123.78 rstuvwx	10.0±3.65 abcdef
0.15	0.00	35 °C	1	1627.0±601.77 ijklmnopq	3.3±1.27 ijklm
0.15	100	35 °C	1	449.4±136.66 wx	9.3±3.36 abcdefghi
0	0.00	35 °C	1	1938.5±179.90 fghijklm	1.8±0.3 lm
015	50.0	35 °C	1	443.5±54.78 wx	9.2±3.07 abcdefghi
015	50.0	35 °C	1	615.5±128.53 uvwx	11.8±0.59 ab
0.05	15.0	35 °C	7	2626.8±259.42 cdefgh	2.1±0.46 lm
0.25	15.0	35 °C	7	1963.1±560.44 fghijklmn	1.6±0.10 m
0.05	85.0	35 °C	7	2390.5±1123.66 defghi	3.1±1.92 jklm

0.25 85.0	35 °C 7	3166.0±417.06 hijklmn	5.4±0.87 cdefghijkl
0 50.0	35 °C 7	2657.0±1653.45 cdefgh	6.9±6.5 abcdefghijkl
0.3 50.0	35 °C 7	922.5±297.3 pqrstuvwx	4.4±1.92 efghijklm
0.15 0.00	35 °C 7	2699.9±766.68 cdef	3.7±1.13 ghijklm
0.15 100	35 °C 7	1084.2±204.72 nopqrstuvwx	3.3±0.37 ijklm
0.00 0.00	35 °C 7	2167.5±487.40 fghijkl	2.3±0.21 lm
0.15 50.0	35 °C 7	2757.7±678.16 cdef	5.1±2.83 Cdefghijklm
0.15 50.0	35 °C 7	1238.0±202.62 lmnopqrstuvwx	4.32±1.94 efghijklm
0.05 15.0	35 °C 14	2691.5±923.95 cdef	2.4±1.28 lm
0.25 15.0	35 °C 14	2662.0±1475.20 cdef	3.3±2.36 ijklm
0.05 85.0	35 °C 14	3731.5±1156.80 b	4.7±0.93 fghijklm
0.25 85.0	35 °C 14	4653.2±178.39 a	11.8±4.65 ab
0 50.0	35 °C 14	3548.9±102.05 bc	11.1±11.37 abc
0.3 50.0	35 °C 14	2258.5±385.36 efghij	6.3±2.31 abcdefghijklm
0.15 0.00	35 °C 14	1604.1±468.2 jklmnopqrstu	6.7±4.54 abcdefghijklm
0.15 100	35 °C 14	2168.8±619.29 fghijkl	9.2±1.45 abcdefghijk
0 0.00	35 °C 14	1610.8±182.06 jklmnopqrstu	1.8±0.45 lm
0.15 50.0	35 °C 14	3238.8±587.04 bcd	6.5±1.64 abcdefghijklm
0.15 50.0	35 °C 14	2209.3±786.78 fghij	10.0±4.61 abcdef

[τ]Means for the same variable (column) followed by the same letter are not significantly different according to Duncan's Multiple Range Test at P = 0.05.

[π]PF = % peanut flour replacing all purposed flour, HSCAS = weight percent of hydrated sodium aluminosilicate in cookie stix formulation.

$^{\alpha}$Hue angle (color descriptor): 0^{o} = red, 90^{o} = yellow; Chroma = intensity of hue; L value (lightness scale): 0 = black, 100 = white.

$^{\delta}$Crunchiness = linear distance of penetration curve / number of resistant forces.

$^{\Phi}$ST = storage temperature.

$^{\sigma}$SD = storage day.

Appendix D. Effect of independent variables on physical properties (means[τ]+ s.d.) of Peanut Paste… (contd on pages 132, 133,134, 135, 136, 137).

Formulation				Outer surface color[α]		
[π]HSCAS ..(%)...	Sugar	ST[θ] [o]C SD[σ]	A_w	L value	Chroma	Hue
0.15	3.00	25 [o]C 1	0.2±0.01 abcde	48.6±3.22 i	27.4±4.68 gh	70.3±0.15 opqrst
0.2	5.10	25 [o]C 1	0.2±0.00 de	55.4±1.07 abcde	31.1±1.83 abcdefg	70.8±0.60 klmnopqrs
0.05	5.10	25 [o]C 1	0.3±0.01 qrstuv	56.4±0.16 ab	31.8±1.17 abcdef	70.0±0.15 pqrst
0.05	0.90	25 [o]C 1	0.3±0.00 stuvw	56.5±0.61 a	32.1±0.67 abcdef	70.0±0.23 pqrst
0.15	6.00	25 [o]C 1	0.2±0.01 abcdz	55.1±0.38 abcdef	31.7±0.44 abcdef	70.7±0.31 lmnopqrs
0.00	0.00	25 [o]C 1	0.2±0.00 abcde	55.7±0.94 abcd	33.1±1.26 abc	70.3±0.15 nopqrst
0.30	3.00	25 [o]C 1	0.2±0.00 abcde	54.8±1.13 abcdefgh	31.0±1.98 abcdefg	70.3±0.12 nopqrst
0.15	0.00	25 [o]C 1	0.2±0.01 abcz	55.8±1.35 abcd	31.3±1.76 abcdefg	69.8±0.42 qrst
0.00	3.00	25 [o]C 1	0.2±0.00 abcyz	55.5±2.19 abcde	30.4±1.78 abcdefgh	70.1±0.72 pqrst
0.25	0.90	25 [o]C 1	0.2±0.00 abcyz	54.7±1.52 abcdefgh	32.9±1.79 abcde	70.3±0.47 nopqrst
0.15	3.00	25 [o]C 1	0.2±0.00 abyz	54.8±0.88 abcdefgh	33.3±0.71 ab	70.3±0.31 nopqrst
0.15	3.00	25 [o]C 7	0.2±0.00 axyz	54.6±0.46 abcdefgh	32.8±1.46 abcde	70.7±0.50 lmnopqrs
0.25	5.10	25 [o]C 7	0.2±0.00 axyz	53.5±2.58 abcdefgh	31.4±1.86 abcdefg	71.6±1.06 ijklmnopq
0.05	5.10	25 [o]C 7	0.3±0.00 rstuvw	54.1±0.95 abcdefgh	31.5±4.07 abcdefg	72.1±0.90 fghijklm
0.05	0.90	25 [o]C 7	0.3±0.00 rstuvw	54.8±2.35 abcdefgh	26.2±5.49 h	70.3±0.60 opqrst
0.15	6.00	25 [o]C 7	0.3±0.01 ,nopq	55.3±2.88 abcdef	29.6±1.83 abcdefgh	71.5±0.97 ijklmnopq
0.00	0.00	25 [o]C 7	0.3±0.01 nopqrst	55.0±2.23 abcdefg	33.5±1.80 ab	70.8±0.15 klmnopqrs
0.30	3.00	25 [o]C 7	0.3±0.01 mnopqr	54.4±1.34 abcdefgh	33.1±0.21 abc	71.0±0.25 jklmnopqr
0.15	0.00	25 [o]C 7	0.3±0.01 qrstu	53.8±0.25 abcdefgh	31.1±0.48 abcdefg	71.9±0.53 ghijklmno
0.00	3.00	25 [o]C 7	0.3±0.01 pqrstu	52.9±1.46 abcdefgh	29.0±3.41 abcdef	72.6±0.81 defhij
0.25	0.90	25 [o]C 7	0.3±0.01 mnopqrs	52.6±0.31 cdefgh	31.4±1.01 abcdef	72.5±0.25 defhij
0.15	3.00	25 [o]C 7	0.4±0.05	55.4±1.36	28.3±2.38	70.9±1.42

			Ghi	abcde	efgh	jklmnopqr
0.15	3.00	25 °C 14	0.4±0.01 efg	55.1±3.08 abcdef	30.6±0.87 abcdefg	72.1±1.25 fghijklm
0.25	5.10	25 °C 14	0.4±0.03 cde	53.8±1.03 abcdefgh	29.2±1.71 bcdefgh	72.2±0.90 fghijkl
0.05	5.10	25 °C 14	0.3±0.02 klmno	53.0±3.26 abcdefgh	30.0±1.24 abcdefgh	74.1±0.49 abcde
0.05	0.90	25 °C 14	0.3±0.01 ijkl	54.1±1.26 abcdefgh	28.0±0.72 fgh	73.7±0.25 bcdef
0.15	6.00	25 °C 14	0.4±0.02 def	51.9±2.78 efghi	29.7±0.97 abcdefgh	74.4±0.38 abc
0.00	0.00	25 °C 14	0.4±0.02 fgh	53.0±1.39 abcdefgh	29.9±0.51 abcdefgh	74.3±0.50 abc
0.30	3.00	25 °C 14	0.4±0.01 abc	52.6±2.89 bcdefgh	29.9±0.49 abcdefgh	73.4±0.81 cdefg
0.15	0.00	25 °C 14	0.3±0.03 pqrstu	53.3±1.22 abcdefgh	28.5±1.31 efgh	74.0±0.61 abcde
0.00	3.00	25 °C 14	0.3±0.01 nopqrst	54.4±0.83 abcdefgh	30.0±1.07 abcdefgh	73.1±1.17 cdefghi
0.25	0.90	25 °C 14	0.3±0.00 nopqrstu	54.6±0.54 abcdefgh	29.3±0.58 abcdefgh	73.9±0.21 abcde
0.15	3.00	25 °C 14	0.3±0.01 opqrstu	54.8±1.88 abcdefgh	30.9±1.54 abcdefg	72.9±1.33 cdefghi
0.15	3.00	35 °C 1	0.2±0.00 cde	56.4±0.23 ab	31.7±1.18 abcdef	70.4±0.10 mnopqrst
0.25	5.10	35 °C 1	0.2±0.00 e	55.7±0.61 abcde	33.0±0.35 abcd	80.0±0.31 jklmnopq
0.05	5.10	35 °C 1	0.3±0.00 uvwx	55.7±0.08 abced	28.5±4.27 fgh	69.1±1.23 st
0.05	0.90	35 °C 1	0.3±0.00 tuvw	55.6±1.15 abcde	28.5±6.21 fgh	68.9±1.10 t
0.15	6.00	35 °C 1	0.2±0.00 abcde	55.1±0.38 abcdef	31.7±0.44 abcdef	70.3±0.29 nopqrst
0.00	0.00	35 °C 1	0.2±0.00 bcde	55.7±0.94 abcd	33.1±1.26 abc	70.4±0.25 mnopqrst
0.30	3.00	35 °C 1	0.2±0.00 abcde	54.8±1.13 abcdefgh	31.0±1.98 abcdef	70.5±0.29 mnopqrst
0.15	0.00	35 °C 1	0.2±0.00 abyz	54.1±0.35 abcdefgh	33.6±0.17 a	70.9±0.50 jklmnopqr
0.00	3.00	35 °C 1	0.2±0.00 abyz	53.7±0.72 abcdefgh	30.6±2.73 abcdefg	69.3±1.35 rst
0.25	0.90	35 °C 1	0.2±0.00 abc	56.0±1.53 abc	32.3±1.03 abcde	70.4±0.50 mnopqrst
0.15	3.00	35 °C 1	0.2±0.00 abyz	54.1±0.35 abcdefgh	32.2±1.92 abcdef	70.8±0.06 klmnopqrs
0.15	3.00	35 °C 7	0.3±0.01 abyz	53.1±2.92 abcdefgh	31.4±1.23 abcdef	72.4±0.65 efghijk
0.25	5.10	35 °C 7	0.3±0.01 vwxy	51.6±1.20 fghi	29.7±1.84 abcdefgh	71.7±0.72 hijklmnop

0.05	5.10	35 °C 7	0.3±0.00 qrstu	54.3±4.66 abcdefgh	29.9±3.55 abcdefgh	72.2±2.31 fghijkl
0.05	0.09	35 °C 7	0.3±0.01 pqrstu	55.6±2.66 abcde	28.0±2.28 fgh	72.2±1.95 fghijkl
0.15	6.00	35 °C 7	0.3±0.01 klmn	55.3±2.88 abcdef	29.6±1.83 abcdefgh	71.5±0.97 ijklmnopq
0.00	0.00	35 °C 7	0.3±0.01 jkli	51.0±2.23 abcdefg	33.5±1.80 ab	70.8±0.15 klmnopqrs
0.30	3.00	35 °C 7	0.3±0.01 jkhi	54.4±1.34 abcdefgh	33.1±0.27 abc	71.0±0.25 jklmnopqr
0.15	0.00	35 °C 7	0.4±0.00 jghi	51.3±0.91 ghi	28.5±1.35 fgh	73.7±0.46 cdef
0.00	3.00	35 °C 7	0.4±0.05 fgh	55.2±0.47 abcdef	29.8±1.31 abcdefgh	74.0±0.46 abcde
0.25	0.90	35 °C 7	0.4±0.03 ghi	51.2±1.66 hi	29.4±1.84 abcdefgh	73.0±0.46 cdefghi
0.15	3.00	35 °C 7	0.4±0.02 fde	53.3±1.30 abcdefgh	30.6±1.04 abcdefg	73.4±0.76 cdefgh
0.15	3.00	35 °C 14	0.4±0.02 cdb	52.1±2.58 defgh	28.7±2.99 defgh	75.3±1.55 ab
0.25	5.10	35 °C 14	0.4±0.03 a	54.6±1.07 abcdefgh	30.0±1.07 abcdefgh	75.5±0.35 a
0.05	5.10	35 °C 14	0.3±0.01 lmnk	55.3±1.81 abcdef	30.4±1.47 abcdefgh	74.1±0.91 abcde
0.05	0.90	35 °C 14	0.3±0.01 lmnkop	54.5±0.69 abcdefgh	29.5±0.18 abcdefgh	75.2±0.32 ab
0.15	6.00	35 °C 14	0.4±0.02 ab	52.7±3.01 bcdefgh	30.5±1.68 abcdefg	75.4±1.35 ab
0.00	0.00	35 °C 14	0.4±0.04 cd	53.9±2.40 abcdefgh	30.8±0.95 abcdefg	74.2±1.51 abcde
0.30	3.00	35 °C 14	0.4±0.00 a	51.4±2.06 ghi	28.8±0.08 defgh	74.2±1.08 abcd
0.15	0.00	35 °C 14	0.3±0.00 lmnkqpo	54.9±1.62 abcdefgh	30.2±1.13 abcdefgh	74.1±1.72 abcde
0.00	3.00	35 °C 14	0.3±0.01 lmnk	53.8±2.12 abcdefgh	29.5±0.74 abcdefgh	74.3±1.00 abc
0.25	0.90	35 °C 14	0.3±0.02 lmnkop	53.9±3.06 abcdefgh	28.8±3.20 defgh	74.1±1.10 Abcde
0.15	3.00	35 °C 14	0.3±0.02 jklm	54.4±1.37 abcdefgh	30.0±1.85 abcdefgh	73.0±1.44 cdefghi

Formulation			Texture	
[π]HSCAS	Sugar	ST[θ] SD[σ]	Adhesiveness	Firmness
..(%)...		°C	(g*mm)	(g)
0.15	3.00	25 °C 1	15.4±13.89 hij	67.5±7.51 jk
0.2	5.10	25 °C 1	0.5±7.1 ji	67.6±11.5 jk
0.05	5.10	25 °C 1	63.4±11.09 ghij	93.2±17.77 jk
0.05	0.90	25 °C 1	25.1±16.98 hij	83.1±5.67 jk
0.15	6.00	25 °C 1	45.7±20.18 ghij	84.2±4.83 jk
0.00	0.00	25 °C 1	63.4±10.7 ghij	93.2±11.13 jk
0.30	3.00	25 °C 1	50.9±23.57 ghij	86.3±19.97 jk
0.15	0.00	25 °C 1	-6.3±31.54 ji	65.1±0.92 jk
0.00	3.00	25 °C 1	26.8±13.85 hij	124.6±34.76 jki
0.25	0.90	25 °C 1	-4.34±35.00 ji	79.8±5.32 jk
0.15	3.00	25 °C 1	15.8±7.50 hij	65.7±16.28 jk
0.15	3.00	25 °C 7	194.5±17.09 cdefghij	136.7±14.22 hijk
0.25	5.10	25 °C 7	206.0±5.91 cdefghij	177.4±19.72 fghijk
0.05	5.10	25 °C 7	221.0±35.79 cdefghij	153.4±8.94 ghijk
0.05	0.90	25 °C 7	188.8±18.35 cdefghij	130.0±29.16 Hijk
0.15	6.00	25 °C 7	231.9±47.25 cdefghij	171.4±43.87 fghijk
0.00	0.00	25 °C 7	233.8±27.12 cdefghij	151.1±44.18 ghijk
0.30	3.00	25 °C 7	173.6±19.25 cdefghij	185.5±24.44 fghijk
0.15	0.00	25 °C 7	177.4±11.22 cdefghij	99.6±26.71 jk
0.00	3.00	25 °C 7	204.3±40.30 cdefghij	188.5±25.61 Fghijk
0.25	0.90	25 °C 7	221.3±34.72 cdefghij	160.0±28.37 ghijk
0.15	3.00	25 °C 7	188.1±23.8	134.0±23.79

			cdefghij	hijk
0.15	3.00	25 °C 14	270.2±8.89 cdefghij	271.5±160.97 fghijk
0.25	5.10	25 °C 14	310.5±108.43 cdefghi	416.4±393.69 efghij
0.05	5.10	25 °C 14	315.7±47.36 cdefghi	285.7±48.68 fghijk
0.05	0.90	25 °C 14	293.3±101.27 cdefghij	238.9±27.47 fghijk
0.15	6.00	25 °C 14	682.2±332.42 a	744.5±151.35 abcd
0.00	0.00	25 °C 14	264.6±40.52 cdefghij	353.8±123.43 efghijk
0.30	3.00	25 °C 14	347.7±3.38 bcdefgh	487.6±82.49 cdefg
0.15	0.00	25 °C 14	270.4±24.26 cdefghij	170.4±56.98 fghijk
0.00	3.00	25 °C 14	459.6±246.91 abc	401.4±127.77 efghijk
0.25	0.90	25 °C 14	291.6±21.4 cdefghij	334.8±55.15 efghijk
0.15	3.00	25 °C 14	267.3±25.60 cdefghij	157.6±134.75 ghijk
0.15	3.00	35 °C 1	79.8±20.70 fghij	71.6±8.15 jk
0.25	5.10	35 °C 1	96.6±34.55 fghij	86.5±28.78 jk
0.05	5.10	35 °C 1	74.4±31.21 fghij	77.0±24.45 Jk
0.05	0.90	35 °C 1	74.1±19.84 fghij	54.7±9.87 k
0.15	6.00	35 °C 1	118.5±50.47 defghij	123.3±39.15 jki
0.00	0.00	35 °C 1	75.4±23.82 fghij	79.1±9.37 jk
0.30	3.00	35 °C 1	86.3±12.22 fghij	68.4±11.45 jk
0.15	0.00	35 °C 1	59.7±9.13 ghij	72.0±3.13 jk
0.00	3.00	35 °C 1	84.4±6.74 fghij	73.0±12.96 Jk
0.25	0.90	35 °C 1	66.7±16.19 ghij	67.5±1 jk
0.15	3.00	35 °C 1	63.9±23.55 ghij	67.6±24.29 jk
0.15	3.00	35 °C 7	209.1±35.84 cdefghij	260.0±69.87 fghijk
0.25	5.10	35 °C 7	233.6±16.54 cdefghij	281.2±59.37 fghijk
0.05	5.10	35 °C 7	236.4±29.78	188.1±120.18

			cdefghij	fghijk
0.05	0.09	35 °C 7	212.5±21.22 cdefghij	157.4±40.42 ghijk
0.15	6.00	35 °C 7	263.6±58.55 cdefghij	180.5±181.46 fghijk
0.00	0.00	35 °C 7	272.8±39.46 cdefghij	130.0±87.77 hijk
0.30	3.00	35 °C 7	258.0±23.50 cdefghij	221.2±144.62 fghijk
0.15	0.00	35 °C 7	234.0±32.01 cdefghij	183.0±42.55 fghijk
0.00	3.00	35 °C 7	236.3±0.39 cdefghij	189.3±104.2 fghijk
0.25	0.90	35 °C 7	240.6±30.69 cdefghij	183.3±120.2 fghijk
0.15	3.00	35 °C 7	277.8±68.07 cdefghij	224.2±137.74 fghijk
0.15	3.00	35 °C 14	-33.8±739.17 j	950.0±192.89 ab
0.25	5.10	35 °C 14	646.3±100.47 ab	967.6±329.74 ab
0.05	5.10	35 °C 14	430.0±80.20 abcde	480.8±320.63 Cdefgh
0.05	0.90	35 °C 14	260.7±100.96 cdefghij	461.1±512.04 defghi
0.15	6.00	35 °C 14	45.6±693.90 ghij	798.9±569.16 abc
0.00	0.00	35 °C 14	473.2±154.44 abc	779.2±497.71 abc
0.30	3.00	35 °C 14	16.4±649.80 hij	1013.3±122.29 a
0.15	0.00	35 °C 14	372.3±20.53 bcdef	414.7±244.96 efghij
0.00	3.00	35 °C 14	450.5±68.16 abcd	652.7±448.18 Bcde
0.25	0.90	35 °C 14	407.1±111.01 abcdef	506.9±382.41 Cde
0.15	3.00	35 °C 14	637.8±81.68 ab	827.9±131.9 ab

[τ]Means for the same variable (column) followed by the same letter are not significantly different according to Duncan's Multiple Range Test at P = 0.05.

[π]HSCAS = weight percent of hydrated sodium calcium aluminosilicate in peanut paste formulation.

[α]Hue angle (color descriptor): 0^o = red, 90^o = yellow; Chroma = intensity of hue; L value (lightness scale): 0 = black, 100 = white.

[θ]ST = Storage temperature

[σ]SD = Storage day

Appendix E. Evaluation of commercial cookies for Aw, Moisture %, L value, Chroma and Hue angle.

Cookie Name	Rep #	Aw	Moisture %	L value	Chroma	Hue °
PEPPERIDGE SUGAR	1	0.497	5.87	59.66	25.23	82.70
PEPPERIDGE SUGAR	2	0.490	6.13	60.70	29.06	83.60
PEPPERIDGE SUGAR	3	0.489	5.59	60.06	29.02	84.20
PEPPERIDGE SNICKERDODDLE	1	0.480	5.78	55.10	33.89	75.20
PEPPERIDGE SNICKERDODDLE	2	0.479	5.74	53.32	32.36	72.80
PEPPERIDGE SNICKERDODDLE	3	0.482	5.35	51.79	30.33	73.80
GV SUGAR	1	0.396	5.08	65.20	30.84	85.40
GV SUGAR	2	0.395	5.40	63.91	29.61	86.80
GV SUGAR	3	0.394	4.87	62.30	30.02	85.50
GV OATMEAL	1	0.407	5.82	53.00	37.80	76.20
GV OATMEAL	2	0.404	5.89	53.21	36.91	76.10
GV OATMEAL	3	0.402	5.71	55.74	34.96	79.20
GV MACAROON	1	0.424	6.13	66.17	31.21	85.80
GV MACAROON	2	0.418	5.72	64.71	29.43	86.50
GV MACAROON	3	0.416	5.44	66.26	30.40	85.80
GV ICED	1	0.418	5.12	72.99	09.60	78.70
GV ICED	2	0.419	5.72	76.42	07.73	84.40
GV ICED	3	0.420	5.46	76.11	07.45	83.10
ROYAL GOLD THICK	1	0.351	5.06	54.34	29.08	72.40
ROYAL GOLD THICK	2	0.342	4.41	52.32	27.26	73.00
ROYAL GOLD THICK	3	0.342	4.86	54.73	25.12	76.40
ROYAL GOLD THIN	1	0.346	5.90	58.77	18.76	65.70
ROYAL GOLD THIN	2	0.341	6.03	50.69	28.09	66.00
ROYAL GOLD THIN	3	0.333	5.87	56.85	25.36	68.50

Appendix F. Evaluation of commercial cookies for Texture (hardness and crunchiness).

Cookie Name	Rep #	F count	Linear distance	Crunchiness	Hardness g (shear force)
PEPPERIDGE SUGAR	1	7	13.68	1.95	727.66
PEPPERIDGE SUGAR	2	2	13.35	6.68	738.93
PEPPERIDGE SUGAR	3	6	15.7	2.62	1017.64
PEPPERIDGE SNICKERDODDLE	1	1	10.36	10.36	238.6
PEPPERIDGE SNICKERDODDLE	2	0	12.66	0	629.77
PEPPERIDGE SNICKERDODDLE	3	3	12.16	4.05	668.48
GV SUGAR	1	12	49.64	4.14	2595.09
GV SUGAR	2	6	44.35	7.39	2624.26
GV SUGAR	3	8	47.54	5.94	3148.02
GV OATMEAL	1	11	50.99	4.64	2647.26
GV OATMEAL	2	11	40.84	3.71	2286.01
GV OATMEAL	3	8	29.1	3.64	1399.18
GV MACAROON	1	17	37.07	2.18	1570.62
GV MACAROON	2	15	42.66	2.84	2127.15
GV MACAROON	3	11	40.59	3.69	1731.43
GV ICED	1	15	32.08	2.14	1577.46
GV ICED	2	11	54.54	4.96	3135.79
GV ICED	3	11	46.56	4.23	2387.35
ROYAL GOLD THICK	1	37	115.49	3.12	3985.81
ROYAL GOLD THICK	2	23	89.34	3.88	4125.1
ROYAL GOLD THICK	3	29	124.8	4.30	3829.1
ROYAL GOLD THIN	1	17	64.08	3.77	1241.77
ROYAL GOLD THIN	2	8	26.23	3.28	838.02
ROYAL GOLD THIN	3	12	40.63	3.39	1162.58

VITA

Shamira M Fernandes

Candidate for the Degree of

Master of Science

Thesis: EFFECT OF HYDRATED SODIUM CALCIUM ALUMINOSILICATE ON THE PHYSICAL PROPERTIES OF TWO DIFFERENT PEANUT BASED FOOD SYSTEMS.

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Name: Shamira M Fernandes Date of Degree: July, 2006

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EFFECT OF HYDRATED SODIUM CALCIUM ALUMINOSILICATE ON THE PHYSICAL PROPERTIES OF TWO DIFFERENT PEANUT BASED FOOD SYSTEMS.

Pages in Study: 139 Candidate for the Degree of Master of Science

Major Field: Food Science

Scope and Method of Study:

Evaluation of physical properties of baked and semi-solid peanut based food systems containing HSCAS (hydrated sodium calcium aluminosilicate).

Findings and Conclusions:

A. *Cookie Stix*: For cookie stix it was observed that HSCAS (at 0.25%) decreased the A_w and thus could have potential for prolonging the shelf life of the product. It also increased the crunchiness which is a desirable quality parameter for cookies.

B. *Peanut paste*: For the peanut paste it was observed that HSCAS and sugar did not adversely affect the textural attributes (firmness and adhesiveness) of the paste for most formulations and storage times. The A_w increased with an increase in sugar and HSCAS, and also with storage time and temperature, but A_w levels were still within a range of (0.18 – 0.55) that would not facilitate microbial growth.

ADVISER'S APPROVAL: Dr. MARGARET J. HINDS