PEANUT SKIN FORTIFIED PEANUT BUTTERS- EFFECTS ON CONSUMER ACCPETABILITY AND QUALITY CHARACTERISTICS

by

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(Under the Direction of Ruthann Swanson)

ABSTRACT

Peanut skins (PS), high phenolic processing by-products, are potential functional ingredients. Peanut butters, which met the standard of identity, were reformulated by incorporating 0, 2.5 or 5.0% ground PS (dry-blanched, light or medium roasted). Objectives were: to assess PS incorporation effects on consumer acceptability (appearance, flavor, texture, overall, and ease of spreadability), texture, and appearance assessed with objective tests and phenolic content. A complete factorial design was used for nonsensory tests. Control and modified formulations differed in firmness, spreadability, gumminess, and presence of particulates, with all increasing as PS incorporation increased ($p < 0.05$); heat treatment effects within PS level varied. Acceptability was assessed on a 9-point scale (n=140), with an incomplete block design augmented by a control. Consumers found 2.5% PS fortified peanut butters prepared with blanched or light roasted skins acceptable; phenolic content was increased 1.5-1.7 times. Potential market positioning as a natural, high antioxidant product should be investigated.

INDEX WORDS: peanut butter, peanut skins, phenolics, antioxidants

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CHAPTER 1: INTRODUCTION

Chronic diseases have become a condition associated with the American lifestyle. Seven of every 10 American deaths are due to chronic diseases, and more than 50% of the deaths in the US each year are due to chronic diseases such as heart disease, cancer, and stroke (CDC 2010). Another chronic disease, arthritis, is the leading cause of disability among adults in the US, and is expected to affect as many 67 million Americans by 2030 (Hootman and others 2006). Much of the suffering, illness, and death related to these chronic diseases can be prevented by modifying risk factors such as alcohol consumption, physical activity, tobacco use, and nutrition (CDC 2010).

Among these chronic diseases, cancer, atherosclerosis, arthritis, and diabetes, are directly associated with oxidative stress (Lindley 1998, Park and others 2009). Oxidative stress is generated by the excess production of reactive oxygen species and their reactions with cellular molecules such as nucleic acids, carbohydrates, lipids, and proteins (Park and others 2009, Davis and others 2010). It is now become widely accepted that dietary antioxidants aid in the prevention of oxidative stress by neutralizing reactive oxygen species, and thus can potentially aid in the prevention of chronic diseases (Lindley 1998, Scalbert and others 2005, Park and others 2009, Davis and others 2010). Antioxidant compounds have been identified in plant materials, such as fruits, vegetables, whole grains, herbs, spices, and legumes (Soong and Barlow 2004, Scalbert and others 2005). Though most research does show overall health benefits from consuming antioxidant rich foods, the levels and types of supplemental antioxidants needed to provide specific health benefits have not yet been identified (IFIC 2009a). Scientific evidence suggests that consumption of diets high in fruits and vegetables leads to a greater reduction in cancer and chronic disease risk due to its synergistic effects on antioxidant activity. This consensus has served as a driving force for recommendations and claims made by agencies such as the Food and Drug Administration, American Heart Association, and the American Cancer Society (IFIC 2009a).

Dietary antioxidants have been divided into four classes, Vitamin E, Vitamin C, carotenoids, and polyphenols, based on their chemistry. These dietary antioxidants scavenge free radicals to reduce oxidative stress by three different mechanisms: Carotenoids quench singlet oxygen, Vitamin C transfers electrons, while Vitamin E and polyphenols donate protons. All of these mechanisms neutralize free radicals, preventing further oxidative destruction. Of these classes of dietary antioxidants, most research has focused on polyphenols because of their abundance in foods and high antioxidant potency in vitro (Catoni and others 2008). Polyphenols also have complex structures and multiple reactive OH groups available that produce advantageous antioxidant capabilities.

Phenolic compounds are known to have antioxidant properties because their constituents can form relatively stable phenoxyl radicals. The formation of these relatively stable compounds disrupts oxidation chain reactions, decreasing the amount of oxidative stress generated (Soong and Barlow 2004, Scalbert and others 2005). These properties of phenolic compounds could be the mechanism through which chronic oxidative and inflammatory diseases are combated (Liu 2004, Hodzic 2009). Inflammatory diseases, such as cancer, arthritis, and atherosclerosis, often occur due to the adverse effects of chronic inflammation, which is the body's response to irritation, injury, or infection. An improper balance of pro and anti-inflammatory cytokines, the modulators of inflammation, can lead to severe sustained bouts of inflammation. The resulting chronic inflammation can injure the vascular endothelium and aid in the development of conditions such as cardiovascular disease and obesity. Chronic inflammation has been associated with the presence of increased levels of pro-oxidants and decreased levels of antioxidants in the blood because of their effects on pro and anti-inflammatory cytokines. Supplementation with antioxidants has been associated with decreased concentrations of pro-inflammatory cytokines suggesting the potential of antioxidants to combat inflammation and associated diseases (Jensen 2006).

In the U.S., the most common high phenolic fruits consumed include cranberry, apple, red grapes, strawberries, pineapple, banana, peach, lemon, orange, pear, and grapefruit; the most common high phenolic vegetables consumed include broccoli, spinach, yellow onion, red pepper, carrot, cabbage, potato, lettuce, celery, and cucumber (Chu and others 2002, Sun and others 2002). Other sources of phenolics include red wine, soy, chocolate, beans, green tea, black tea, parsley, plums, coffee, and cider. Phenolic compounds present in foods include flavonols, anthocyanins, hydroxybenzoic acids, hydroxycinnamic acids, flavones, flavanones, isoflavones, and monomeric flavanols. These compounds differ in the number of aromatic rings and hydroxyl groups present (Manach and others 2004).

Table 1.1 provides a breakdown of specific phenolic compounds present in some foods. As shown above, phenolics are present in a variety of foods and the incorporation of these kinds of foods into the diet would presumably defend against chronic diseases and potentially confer positive health benefits (Liu 2004, Soong and Barlow 2004, Scalbert and others 2005, IFIC 2009a). In particular, diets typically rich in fruits and vegetables have been associated with decreased incidence of chronic diseases; this association has been made because of the antioxidant capacities of these foods.

Table 1.1 Types of polyphenols present in foods

	Source (serving size)	Polyphenol content By wt or vol	Polyphenol content By serving
		mg/kg fresh wt (or mg/L)	*mg/serving*
Hydroxybenzoic acids (2, 6)	Blackberry (100 g)	80–270	8–27
Protocatechuic acid	Raspberry (100 g)	60–100	6–10
Gallic acid	Black currant (100 g)	40–130	4–13
p-Hydroxybenzoic acid	Strawberry (200 g)	20–90	4–18
Hydroxycinnamic acids (2, 5–7)	Blueberry (100 g)	2000–2200	200–220
Caffeic acid	Kiwi (100 g)	600–1000	60–100
Chlorogenic acid	Cherry (200 g)	180–1150	36–230
Coumaric acid	Plum (200 g)	140–1150	28–230
Ferulic acid	Aubergine (200 g)	600–660	120–132
Sinapic acid	Apple (200 g)	50–600	10–120
	Pear (200 g)	15–600	3–120
	Chicory (200 g)	200–500	40–100
	Artichoke (100 g)	450	45
	Potato (200 g)	100–190	20–38
	Corn flour (75 g)	310	23
	Flour: wheat, rice, oat (75 g)	70–90	5–7
	Cider (200 mL)	10–500	2–100
	Coffee (200 mL)	350–1750	70–350
Anthocyanins (8–10)	Aubergine (200 g)	7500	1500
Cyanidin	Blackberry (100 g)	1000–4000	100–400
Pelargonidin	Black currant (100 g)	1300–4000	130–400
Peonidin	Blueberry (100 g)	250–5000	25–500
Delphinidin	Black grape (200 g)	300–7500	60–1500
Malvidin	Cherry (200 g)	350–4500	70–900
	Rhubarb (100 g)	2000	200
	Strawberry (200 g)	150–750	30–150
	Red wine (100 mL)	200–350	20–35
	Plum (200 g)	20–250	4–50
	Red cabbage (200 g)	250	50
Flavonols (11–18)	Yellow onion (100 g)	350–1200	35–120
Quercetin	Curly kale (200 g)	300–600	60–120
Kaempferol	Leek (200 g)	30–225	6–45
Myricetin	Cherry tomato (200 g)	15–200	3–40
	Broccoli (200 g)	40–100	8–20
	Blueberry (100 g)	30–160	3–16
	Black currant (100 g)	30–70	3–7
	Apricot (200 g)	25–50	5–10
	Apple (200 g)	20–40	4–8
	Beans, green or white (200 g)	10–50	2–10
	Black grape (200 g)	15–40	3–8
	Tomato (200 g)	2–15	0.4–3.0
	Black tea infusion (200 mL)	30–45	6–9
	Green tea infusion (200 mL)	20–35	4–7
	Red wine (100 mL)	2–30	0.2–3
Flavones (11–12, 14, 18)	Parsley (5 g)	240–1850	1.2–9.2
Apigenin	Celery (200 g)	20–140	4–28
Luteolin	Capsicum pepper (100 g)	5–10	0.5–1
Flavanones (19–21)	Orange juice (200 mL)	215–685	40–140
Hesperetin	Grapefruit juice (200 mL)	100–650	20–130
Naringenin	Lemon juice (200 mL)	50–300	10–60
Eriodictyol			
Isoflavones (22–25)	Soy flour (75 g)	800–1800	60–135
Daidzein	Soybeans, boiled (200 g)	200–900	40–180
Genistein	Miso (100 g)	250–900	25–90
Glycitein	Tofu (100 g)	80–700	8–70
	Tempeh (100 g)	430–530	43–53
	Soy milk (200 mL)	30–175	6–35
Monomeric flavanols (6, 17, 26, 27)	Chocolate (50 g)	460–610	23–30
Catechin	Beans (200 g)	350–550	70–110
Epicatechin	Apricot (200 g)	100–250	20–50
	Cherry (200 g)	50–220	10–44
	Grape (200 g)	30–175	6–35
	Peach (200 g)	50–140	10–28
	Blackberry (100 g)	130	13
	Apple (200 g)	20–120	4–24
	Green tea (200 mL)	100–800	20–160
	Black tea (200 mL)	60–500	12–100
	Red wine (100 mL)	80–300	8–30
	Cider (200 mL)	40	8

Manach and others 2004

Unfortunately, another issue facing Americans is the lack of consumption of fruits and vegetables. *Healthy People 2010* is a national health promotion and disease prevention initiative overseen by the U.S. Department of Health and Human Services. One of the initiatives for this program was to increase the number of people who consume two or more servings of fruit daily to over 50% and those who consume more than three servings of vegetables daily to over 75%. As estimated in 2009, only 32.5% of adults consumed two or more servings of fruit daily, and only 26.3% of adults consumed three or more servings of vegetables daily. Demographics associated with the greatest prevalence of fruit and vegetable consumption included: women, people over the age of 65, college graduates, people with annual household incomes at or above $50,000, and people with body mass indexes below 25. However, none of these demographics met the fruit and vegetable consumption goal of Healthy People 2010. Reaching these consumption goals will require more intensified multi-setting and multi-sector approaches than previously utilized (Grimm and others 2010). Along with government dietary guidance directed toward increasing fruit and vegetable intake among consumers, researchers are trying to find new ways to incorporate more antioxidants into the typical diet.

As more Americans try to achieve a healthful diet, functional foods are increasingly providing more opportunities to meet this goal. Functional foods are foods or food components believed to reduce the risk of specific diseases or to improve overall health (IFIC 2009b). Top functional foods identified by consumers include fruits and vegetables, fish, fish oil, seafood, dairy products including milk and yogurt, meat and poultry, herbs, spices, fiber, tea, green tea, nuts, whole grains and other grains, water, cereal, oats/oat bran/oatmeal, and vitamins/supplements (IFIC 2009b). American consumers also view foods with added functional ingredients positively. Among Americans, 43% are interested in learning more about functional foods, and the majority of consumers have no specific concerns about functional foods. Indeed, more than 85% of Americans are currently consuming or are interested in consuming foods and beverages with added benefits such as improving immune function, heart health, or reducing the risk getting specific diseases (IFIC 2009b).

Additionally, American consumers are becoming more aware of food components and their associated health benefits as indicated by 54% of them consuming antioxidants to protect against chronic diseases associated with free radical damage. In particular, consumer awareness of the role of antioxidants in providing protection from free radical damage has increased significantly up to 81% in 2009 from 72% in 2007.

With these emerging trends, there have been more efforts to educate consumers about chronic inflammatory diseases and preventative measures. Dr. Andrew Weil designed an anti-inflammatory food pyramid to educate consumers about anti-inflammatory foods, beverages, and spices. This pyramid emphasizes consumption of fruits, vegetables, whole grains, and healthy fats because of their associated anti-inflammatory properties. Dr. Weil's website (**http://www.drweil.com)** containing this information has received hundreds of thousands of e-newsletter subscribers, visitors, and page viewers (Weil Lifestyle 2011). This suggests that consumers have a desire to understand the effects of inflammation on health as well as how to prevent or reduce the effects of chronic inflammation. These consumer trends indicate that there is a market for functional foods.

Rationale

Polyphenols are plant derived dietary constituents that have been shown to limit the development of cancers, cardiovascular diseases, diabetes, neurodegenerative diseases, and osteoporosis

(Scalbert and others 2005, Ullah and Khan 2008). Polyphenols have antioxidant properties and their incorporation into typically consumed foods would provide an additional mechanism to increase dietary intake without the added challenge of convincing consumers to greatly modify their customary diets. However, incorporation of antioxidants into foods needs to be both economical and effective because of the possible toxicity and high manufacturing costs of synthetic antioxidants (Soong and Barlow 2004). Peanut skins, a common waste product of peanut processing, are a rich source of phenolic compounds that have the potential as a functional ingredient in other foods (Davis and others 2010). The USDA oxygen radical absorbance capacity (ORAC) database is a listing of all quantified foods and ingredients that contain antioxidants; the inclusion of peanut skins would rank as the fifth highest food or food ingredient in this database. Consumer trends indicate a market for functional foods and an increased awareness of the benefits of antioxidants (IFIC 2009b). The overall goal of this study was to assess quality and acceptability effect of peanut butter products in which natural antioxidants from peanut skins had been incorporated by evaluating the product characteristics, phenolic content, and consumer acceptability of the product.

Hypothesis

It was hypothesized that increasing phenolic content of peanut butter by adding peanut skins would not adversely affect product quality or acceptability of the resulting high phenolic product.

Objectives

- To determine the phenolic content in peanut butter reformulated with the addition of peanut skins.

    It was hypothesized that adding peanut skins to peanut butter would increase the phenolic content of the peanut butter.

- To evaluate the formulations for physical characteristics that influence acceptability such as color, presence of particulates, firmness, adhesiveness, and spreadability.

    It was hypothesized that the changes in appearance and spreadability would be acceptable when compared to a peanut butter formulated without the addition of peanut skins.

- To evaluate the formulations for product quality characteristics such as appearance, texture, consistency, spreadability, flavor, and overall acceptability

    It was hypothesized that the changes in appearance, texture, flavor, and overall acceptability and ease of spreadability when evaluated by consumers would be acceptable.

    It was hypothesized that there would not be significant differences in consistency when high phenolic peanut butters and peanut butter formulated without peanut skins were compared.

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CHAPTER 2: LITERATURE REVIEW

Phytochemicals

Phytochemicals are naturally occurring non-nutrient plant chemicals that are found in fruits, vegetables, grains, and other plant foods (Liu 2004). In plants, phytochemicals act as a natural defense system, offer protection against microbial threats, and provide color, aroma, and flavor (Mahan and Escott-Stump 2008). Over 5000 of these plant-derived compounds have been identified and some are used in numerous commercial medications for an array of diseases ranging from asthma to cancer. Phytochemicals are separated into classes based on the structure of the basic skeleton and by the number and kind of constituent atoms. As shown in figure 2.1, these phytochemical classes include carotenoids, phenolics, alkaloids, nitrogen-containing compounds, and organosulfur compounds. Of these classes, the two most studied are carotenoids and phenolics because of their antioxidant and anticarcinogenic roles (Liu 2004).

Phenolics

Phenolic compounds contain one or more aromatic rings with one of more hydroxyl groups (Hodzic 2009). In plants, phenolic compounds function to protect them from predators, pathogens, and parasites (Drewnowski and Gomez-Carneros 2000). The subclasses of phenolic compounds include phenolic acids, flavonoids, stibenes, coumarins, and tannins. Of these subclasses, two-thirds of the phenolics in the diet come from derivatives of flavonoids and one-third come from derivatives of phenolic acids. The main dietary sources of phenolic compounds are fruits, vegetables, nuts, spices, herbs, legumes, and beverages.

Certain fruits such as apples, cherries, grapes, pears, and various berries can contain between 200-300 mg of polyphenols per 100 g of fresh weight whereas an 8 oz. glass of red wine or a cup of tea or coffee can contain about 100 mg of polyphenols (Manach and others 2004, Scalbert and others 2005).

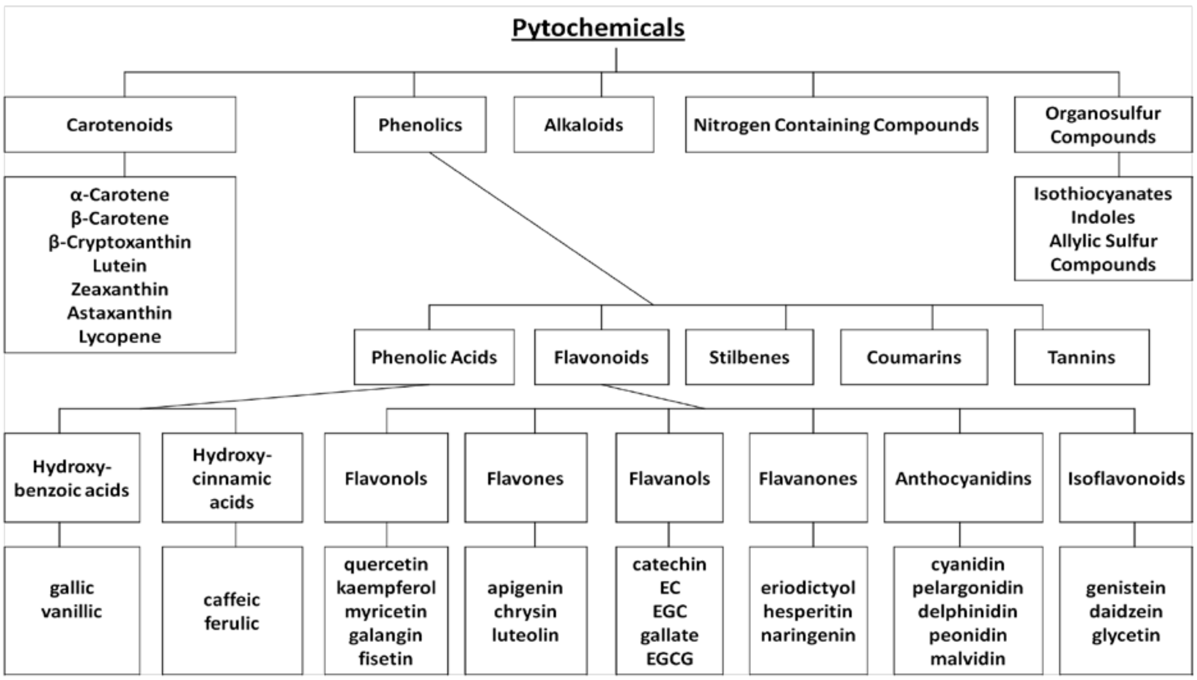

Figure 2.1: Classification of dietary phytochemicals (Liu 2004)

Mature plants generally tend to contain less phenolic compounds than do sprouts and seedlings (Drewnowski and Gomez-Carneros 2000). Phenolics have great reducing capacities giving them strong antioxidant properties (Hodzic 2009).

Phenolics have a potential role in the management or prevention of chronic diseases. Chronic diseases linked with aging are associated with the accumulation of oxidative damage caused by reactive oxygen species. Polyphenols can protect cell constituents against oxidative damage by either acting directly on the reactive oxygen species or stimulating endogenous defense systems to limit cancer development, neurodegenerative diseases, and osteoporosis. Chronic inflammation is associated with increased pro-oxidants and decreased antioxidants. Diets that were enriched with antioxidants were shown to reduce levels of proinflammatory cytokines as well as improve gas exchange, respiratory dynamics, and other improved health outcomes when compared to formulas not enriched with antioxidants (Jensen 2006).

Figure 2.2 shows the structures of common polyphenols that are found in food products. With the exception of caffeic acid and ferulic acid which are phenolic acid derivatives, the other compounds shown are derviatives of flavonoids. The complexity of these chemical structures allow for the phenolic groups to accept electrons to form stable phenoxyl radicals and interrupt cellular oxidation reactions (Scalbert and others 2005).

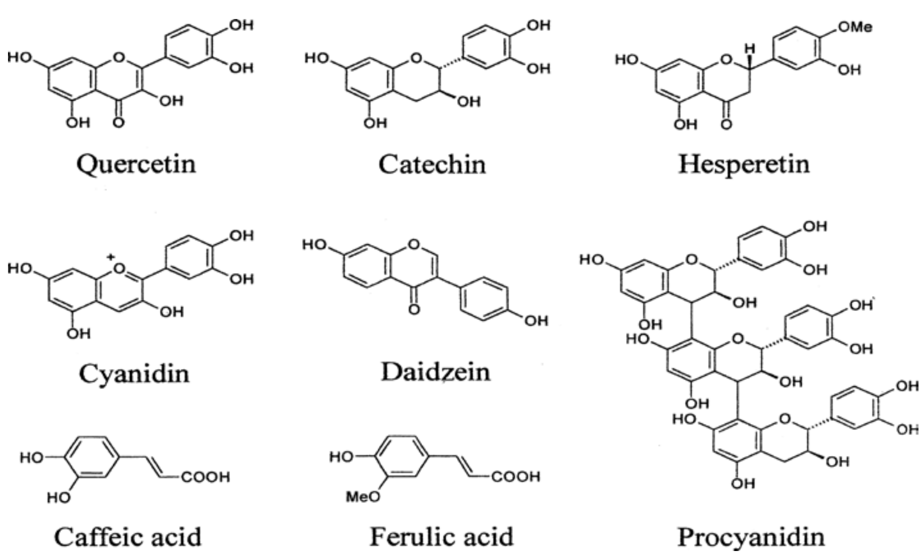

Figure 2.2: Structures of common polyphenols (Scalbert and others 2005)

The estimated intake of phenolics in the US is about 1 g/d, higher than all other dietary antioxidants (Scalbert and others 2005). Though the potential benefits of polyphenols have been identified, there is limited research on increasing the total phenolics in a commonly consumed food product and its effects on product characteristics.

From a food quality standpoint, phenolics in foods have been associated with both positive and negative effects. Effects on color, odor, flavor, and oxidative stability have been reported. Among the most notable negative effects of phenolics in foods are the associated bitter, astringent, and acrid flavors. Many plants secrete phenols as well as other natural pesticides or toxins to decrease their palatability as a defense from predators (Drewnoski and Gomez-Carneros 2000). Phenols can also have positive effects on food quality by decreasing the food's susceptibility to oxidative degradation. By protecting foods from oxidative degradation, polyphenols can help maintain and preserve the sensory quality of foods over time (Naczk and Shahidi 2004).

The food industry has systematically eliminated bitter compounds in foods to satisfy consumer preferences, and phenols are among those bitter compounds eliminated (Drewnowski and Gomez-Carneros 2000). More specifically, lower molecular weight phenolic compounds tend to be bitter whereas higher molecular weight phenolic compounds tend to be more astringent; neither of these attributes are desirable in foods by consumers. These negatively associated attributes led the food industry to remove phenolic compounds, flavonoids, isoflavones, terpenes, and tannins from foods through methods such as selective breeding, and debittering processes including resin adsorption, polymer trapping, or solvent extraction. With perceived health and nutrition value becoming a bigger influence in consumer food selection, the food industry has shifted their efforts to exploring the formation of bitter compounds, their role during the transition from immature to ripened product, and their breakdown in food or juice (Drewnowski and Gomez-Carneros 2000).

Phenol assays

There are a variety of tests that can be used to determine the phenolic content in foods. The oxygen radical adsorption capacity assay, or ORAC, measures antioxidant capacity by the oxidative degradation of the molecule after mixing it with free radical generators (Huang and others 2005, Davis and others 2010). This assay has recently been used to generate the USDA ORAC database for foods and ingredients containing antioxidants. Ferric-reducing ability of plasma, or FRAP, is a single electron transfer based assay that measures the antioxidant potency of polyphenols by determining its ability to trap free radicals and reduce other chemicals; ferric ions are the commonly used oxidants (Huang and others 2005, Scalbert and others 2005). Total Phenolic Content, or TPC, is a single electron transfer based assay where phenolic compounds react with Folin-Ciocalteu reagent. The Folin-Ciocalteu reagent acts through an oxidation-reduction reaction where the antioxidant in question reduces this phosphomolybdic/phosphotungstic acid reagent. Under basic conditions, the reaction creates a blue colored molybdenum oxide with its color intensity being proportional to the total quantity of phenolic compounds present in the sample (Park and others 2009). Numerous researchers have found excellent linear correlations between total phenolic profiles from TPC and antioxidant activity from FRAP, but TPC is a more phenolic compound sensitive test than FRAP or ORAC (Huang and others 2005). In addition, TPC is a commonly accepted assay with a standardized procedure that is used in dietary antioxidant research laboratories worldwide with a large body of comparable data (Huang and others 2005). Because of these reasons, the total phenolic content assay was used to determine phenolic content of foods.

Peanuts

According to The Peanut Institute (2004), peanuts contain more protein than any other legume or nut, mostly polyunsaturated and monounsaturated fats, beneficial nutrients such as Vitamin E, fiber, folate, B vitamins, and many phytochemicals. The National Peanut Research Lab (2009) concluded that peanuts and peanut butter are cholesterol free, can help reduce LDL cholesterol and risk of cardiovascular disease, and inhibit the growth of certain cancers (Ferrero and others 1998, Hu and others 2001, Alper and Mattes 2003, de Jong and others 2003). The American Peanut Council adds that peanuts and peanut butter contribute over 10% of the protein consumed in the U.S. and are less expensive forms of protein. In the United States, 2.4 billion pounds of peanuts are consumed each year, with about 1.2 billion pounds of peanuts consumed as peanut butter (The Peanut Institute 2004). The average American consumes more than seven pounds of peanut products per year.

Peanuts and peanut products contain phenolic compounds (Table 2.1) including beta-sitosterol, a phytosterol associated with decreasing blood cholesterol levels, and resveratrol, a phenolic compound reported to have a wide range of beneficial effects such as blocking platelet aggregation, vasodilatation, and cancer prevention (Mahan and Escott-Stump 2008, Ballard and others 2009). This information suggests that peanut butter inherently contains compounds associated with positive health benefits due to the phenolic components present.

There have been some food safety concerns associated with peanuts, both historical and recent. Aflatoxin is a naturally occurring toxin produced by certain fungi that acts as a potent liver carcinogen. The occurrence of aflatoxin is influenced by the weather, with a warm temperature and high humidity being preferable for growth.

Table 2.1: Peanuts as a source of phytosterols (by component)			
	Resveratrol	Beta-sitosterol (mg)	Total phytosterols (mg)
Raw Peanuts (1 oz.)	Present	18.4	62.4
Dry Roasted, Salted Peanuts (1 oz.)	Present	18.4	62.4
Oil-Roasted, Salted Peanuts (1 oz.)	Present	18.4	62.4
Peanut Oil (1 tbsp.)	n/a	25.7	28
Peanut Butter, smooth style, with salt (2tbsp.)	Present	43.2	33
Peanut Butter, chunky style,with salt (2 tbsp.)	Present	43.2	32.6

Awad and others 2000, USDA 2006

This toxin can be found in products such as corn, peanuts, and further processed products such as peanut butter. Exposure to aflatoxin can cause vomiting, abdominal pain, pulmonary edema, convulsions, coma, and possible death (EHSO 2010). The USDA chemically checks peanuts for aflatoxin presence and has determined that when amounts present are less than 15 ppb, the peanuts are acceptable for use in human food. If peanuts do not meet this standard they can be used to make peanut oil, which after processing is free of aflatoxin (NPRL 2009).

Another food safety concern recently in the spotlight that focused on peanuts and peanut products caused one of the largest food recalls in U.S. history. Salmonella is a rod-shaped bacterium that can transfer to humans or animals through the feces. Consuming these bacteria in food can cause the infection Salmonellosis, which-causes fever, abdominal cramps, and diarrhea. The onset of these symptoms can occur between 8 and 72 hours after ingestion with the symptoms typically disappearing after four to seven days; in rare cases, death may result (USDA FSIS 2006). If contamination occurs after peanuts are roasted, no further processing step exists to kill the salmonella The low water activity and high fat environment of peanut butter produces a synergistic effect allowing for the survival of salmonella after contamination of the finished product (Grocery Manufacturers Association 2009). Between November 2008 and April 2009, contamination of peanut butter traced to two intermediary peanut processors, led to 714 cases of Salmonellosis. This contamination resulted in the recall of more than 3900 products from over 200 companies, each of which contained either peanut paste or peanut butter. Though this recall caused an initial decline in purchases of peanut products, sales returned to previous levels four months later. As a result of this outbreak, states, including Georgia, have passed legislation to strengthen safety guidelines and increase monitoring of food production. At the present time, the demand for peanuts and peanut products is still high despite the multi-state outbreaks of late 2008 to early 2009 (Wittenberger and Dohlman, 2010).

Peanut butter

According to industry standards and standards of identity in the U.S., any product labeled as peanut butter must contain at least 90% peanuts with the remaining 10% being used for salt, emulsifying agents and sweeteners; the fat content cannot exceed 55% (American Peanut Council 2010). The standards of identity for peanut butter are located in Title 21 part 164.15 of the Code of Federal Regulations. These regulations specify that peanut butter is made from ground, shelled, and roasted peanut ingredients either from blanched peanuts in which the germ may or may not be added or unblanched peanuts, which includes the skins and germ. Seasoning and stabilizing ingredients may be added as long as they are not artificial flavors, chemical preservatives, artificial sweeteners, and color additives. Food additives are also not to be used unless they conform to the regulations of the Federal Food, Drug and Cosmetic Act. Shelled, roasted peanuts that have been either cut or chopped may be added to the ground peanuts, and the oil content of the peanut butter can be adjusted with either the addition or subtraction of peanut oil. If oil products are used as optional stabilizers, only hydrogenated or partially hydrogenated vegetable oil can be used. Lastly, if the peanut butter is prepared with unblanched peanut skins, this must be clearly and prominently indicated on the label before or after the words peanut butter (FDA HHS 2009).

The quality grading standards for peanut butter have been set by the Agricultural Marketing Service of the USDA (1972). The peanut butter grade is based on color, consistency, absence of defects, and flavor and aroma. To receive the highest grade classification for peanut butter, U.S. Grade A or U.S. Fancy, the peanut butter must meet or exceed the following specifications:

- color that is between a rich light brown to brown with no hint of a dull, gray, or abnormal cast
- consistency that shall spread easily, not be either too thin or stiff, and no noticeable oil separation or oil separation that can be fixed with slight mixing depending on whether the peanut butter is stabilized or non-stabilized
- practically free of defects, meaning that the presence of dark particles only slightly affect the appearance of the product and that not more than 8 milligrams of water-insoluble inorganic residue per 100 grams of peanut butter are present
- a flavor and aroma typical of freshly roasted and ground peanuts free from staleness, rancidity, objectionable flavors and objectionable odors of any kind with a salt content between 1.0% and 1.8% of the peanut butter by weight

The United States Standards for grading peanut butters also defines varieties of peanut butter products by texture, type, and style. Texture can be used to divide peanut butter into three categories: smooth, where the texture is fine to very fine with no perception of grainy peanut particles, medium, where there is a definite grainy peanut texture, in which the particulates are not more than 1/16 of an inch in any dimension, and chunky or crunchy, where there is either a partially grainy or partially fine texture with substantial amounts of peanut particles greater than 1/16 of an inch in any dimension. Types of peanut butter include those that are stabilized and those that are non-stabilized. Stabilized peanut butter products are prepared by any special process that prevents oil separation, and non-stabilized peanut butters are not prepared in any special way to prevent oil separation. Lastly, there are two styles of peanut butter; regular pack style is a stabilized peanut butter in which the skins have been removed from the peanuts and salt and nutritive sweeteners have been added, whereas specialty-pack style is any type or style of peanut butter that does not fit into the regular-pack style definition.

Peanuts used for peanut butter are shelled prior to processing and undergo the processes of both roasting and blanching. For peanuts that have already been shelled, there are two different types of roasting; oil roasting and dry roasting. In the oil roasting process, the peanuts are exposed to steady stream of hot oil in continuous cookers for about five minutes, followed by draining and salting. In the dry roasting process, the peanuts are heated in a large dry oven with hot forced air. After dry roasting, spicy seasonings are typically added to the peanuts (American Peanut Council 2010).

In the process of making peanut butter, the peanuts are roasted (dry or oil) and cooled before blanching occurs. Blanching is the process that removes the skin from the kernels. This can be done by exposing the kernels to warm air for a period of time to loosen the skins before passing the kernels through a blanching machine where large rollers rub the surfaces of the kernels until the skins fall off. Whole nut or split nuts may be subjected to dry blanching (American Peanut Council 2010). Temperatures for dry blanching range from 94^{o}C to 175^{o}C with a heating period that ranges between 5 and 25 minutes (Francisco and Resurreccion 2009).

Alternatively, the peanuts can undergo water blanching. In the water blanching process, the peanuts are put-on conveyor belts where blades slit the peanut skins. After this occurs, the skins are loosened by hot water sprayers and are removed by large rollers. Peanuts that go through water blanching must be dried before further processing into peanut butter (EPA 1995). To ensure that the blanching process is complete, the kernels are checked with electronic color sorters (American Peanut Council 2010).

Peanut skins

Peanut skins are the protective layer immediately surrounding the peanut seed that are currently used in a variety of products such as papermaking, some specialty types of peanut butter, brandy, liquor, tea, and low-value animal feed (NPRL 2009, American Peanut Council 2010, Davis and others 2010). Peanut skins have been historically regarded as a low value by-product of the peanut blanching process and large quantities are still discarded today (NPRL 2009). World production of peanut skins is estimated to reach as much as 1 million tons annually (Davis and others 2010). Recently, research has shown that peanut skins can be more than just a by-product of peanut production; this by-product has potential as a functional ingredient in foods.

Nepote and others (2002) reported that while both peanut skins and peanut hulls contain phenolic compounds, peanut skins could be a higher source of phenolic compounds than are peanut hulls. Through various methods of extraction, the authors indicate that important sources of antioxidants can come from peanut skins and can be efficiently extracted using methanol or ethanol as extraction solvents. Peanut skins contain 12% protein, 16% fat, and 72% carbohydrates with the total phenolics of defatted peanut skins ranging from 60mg/g-150mg/g. These phenolics include phenolic acids, flavonoids, and resveratrol (Nepote and others 2002, Yu and others 2005). Peanut skins contain procyanidin with both A-type and B-type dimers, each known for varying antioxidant capacities. The A-type dimers are formed through a 4-8 C–C bond and an interflavonid C–O bond and have been associated with stimulating endothelial dependent relaxation and suppressed allergic responses against ovalbumin. A-type dimers are typically found in peanuts, plums, cranberries and cinnamon. B-type dimers are formed through 4-8 or 4-6 C–C bonds of flan-3-ol monomers, and are found in apples, cocoa, and grape seeds and have been associated with the inhibition of LDL oxidation (Yu and others 2006, Appeldoorn and others 2009). Thus peanut skins appear to have potential as an inexpensive source of antioxidants that could be developed into functional food ingredients.

Yu and others (2006) investigated the effects of industrial processes on peanut skin phenolics. Peanut skins were processed by one of three methods: directly peeled by hand from raw peanuts, peeled after wet blanching, or peeled after roasting. Their study revealed that wet blanching significantly reduced (88.9%) the concentration of polyphenols in peanut skins while roasting only slightly reduced (4.6%) the concentration when compared to peanut skins that were directly peeled from raw peanuts. The water blanching process reduces the amount of phenolic compounds in peanut skins because of their solubilization in water. In particular, procyandins are highly soluble in hot water. With the roasting process, the heat increases the total phenolic contents of the skins by the degradation of other phenolic structures that have low extractability by the destruction of cell structures (Yu and others 2006, Garrido and others 2008).

Francisco and Resurreccion (2009) investigated the effects of dry blanching on the phenolic content of peanut skins from Runner, Virginia, and Spanish peanuts. During dry blanching, amino acid and sugar interactions in the peanut skin produce melanins which increase its brown color. These melanins, as well as other Malliard reaction products possess antioxidant capacity; this suggests that blanching can increase the antioxidant capacity of peanut skins in addition to providing a darker brown color. Runner peanut skins contained the most total phenolics followed by Virginia, then Spanish; runner peanuts are the type of peanut most often used for peanut butter production (AgMRC 2011). These researchers did not find many significant differences in phenolic content in the skins over a range of heating temperature and time periods, indicating that these factors might not serve as the best predictors of phenolic content in peanut skins.

In another study, Yu and others (2005) examined the effects of extraction solvents on the phenolic content of peanut skins. The solvents used for peanut skin extraction were water, 80% ethanol, and 80% methanol and each of these solvents was used for raw hand- peeled peanut skins, wet blanched peanut skins, and roasted peanut skins. Ethanol and methanol were more efficient than was water in extracting phenolic compounds. The authors also note that the amount of phenolic compounds extracted from the peanut skins can be significantly affected by the combination of solvent used and processing method; methanol was a more efficient solvent for raw peanut skins while ethanol was a more efficient solvent for extracting phenolic compounds from roasted peanut skins. This research also reaffirms that the process of roasting is better for retaining phenolic compounds in peanut skins when compared to wet blanching.

Commercially available peanut butters in the U.S.

During 2009-2010, Jif peanut butter (J.M. Smucker Co. Lexington, KY) had a 30% share of the peanut butter market, which represented about $327 million in sales. Skippy peanut butter (Unilever Co. Little Rock, AK) is the number two peanut butter brand capturing a 19.8% share of the market, creating $217 million in sales in 2009-2010. Peter Pan peanut butter (Con Agra Foods Inc, Omaha, NE) accounts for 7.9% of the market share, experiencing a 7% sales decline in 2009-2010 to $77 million. Since Peter Pan peanut butter was pulled off the shelves in 2007-2008 due to salmonella contamination and re-introduced in 2008, its sales and market share have declined.

In Table 2.2, a more extensive list of brand sales, brand shares, and sales growth of some commercially available peanut butters is shown.

Table 2.2: Brand sales and market shares of commercially available peanut butters

Brand	2010 sales ($ million)	% Market Share	Sales Growth 2009-2010
Jif [a]	327	29.8	4.3
Smucker's [a]	30	2.8	-0.4
Goober [a]	18	1.6	5.2
Simply Jif [a]	17	1.5	2.3
Laura Scudder [a]	12	1.1	4.4
Adams [a]	11	1	-1.5
Jif To Go [a]	8	0.7	5.8
Skippy [b]	173	15.8	4
Skippy Super Chunk [b]	23	2.1	-0.9
Skippy Natural [b]	21	1.9	9.9
Peter Pan [c]	77	7	-7
Peter Pan Smart Choice [c]	7	0.6	-8.1
Private label	221	20.2	5.3
Other	146	13.3	22.1

[a] J.M. Smucker Co., Lexington, KY
[b] Unilever Co., Little Rock, AK
[c] Con Agra Foods Inc., Omaha, NE
Mintel 2010

Consumer interest in natural and organic products is also becoming a stronger market, with Skippy's Natural peanut butter (Unilever Co. Little Rock, AK) gaining a 9.9% increase in sales in 2009-2010. Natural peanut butters are traditionally only peanuts, but definitions have been expanded to include no preservatives or hydrogenated oil, as in the case of Skippy's Natural peanut butter. Consumers have begun looking for more products carrying the "natural" claim because they tend to associate natural with minimal processing and positive health benefits. The largest increase in brand growth from 2009-2010 came from “other brands;” these are peanut butters that are not private labels or produced by JM Smucker, Unilever, or Con Agra Foods. The 22.1% increase seen in this category is indicative of consumers trying new and less familiar brands, representing a change from past consumer brand loyalty (McNeill and others 2000, Mintel 2010).

Food reformulation

Food reformulation is a common practice amongst leading food companies as consumers look for more options; often the focus of reformulation is improvement in the nutritional profile of foods. Food reformulation does not just focus on nutrients associated with negative health outcomes, but also maintaining compounds that promote positive health outcomes that may be removed during processing. When reformulation occurs to improve the nutritional profile or health benefits associated with product consumption, it should be aimed at basic foods that are eaten across all socio-economic classes to enable the associated benefits to reach the most people. The biggest key to the success of a product reformulated for nutritional reasons is an increased intake of a nutrient or nutrients lacking in the diet of the target population. Common limits to food reformulation include consumer acceptance, food safety, technological challenges and food legislation (van Raaj and others 2008).

More foods are being developed with nutrients and ingredients associated with positive health outcomes because consumers are looking for more nutritious options (van Raaj and others 2008). This emerging demand for healthier foods has led to the creation of functional fresh products. A functional fresh product contains ingredients consumers would typically associate with the product that have also been associated with positive health outcomes (Sloan 2009).

Though the name might imply that products associated with this trend are not processed, the functional fresh trend is related to consumers moving away from fortification, rather than away from processing.

Sensory attributes of peanut butter

McNeill and others (2000) conducted a study to develop a consumer sensory questionnaire for the attributes of peanut butter. In this study, two consumer focus groups used three different methods for the sensory evaluation of peanut butter. These methods which were used to describe four commercially available peanut butter products included: (1) the panelists providing descriptive characteristics unaided, (2) the panelists providing descriptive characteristics aided by tasting, and (3) the panelists providing descriptive characteristics with the aid of attribute scales that were based-on descriptors that they provided for appearance and aroma before sampling, and flavor and texture after sampling. The panelists concluded that the characteristic optimal aroma of peanut butter was that of fresh roasted peanuts. The presence of rancid, sour or burnt off-notes was considered as defects. Appearance attributes were determined to be extremely important to consumers. The optimal appearance of peanut butter was a rich, warm, golden, caramel color; samples that were too light in color appeared to be bland, whereas samples that were too dark appeared to be burnt. When determining characteristics for flavor, panelists were always able to note when a sample lacked saltiness or sweetness. Overall, panelists described the optimal flavor of peanut butter as having a fresh roasted peanut, nutty, honey, or buttery flavor, and without old, rancid, or stale notes. Respondents described the optimal consistency of peanut butter as firm and smooth, with attributes such as stiff, runny, gluey, and pasty as undesirable. The panelists were suspicious of dark particles in peanut butter, and ideally wanted a gloss or sheen without the visual appearance of oiliness. Optimal texture was described as smooth and creamy, not gritty or dry. These focus groups also looked at other non-attribute purchase drivers including brand loyalty, price, and jar size.

The use of consumer focus groups for sensory evaluation of peanut butter generated a consumer- based lexicon for peanut butter; this lexicon was different from peanut lexicon developed by experienced peanut flavor workers. Untrained consumer panelists were able to differentiate peanut butters based on characteristics such as appearance, texture, and flavor (McNeill and others 2000). Utilizing a nine-point hedonic scale with the generated consumer lexicon allows untrained consumer panelists to effectively evaluate peanut butters for sensory characteristics such as appearance, texture, and flavor. The use of a hedonic scale is also valuable because it allows untrained consumer panelists to identify characteristics they might find acceptable or unacceptable without attempting to quantify the degree of difference. Trained descriptive panelists are better than consumer panelists at identifying and quantifying differences between formulations. Conversely, acceptability ratings from untrained consumer panelists are more likely to provide external relevance to the consumer market. This information provides consumer insight into the acceptability of each peanut butter formulation independent of other formulations and aids in the identification of what consumers find acceptable or unacceptable about the formulation.

Textural analysis

Peanut butter texture has been evaluated historically by fundamental tests such as lubricated squeezing flow viscometry, capillary extrusion rheometry, and empirical tests using a cone penetrometer and an Instron Universal testing machine equipped with a plunger attachment (Muego and others 1990). The fundamental tests measure rheological properties and empirical tests measure parameters which have been shown to relate to textural quality. Muego and others

(1990) sought to characterize the texture of three spreadable peanut-based products using various physical assessments as well as sensory assessments. Three different methods were used for instrumental textural analysis; a Precision universal penetrometer with a cone shaped probe, an Instron universal testing machine with a flat ended cylindrical plunger attached to a 5 kg compression load cell, and an Instron universal testing machine with a flat plate attached to a 5 kg compression load cell. These three instrumental methods were compared with sensory evaluations of the spreadable peanut products for validity. Pearson correlation coefficients for all of the instrumental and descriptive sensory measures were computed to determine the association between similar textural parameters.

These researchers (Muego and others 1990) determined that the cone penetration instrumental method was simplest to perform and most rapid but both instrumental methods that utilized the Instron universal testing machine provide more information on textural characteristics. None of the three instrumental methods correlated strongly with sensory adhesiveness, an important property of spreadable products. Descriptive sensory evaluations of wetness or spread did correlate with depth of penetration measured from the cone penetration method, maximum force, an indicator of hardness, measured using the flat ended cylindrical plunger, and hardness determined by compressing with a flat plate. These authors concluded that all of the instrumental measures could differentiate textural attributes of the spreadable peanut products but the test conditions using either compression method provided better correlations with descriptive sensory evaluations (Muego and others 1990).

Particulate presence

The United States Department of Agriculture (1983) published a grading manual for peanut butters which includes an analysis of the presence of dark particles. In addition to other attributes such as color, texture, consistency, odor, and flavor, the USDA uses presence of dark particles to help determine the quality grade of the peanut butter. Particle presence is also important in the consumer assessment of peanut butter quality; past respondents were highly suspicious of particulates in peanut butter samples, particularly darker colored particulates (McNeill and others 2000). To determine the presence of dark particles, the USDA graded peanut butters uses photographic guides that illustrate the extent to which dark particles are present in peanut butter.

Color determination

Consumers determined color to be an important quality assessment of peanut butters; consumers have expressed strong initial reactions to peanut butters based solely on evaluation of appearance attributes such as color (McNeill and others 2000). As previously mentioned, the USDA includes color assessments when determining the quality grades of peanut butter. While the USDA methodology requires a visual comparison with peanut butter color standards, commercial peanut butter producers use Hunter color difference values for quality assurance standards (Pattee and others 1991). CIELAB L*a*b* has also been used to describe the degree of roast in peanut paste samples. CIELAB is one of the most widely used color scale in the food industry and is based on the opponents color theory. This theory states that the red, green, and blue human eye cones are remixed in to opponent coders as black-white, red-green, or yellow-blue when perceived in the optic nerve of the human brain. The measurements from CIELAB provide three values: lightness (L*) where 0= white and 100= black, red-green axis (a*) where –a is green, 0 = neutral, and +a = red, yellow-blue (b*) axis where –b = blue, 0 =neutral, and +b= yellow (Good 2002). Pattee and others (1991) sought to compare color assessments of roasted peanuts using these two instrumental methods. The authors used a Minolta Chroma Meter to measure CIELAB L*a*b* values, a Model 96 Spectrogard color system to obtain Hunter L*a*b* values, and compared the instrumental results to those of a trained roasted peanut flavor profile panel that characterized the color of the roasted peanuts. Through their work, a mathematical relationship between Hunter L*a*b* and CIELAB L*a*b* was established, and color of the roasted peanuts could be obtained accurately with Minolta Chroma meter. These authors concluded that using the Minolta Chroma Meter saved time over the Spectrogard color system while still providing accurate color assessments of the roasted peanuts (Pattee and others 1991).

Peanut skin inclusion in products

Nepote and others (2004) examined the antioxidant effects of peanut skins on honey roasted peanuts with a consumer test, chemical analysis, and descriptive sensory analysis. These researchers assert that having edible peanut coatings can protect against moisture loss and oxidation, as well as serve as a vehicle for antioxidants and flavor compounds. The researchers compared the antioxidant effects in honey roasted peanuts, honey roasted peanut skins with natural antioxidant from peanut skins, and honey roasted peanut skins with the antioxidant butylated hydroxytoluene (BHT). Honey roasted peanut skins with either BHT or antioxidants from peanut skins significantly slowed the rate of oxidation when compared to honey roasted peanuts. There were also not any significant differences in sensory attributes when these peanut products were assessed during storage by a descriptive analysis or consumer sensory panel. In general, the products had acceptance scores of approximately six “like slightly” on a nine-point hedonic scale where one equaled “dislike extremely” and nine equaled “like extremely”.

For peanuts and peanut butter, shelflife is limited by oxidation of the unsaturated fatty acids present; consumers indicated that the flavor associated with rancidity was undesirable (McNeil and others, 2000). O’ Keefe and Wang (2006) investigated the effect of peanut skin phenolic extract on storage stability and sensory quality in various kinds of ground beef. These researchers found that adding phenolic compounds extracted from peanut skins in the range of 200-400ppm significantly reduced meat oxidation during cooking and storage, but this effect did not show a linear relationship with amount of phenolic extract incorporated. At rates of incorporation above 400ppm, further improvement in storage effects were not found and excessive amounts of phenolic compounds in the system can potentially accelerate the rate of autoxidation. A slightly darker color and increased phenolic compounds were noted in the cooked beef, but the color was not significantly different until phenolic compounds reached levels of 800ppm. The researchers used a nine-point hedonic scale to measure the aroma acceptance and did not find a significant difference from the control formulation. It should be noted that this study only measured consumer acceptability of aroma of the formulations, overlooking the potential impact of bitter flavor associated with phenolic compounds. Both of these studies have shown that the incorporation of phenolic compounds from peanut skins promote the reduction of oxidation in foods without significantly impacting consumer acceptance of aroma.

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CHAPTER 3: MATERIALS AND METHODS

The effects of peanut skin incorporation into peanut butter on product characteristics and consumer acceptability were investigated with a nested factorial design (Table 3.1). Nineteen potential peanut butter formulations were screened by 3-4 researchers for inclusion in the study. Inclusion criteria were the absence of notable bitterness and presence of attributes that consumer focus groups have identified as important in peanut butter (McNeill and others 2000). Seven samples were selected for evaluation in this study

Peanut skins subjected to three different heat treatments (blanched, light roast, medium roast) were nested within three levels of incorporation (0, 2.5, and 5.0%). The sample with 0% peanut skins served as the control.

To meet the USDA (1983) standard of identity for peanut butter, each formulation contained 90% peanuts, 6.5% sugar, 1.5% salt, and 2% stabilizer. Roasted peanut kernels were supplied by Seabrook Ingredients (Edenton, NC). Confectioner's sugar incorporated was processed by Domino Sugar Corporation (New York, NY), and flour salt was obtained from Cargill Salt (Minneapolis, MN). The stabilizer selected was a hydrogenated blend of rapeseed and cottonseed oils from Loders Croklaan (Channahon, IL). The formulations are found in table 3.2. In the products formulated with peanut skins, the peanut skins (Golden Peanut Company Blakely, GA) and peanut oil (Planter's Nut and Chocolate Company Glenview, IL) in combination replaced the percentage by weight of the peanuts that equaled the stated percentage of skins. Peanut skins incorporated were subjected to 3 different heat treatments: dry-blanched, light roast and medium roast. Roasting conditions were at 255°F for 11 minutes, then at 310°F for 14 minutes for light roasted samples. Medium roasted conditions were at 255°F for 11 minutes, then at 334°F for 14 minutes.

Table 3.1 Nested factorial design for chemical, instrumental and sensory tests

Assessment	Factors
Chemical, Physical/, Physicochemical Tests	
Total Phenolics	3x3x3 [a]
Texture: Spreadability	3x3x6 [b]
Texture: TPA	3x3x6 [c]
Particulate Presence	3x3x3x3[d]
Color (L* a* b*)	3x3x3x2
Sensory Tests	
Consumer Panel: Appearance	3x3x140[f]
Consumer Panel: Texture	3x3x140[f]
Consumer Panel: Consistency	3x3x140[f]
Consumer Panel: Spreadability	3x3x140[f]
Consumer Panel: Flavor	3x3x140[f]
Consumer Panel: Overall Acceptability	3x3x140[f]

[a] Peanut skin level x heat treatment x samples; measured using total phenolic content with Folin-Ciocalteu reagent. Each sample underwent extractions with both 70% acetone/0.1%HCl to separate protein and hexane to separate fat prior to TPC determination (Xu and Chang 2007).

[b] Peanut skin level x heat treatment x samples; measured using the texture analyzer (*TAX-T2*, Texture Technologies Corp., Scarsdale, NY, USA/Texture Exponent 32, Stable Micro Systems Lt, Godalming, Surrey, England) with a 5 kg load cell and contact speed of 5mm/s. Six samples were used from each formulation and each sample was penetrated with TTC spreadability rig once to a distance of 2mm (Ahmed and Ali 1986).

[c] Peanut skin level x heat treatment x samples; measured using the texture analyzer (*TAX-T2*, Texture Technologies Corp., Scarsdale, NY, USA/Texture Exponent 32, Stable Micro Systems Lt, Godalming, Surrey, England). Six samples from each formulation were compressed twice with a 7.62cm diameter compression disc until the clearance between the plates at maximum compression was 2mm. There was a 5 second wait time between compressions. Samples were deposited with a #100 scoop onto a base-plate and the load cell was 5 kg with a contact speed of 5mm/s (Muego and others 1990).

[d] Peanut skin level x heat treatment x samples x evaluators assessments; measured by comparison to 6-point particulate presence scale ordered by increasing prevalence of visible particulates and was adapted from USDA grading methodology (1983).

[e] Peanut skin level x heat treatment x samples x assessments; measured using a Minolta spectrophotometer (model CM-700d, Minolta Corp., Ramsey NJ) with specular component excluded, with instrument set to 10-degree observer function and cool white fluorescent F6 illuminant.

[f] Peanut skin level x heat treatment x panelists

For dry blanching, heating conditions were less intense, with temperatures ranging from 94°C to 175°C. Dry blanching loosened the skins to allow for their removal from the peanut.

Table 3.2 Ingredient components of peanut butter formulations (kg)

	Peanut Skin Formulation Level (kg) [a]		
	0 [b]	2.5 [b]	5 [b]
Peanut	2.7	2.625	2.55
Peanut Skins	0	0.047	0.094
Peanut Oil	0	0.028	0.056
Sugar	0.195	0.195	0.195
Salt	0.045	0.045	0.045
Stabilizer	0.06	0.06	0.06

[a] Each formulation produced a 3 kg batch of peanut butter
[b] Peanut skin amount + peanut oil amount equals stated percentage by weight

Phenolics determination

All chemicals used in this assay except the hexane (Baker analyzed ACS reagent; Mallinckrodt Baker Inc, Phillipsburg NJ) were obtained from Sigma Aldrich Co, St Louis MO; these chemicals included: 70% acetone/0.1% HCl solution , 20% sodium bicarbonate solution, gallic acid, and the Folin-Ciocalteu Reagent.

The phenolic content of the peanut butter formulations was measured using the total phenolic content (TPC) assay with the Folin-Ciocalteu reagent (Xu and Chang 2007). Standards were prepared from a gallic acid stock solution with concentrations of 0.05 mg/mL, 0.1 mg/mL, 0.15 mg/mL, 0.25 mg/mL, and 0.5 mg/mL prior to phenolic analysis. 9 mL of 70% acetone/0.1% HCl solution were mixed with 1 g of each peanut butter formulation to separate the protein. The solution was stirred for one hour before centrifuging for 10 minutes. The residual supernatant was taken and used for hexane extraction. 2 mL of each acetone/HCl extracted sample was then mixed with 2mL hexane to remove the fat. This solution was inverted five times and held at room temperature for 30 minutes; this inversion step was repeated and the sample was held for an additional 30 minutes. The heavier liquid was extracted from the solution and used for TPC. To determine TPC, each sample and standard was vortexed in a 1.5 mL tube with 1 mL of distilled water, 12.7 µL of the standard or sample, and 63.3 µL of Folin-Ciocalteu reagent. After being vortexed, 189.9 µL of 20% sodium carbonate was added and the solution was vortexed again. After incubation at room temperature for 45 minutes, absorbance of the samples was checked against a blank at 765 nm. Because most of the samples did not fall within the range set by the Gallic acid standards, the peanut butter extracts were diluted by a factor of 100 to fit within the standard Gallic acid curve. 100 µL of the twice extracted sample was diluted with 900 µL of distilled water. 12.7 µL of the diluted sample was used for the phenolics determination. This protocol is referenced in previous research (Nepote and others 2002, Xu and Chang 2007).

Quality characterization

Texture assessments

Instrumental texture assessments were conducted with a *TAX-T2* texture analyzer (Texture Technologies Corp., Scarsdale, NY) equipped with a 5 kg load cell. Data were extracted with Texture Exponent 32 software (Stable Micro Systems Lt, Godalming, Surrey, England). For both of the tests used for the instrumental assessment of texture, the crossarm moved at a pre-test speed of 5mm/sec, a contact speed of 5mm/sec and a post-test speed of 5 mm/sec. Six room temperature samples (21-22^{o}C) from each peanut butter formulation were analyzed using each instrumental assessment of texture. Each sample was a #100 scoop portion (11.4 g, n = 6).

The maximum force and work of shear (Figure 3.1) of the peanut butter formulations, which served as an indicator of firmness and spreadability, respectively were assessed-with the Textural Technologies Corporation (TTC) spreadability rig. Maximum force was identified at the point of maximum penetration on the time-force curve (Ahmed and Ali 1986), while work of shear was identified as the area under the penetration curve. Each sample (11.4 g) was deposited in the holder and leveled prior to penetration once to a distance of 2 mm. This methodology was also used in research conducted by Ahmed and Ali (1986).

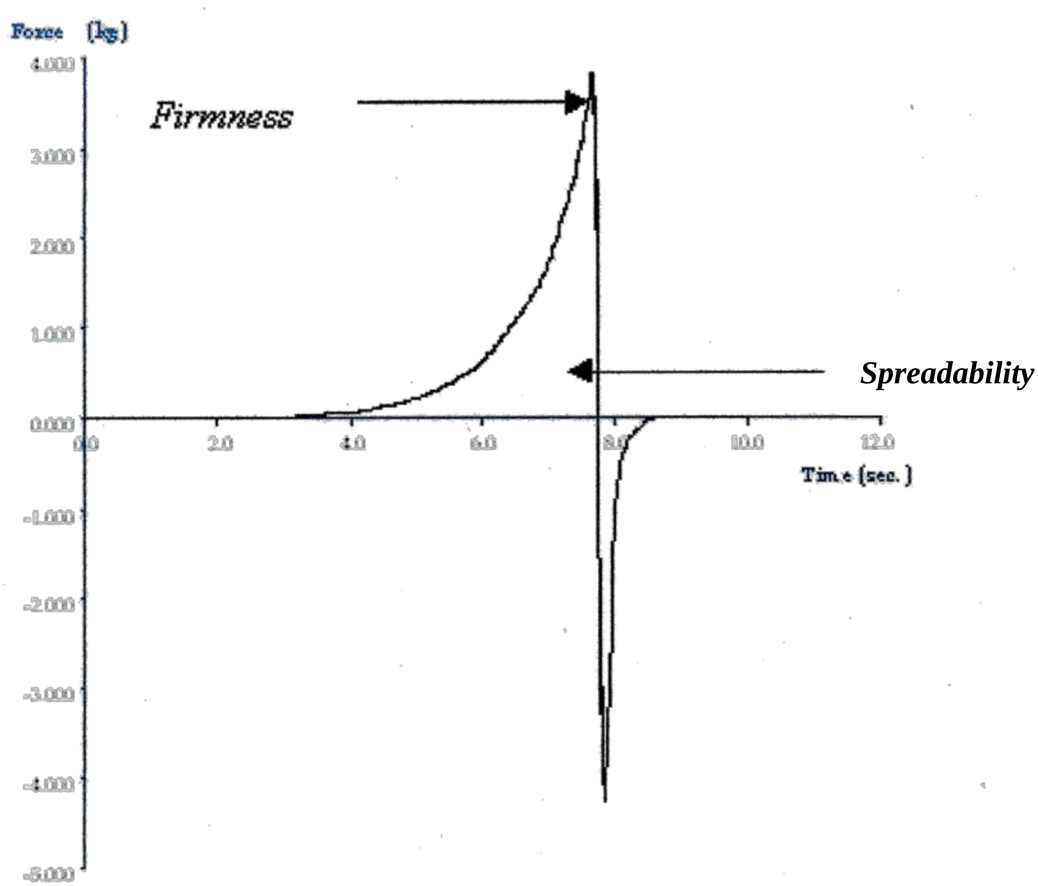

Figure 3.1: Time-force curve for TTC spreadability rig parameters (adapted from: Texture Technologies 2008)

Texture profile analysis (TPA) was used to determine firmness, adhesiveness, cohesiveness, and gumminess (Figure 3.2) of the peanut butter formulations. Each sample was compressed twice, with a 7.62 cm diameter compression disc with a 5 second wait between compressions. Compression occurred until the clearance between the plates at maximum compression was 2mm. Peanut butter samples (11.4 g), scooped with a #100 disher were deposited intact directly on the base plate. Contact paper covered the compression disc and baseplate to reduce friction with the deposited sample. Values were extracted from the time-force curve as described by Muego and others (1990).

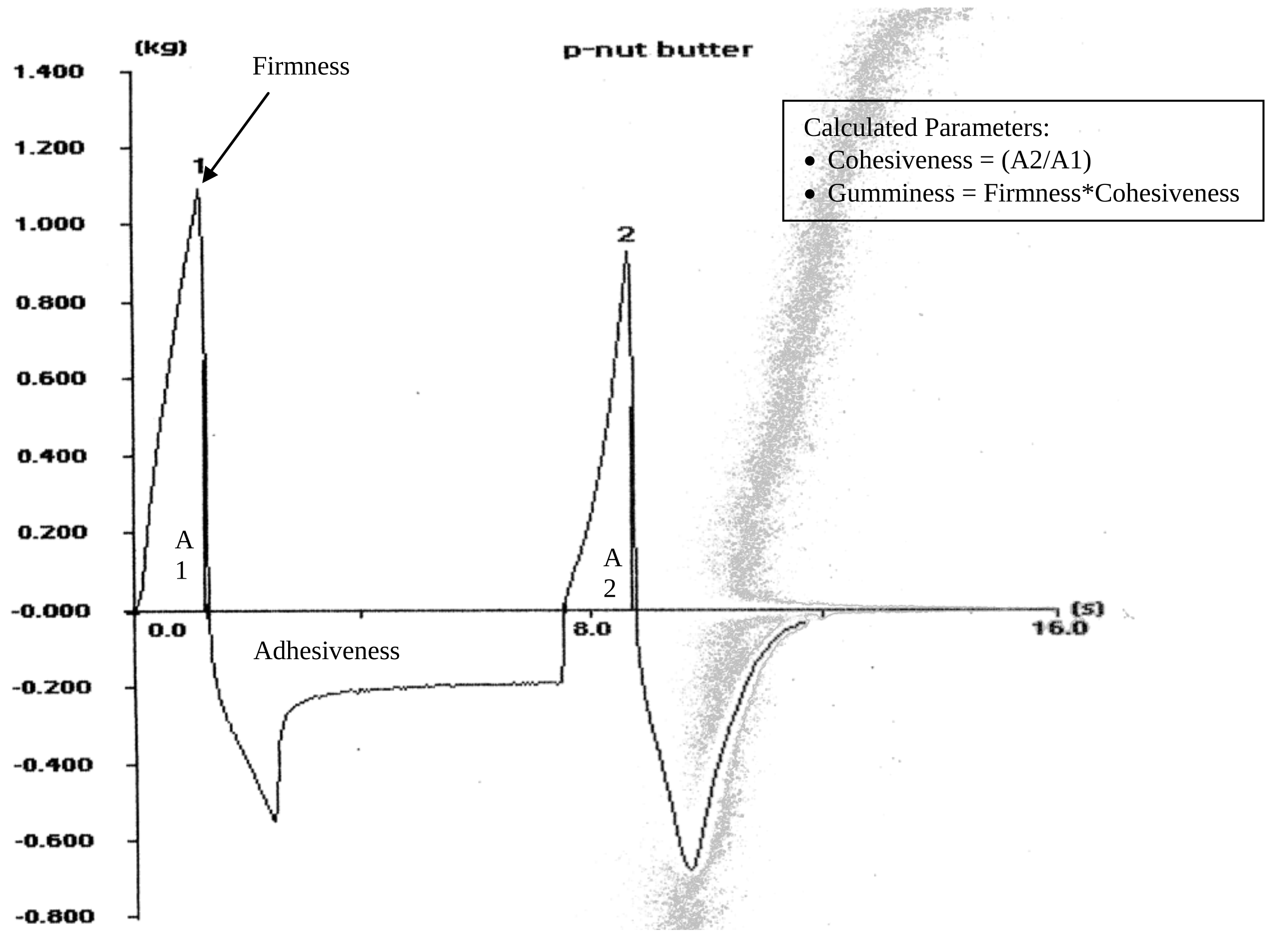

Figure 3.2: Time-force curve for TPA parameters

Particulate presence

To evaluate the peanut butter formulations for presence of particulates, a particulate presence reference scale was created using six commercially available peanut butters, (Table 3.3). Products (1 #60 scoop portion, ~ 15 g) were evenly spread onto particle analysis sheets provided by the USDA; each reference sample completely covered an area 4 ½ in x 2 7/8 in . These reference peanut butter samples were ordered by increasing prevalence of visible particulates. Appendix A shows the visual reference anchors for each point on the 6-point scale used for particulate presence evaluation.

Table 3.3: Commercially available peanut butters in particulate presence scale

Commercial Peanut Butter	Product Information	City, State	Position on Particle Scale
Reese's Creamy Peanut Butter	Hershey Co.	Hershey, PN	1
Welch's Bama Peanut Butter	Algood Food Co.	Louisville, KY	2
Skippy Creamy Peanut Butter	Unilever Co.	Little Rock, AK	3
Jif Creamy Peanut Butter	J.M. Smucker Co.	Lexington, KY	4
Smuckers Natural Peanut Butter	J.M. Smucker Co.	Lexington, KY	5
Earthfare Organic Creamy Peanut Butter	Earth Fare	Flectcher, NC	6

Samples (1 #60 scoop portion, ~ 15 g), of each peanut butter were spread onto USDA particle analysis sheets. Three samples were used for each peanut butter formulation and each sample was identified with a random three-digit code. Three trained observers evaluated the formulations against the particle scale created by the commercially available products and gave each peanut butter formulations a value of 1 – 6 with 1 indicating the presence of the least number of particulates and 6, the presence of the highest number of particulates. This methodology was adapted from the methodology outlined by USDA for grading peanut butter (USDA 1983).

Color determination

Samples were evaluated for color using a Minolta spectrophotometer (model CM-700d, Minolta Corp., Ramsey NJ). The white calibration cap standard was CM-A177, the measurement area was degrees 8mm, and the F6 illuminant (cool white fluorescent) setting was used as the light source. The spectrophotometer was set to the 10-degree observer function and the Specular Component Excluded (SCE setting). These settings allowed the instrument to assess color in the same way as humans perceive it. The samples prepared for particle size distribution assessment were also used for color evaluation. The color measurements were taken at two different locations on each sample. The recorded value given by the spectrophotometer was an average of 5 readings and was reported as L*a*b* where L* is lightness, a* is the red-green axis and b* is the yellow-blue axis. Similar methodology was used by Pattee and others (1991).

Sensory evaluation

A 3x3 incomplete block design augmented by a control (Gacula 1978) was used to assess consumer acceptability of the six peanut butter formulations. Before any procedures with human subjects were initiated, all methods and procedures were approved by the University of Georgia Institutional Review Boards on Human Subjects. The targeted group of consumers was at least 18 years old and of a non-specific gender or race. The panelists, who were self-screened for peanut allergies prior to participating in sensory evaluation, were identified only by a 3-digit code, and only aggregate data were released. One hundred forty panelists performed the sensory evaluation of the food products. Most participants had not previously served as consumer sensory panelists.

All products were portioned (one #100 scoop portion, 11.4 g) into plastic soufflé cups, covered, and held at room temperature for 24 hours prior to sensory evaluation. Each formulation was coded with a three-digit random number. Each panelist evaluated the control sample and three additional formations. Presentation order was randomized for each panelist. Judges were seated in individual booths equipped with white lights. Room temperature water and carrots (Bolthouse Farms baby cut carrots, WM Bolthouse Farms, Inc., Bakersfield, CA) were used as palate cleansers between samples; unsalted saltine crackers (Nabisco premium unsalted tops saltine crackers, Kraft Foods Global, Inc., East Hanover, NJ) were used as carriers. Judges were also provided with plastic knives (Bakers & Chefs, Sam's West Inc., Bentonville, AR) and napkins for use during product evaluation. When evaluated, the temperature of the peanut butter samples was between 21-22 ºC, within the USDA grading guidelines for product temperature, 21-27 ºC (USDA 1983). The panelists were presented one sample at a time and when they completed the evaluation, they received the next sample.

Samples were evaluated for appearance, texture, flavor, consistency and overall acceptability. The anchors on the nine- point hedonic scale were 1 = "dislike extremely" and 9 = "like extremely" for appearance, texture, flavor, and overall acceptability. The anchors on the scale for consistency were 1 = "runny" and 9 = "stiff". On the nine-point hedonic scale, values above 6.0 were considered acceptable. In order for values above 6.0 to be considered significant, power analysis revealed that a sample size of at least 68 people was needed (DSS Research 2009).

The sensory scorecard is found in Appendix B. Panelists were asked to sample the product and evaluate the texture, flavor, and overall acceptability of the product after they spread the sample on an unsalted top saltine cracker (Nabisco premium unsalted tops saltine crackers, Kraft Foods Global, Inc., East Hanover, NJ). Panelists evaluated consistency by assessing the ease of spreading the peanut butter onto the cracker. Sample appearance was evaluated prior to spreading the sample on the cracker. Panelists were also asked to indicate what in particular they liked or disliked about each sample (Meilgaard and others 1999).

A consumer questionnaire, presented in Appendix C, was used to profile the sensory panelists. Panelists answered questions related to gender and age. Peanut product consumption habits were determined when panelists indicated the frequency in which they consumed products containing peanuts, how often they consume peanut butter in particular, and what commercially available brand of peanut butter they purchase most often. To assess the potential impact of a marketing claim on intent to purchase food products in general, the panelists were asked if they were more likely to purchase a product if it carried claims such as whole-grain, low/reduced, no sugar, low/reduced fat, no trans-fat, low/reduced calorie, low/reduced sodium, low carbohydrate, protein-rich, calcium-fortified, no chemical additives, no preservative, natural, reduces risk of heart disease, reduces risk of cancer, reduces risk of hypertension, high fiber, low glycemic index, high in antioxidants, prebiotic/probiotics, organic, or vitamin-fortified. They were also asked to indicate if a peanut butter, other than the preferred peanut butter, carried the antioxidant claim, if they would be more likely to purchase it rather than the preferred peanut butter. These questions were answered after the sensory evaluation of the products was complete.

Statistics

Data were analyzed using SAS (SAS version 9.2, SAS Institute Inc., Cary, North Carolina). Proc Univariate was used to identify outliers among sample values, as well as normal distribution of the samples. Proc Mixed was used to generate least squares means and standard errors and to identify significant differences due to the main effects and nested effects at P <

0.05. When appropriate, log transformations were used for the Proc Mixed analysis. Descriptive statistics (Proc Freq) were used to summarize demographic and peanut butter consumption and purchasing information; this information was used to profile the sensory panel. Pearson Product Moment correlations coefficients ($p \leq 0.1$ were used to identify relationships between the instrumental textural parameters. Proc Stepwise was used to create a stepwise multiple regression equation to explain variability in overall acceptability; all variables left in the model were significant at $P \leq 0.15$ level.

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CHAPTER 4: RESULTS AND DISCUSSION

Phenolic content

Phenolic content (Table 4.1) was measured for both the control and modified peanut butter formulations. The control formulations averaged 3.4 ± 0.30 mg GAE/g. The highest phenolic levels were found in the peanut butter formulations with 5% peanut skin incorporation. Phenolic values in these samples were approximately three times higher than the level found in the control product.

Table 4.1: Total phenolic content (mg GAE/g) [a] of peanut butters as affected by peanut skin incorporation and heat treatment within level of peanut skin incorporation (n=3)

	Heat	**LS-Means ± SEM**			
Skin [b]		**0**	**2.5**	**5**	**StdErr**
		3.4c	5.6b	10.0a	0.30
Heat(Skin) [b]	Blanched	3.3f	5.7d	10.0b	0.52
	Light	3.9ef	5.9d	12.2a	0.52
	Medium	3.0f	5.3de	7.7c	0.52

[a] Total phenolic content was determined with Folin Ciocalteu reagent and reported in mg Gallic acid equivalents (GAE)/g peanut butter.
[b] LS-means followed by different letters are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF

The nested effects of heat treatment within level of peanut skin incorporation identified significant differences between formulations. The extent of heat treatment influenced the phenolics levels present when peanut skins were incorporated at the 5% level. Formulations with 5.0% peanut skins subjected to light roasting had the highest phenolic content followed by those peanut butter samples formulated with blanched peanut skins; at 5% incorporation, the medium roasted skins resulted in samples with the lowest phenolics levels. With incorporation at the 2.5% level, both blanched skins and light roasted skins resulted in phenolics levels that were significantly greater than was found in the control samples; 5% incorporation of medium roasted peanut skins resulted in lower phenolics levels. At 5% peanut skin incorporation, phenolics levels of the peanut butter were higher than reported for nearly every tree nut, peanuts and traditional peanut butter in the USDA ORAC database with the exception of pistachios, pecans, and English walnuts. Incorporation at the 2.5% level produced similar high phenolic rankings, with only hazelnuts added to the other exceptions listed above. Phenolic levels in these nuts reportedly ranged from 0.68 to 20.16 mg GAE/g (USDA 2010) .

Because absolute values reported are impacted by extraction and assay methods employed, as well as cultivar and environmental conditions, a range of values is typical for any food. Therefore relative levels present, rather than absolute amounts, should be used for comparison purposes. When compared to the USDA database for phenolic foods and ingredients, these peanut butters formulated with either 2.5% or 5.0% peanut skin incorporation would rank among the higher phenolic foods (USDA 2010). These findings continue to illustrate the phenolic capacities of peanut skins, and its potential to increase the phenolic content of products as previously suggested (Davis and others 2010).

Effects of roasting on phenolic content may be associated with the Maillard browning reaction. Maillard browning products, which may be phenolic compounds, are generated through increased heat treatment. These Maillard products could be responsible for a greater proportion of the phenolics in the light roasted formulations. Increased heating increases Maillard browning reactions, which presumably increase phenolic compounds generated. Though it is known that roasting can increase the phenolic content of products through degradation of cell structures, higher heat treatments to the extent of medium roasting can decrease phenolic content through excessive breakdown of the cell structures. This excessive breakdown may cause phenolic components to escape the food matrix and decrease the phenolic content of the food (Davis and others 2010).

The trend toward decreased phenolic levels when medium roasted peanut skins, rather than blanched or light roasted skins, are incorporated, may be explained by the effect of heat on specific phenolic compounds (Davis and others 2010). Schmitzer and others (2011) identified the specific phenolic compounds in skins and nutmeats from various hazelnut cultivars and skins and examined the effects of roasting on phenolic content. They found that roasting significantly decreased flavan-3-ols and had negative effects on procyanidin dimers and trimers, but had a small effect on the overall phenolics levels in hazelnuts. These authors (Schmitzer and others, 2011) suggested that thermal degradation only decreases the content of some individual phenolic compounds. Yu and others (2006) characterized the concentration of procyandins in peanut skins after roasting and found that there were significant decreases in procyanidin monomers, b-type dimers, a-type trimers and tetramers. These authors (Yu and others, 2006) suggested that heating increased monomer polymerization and degradation of the a-type polymers through a mechanism that favors a-type dimer formation. As a-type trimers and tetramers are present in higher concentrations in peanut skins than are other procyandins, the heat intensity of medium roasting may increase degradation of these compounds and decrease the overall phenolic content of the skins, which is reflected in the reformulated peanut butters.

Quality Characterizations

Instrumental assessments such as Texture Profile Analysis (TPA) are used to quantify mechanical parameters of texture that can potentially be correlated with consumer assessments of texture (Szczesniak and others 1963). TPA textural parameters that would be important to consumers for peanut butter include adhesiveness, cohesiveness, gumminess, and firmness. The texture analyzer can also be used to measure textural parameters of peanut butter with the Texture Technologies Corporation (TTC) spreadability rig. Parameters measured with this test cell include maximum force and work of shear, which are indicators of firmness and spreadability, respectively (Ahmed and Ali 1986).

Texture

Maximum force and work of shear are two parameters from the time-force curve previously used to describe firmness and spreadability when peanut butters were evaluated with the Texture Technologies Corporation (TTC) spreadability rig (Ahmed and Ali 1986). The significant main effect of peanut skin incorporation and the nested effects of heat treatment within peanut skin incorporation on firmness and spreadability of the formulations are presented in table 4.2.

Peanut skin incorporation significantly increased firmness (maximum force required to penetrate to 2mm) when compared to the samples prepared without peanut skins as an ingredient. Peanut skin incorporation at 5% produced the firmest peanut butter. 2.5% peanut skin incorporation increased firmness to a lesser extent, although force was significantly greater than was found in the absence of peanut skins.

The nested effects of heat treatment within peanut skin incorporation on firmness showed significant differences with the extent of heat treatment. The firmest peanut butter sample was formulated with the highest level of peanut skins that had been subjected to the most severe heat treatment; this formulation exhibited significantly higher maximum force values when compared to all other samples. When either the blanched or light roasted skins were incorporated, increasing the level of incorporation from 2.5 to 5.0% did not further increase firmness of the peanut butter significantly.

Table 4.2: TTC spreadability rig results: texture of peanut butters [a] as affected by level of peanut skin incorporation and heat treatment within peanut skin incorporation (n=6)

	Parameter	**Heat**	**LS-Means ± SEM**			
Skin [b]			**0**	**2.5**	**5**	**StdErr**
	Firmness (kg)		0.9c	1.4b	1.7a	0.04
	Spreadability (kg.sec)		0.8c	1.2b	1.6a	0.04
Heat(Skin)[c]	Firmness (kg)	Blanched	0.9e	1.3cd	1.2d	0.06
		Light	0.9e	1.4bc	1.5b	0.06
		Medium	1.0e	1.6b	2.4a	0.06
	Spreadability (kg.sec)	Blanched	0.8d	1.1c	1.1c	0.07
		Light	0.8d	1.2bc	1.4b	0.07
		Medium	0.8d	1.4b	2.4a	0.07

[a] Data were collected using the texture analyzer (*TAX-T2*, Texture Technologies Corp., Scarsdale, NY, USA) equipped with Texture Exponent 32 software (Stable Micro Systems Lt, Godalming, Surrey, England) and a 5 kg load cell at a contact speed of 5 mm/s. Six samples were used from each formulation and each sample was penetrated with the TTC spreadability rig once to a distance of 2mm. Maximum force was extracted as the highest peak in the time/force curve and work of shear was the area above the curve associated with removal of the cone after penetration.

[b] LS-means for each parameter followed by different letters within a row are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF

[c] LS-means for each parameter followed by different letters within the heat treatment nested in peanut skin matrix are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF

Work of shear has been used to describe spreadability of peanut butters. Spreadability is an important characteristic to consumers and is included in the grading standards set by the USDA (1983). While firmness represents the amount of force required to penetrate the peanut butter (Ahmed and Ali 1986), spreadability indicates the area under the penetration curve. Spreadability revealed the same patterns found with firmness (Table 4.2); the samples that were most difficult to spread contained peanut skins that had been subjected to the most severe heat treatment at the highest level of incorporation.

Because of the apparent relationship between firmness and spreadability, Pearson correlation coefficients were calculated to identify any correlations present; these data are presented in table 4.3.

Table 4.3: Pearson product moment correlation between firmness and spreadability [a]

% Peanut Skins; Heat Treatment	Firmness & Spreadability
0 Blanched	r = 0.9; p = 0.0002
2.5 Blanched	r = 0.8; p = 0.04
5.0 Blanched	NS
0 Light	r = 1.0; p = <0.0001
2.5 Light	NS
5 Light	r = 0.8; p = 0.04
0 Medium	NS
2.5 Medium	r = 0.9; p = 0.005
5 Medium	NS

[a] Data were collected using the texture analyzer (*TAX-T2*, Texture Technologies Corp., Scarsdale, NY, USA/Texture Exponent 32 software, Stable Micro Systems Lt, Godalming, Surrey, England) with a 5 kg load cell and contact speed of 5 mm/s. Six samples were used from each formulation and each sample was penetrated with the TTC spreadability rig once to a distance of 2mm. Maximum force was extracted as the highest peak in the time/force curve and work of shear was the area above the curve associated with removal of the cone after penetration.

Incorporation of 5.0% blanched peanut skins, 2.5% light roasted peanut skins, and incorporation of 0% or 5.0% medium roasted peanut skins did not have significant correlations between firmness and spreadability. For the remaining formulations, firmness and spreadability showed strong positive linear correlations. Based on these results both assessments are required to describe the texture of these products when assessed by using the TTC spreadability rig.

Texture profile analysis (TPA) parameters have been found to correlate with descriptive panelists' assessment of sensory attributes for an array of food products (Szczesniak and others 1963). The use of TPA has been shown to better describe spreadable peanut products than does textural assessment using the TTC spreadability rig (Muego and others 1990). Data for the specific TPA parameters applicable to peanut butter, firmness, adhesiveness cohesiveness, and gumminess, are presented in table 4.4.

In TPA, firmness, a primary textural attribute also referred to as hardness, is the peak force during the first compression cycle. From a sensory perspective, firmness or hardness is the force required to penetrate a substance with molar teeth (Szczesniak and others 1963, Bourne 1978). All levels of peanut skin incorporation produced significantly firmer formulations when compared to the control, with the increase in firmness associated with increasing level of incorporation (Table 4.4). Samples with incorporation of 2.5% peanut skins were significantly less firm than were samples with 5.0% peanut skin incorporation, which produced the firmest peanut butter formulations. Heat treatment within peanut skin level was not influential. (Table 4.4)

In TPA, adhesiveness is defined as the negative force area for the first compression (Bourne 1978). As a sensory measure, adhesiveness would be determined as the force required to remove the material that adheres to the mouth (Szczesniak and others 1963). Level of peanut

Table 4.4: Textural profile analysis results: texture of peanut butters [a] as affected by level of peanut skin incorporation and heat treatment within peanut skin incorporation (n=6)

	Parameter	**Heat**	**LS-Means ± SEM**			
Skin [b]			**0**	**2.5**	**5**	**StdErr**
	Firmness(g)		126.3a	235.7b	294.5c	13.19
	Adhesiveness (g mm)		-139.9a	-176.6b	-186.5b	12.78
	Cohesiveness		0.4	0.4	0.4	0.02
	Gumminess (g)		69.5a	152.9b	158.8b	5.80
Heat(Skin) [c]	Firmness (g)	Blanched	118.7	215.3	317.2	22.85
		Light	142.8	249.0	258.8	22.85
		Medium	117.5	242.6	307.4	22.85
	Adhesiveness (g mm)	Blanched	-140.4	-191.1	-197.3	22.14
		Light	-140.6	-139.1	-165.7	22.14
		Medium	-138.6	-199.4	-196.3	22.14
	Cohesiveness	Blanched	0.4	0.4	0.4	0.03
		Light	0.4	0.4	0.4	0.03
		Medium	0.4	0.4	0.4	0.03
	Gumminess (g)	Blanched	63.6d	144.2bc	126.3c	10.04
		Light	80.3d	144.1bc	176.9a	10.04
		Medium	64.6d	170.3ab	173.1a	10.04

[a] Data were collected using the texture analyzer (*TAX-T2*, Texture Technologies Corp., Scarsdale, NY, USA/Texture Exponent 32 software, Stable Micro Systems Lt, Godalming, Surrey, England) equipped with a 5kg load cell. Six samples were used from each formulation and each sample was compressed twice with a 7.6 cm diameter compression disc with a contact speed of 5 mm/s. Samples were portioned on a base-plate. Values for each parameter were taken from time/ force curve (Bourne 1978).
[b] LS-means for each parameter followed by different letters within a row are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF
[c] LS-means for each parameter followed by different letters within the heat treatment nested in peanut skin matrix are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF

skin incorporation (Table 4.4) significantly impacted adhesiveness. Peanut skin incorporation at 2.5% and 5%, which did not differ from each other, produced significantly higher levels of adhesiveness than was found for the control formulation. Therefore, adhesiveness is significantly increased with peanut skin incorporation, but the level of incorporation within the range tested was not influential. The nested effect of heat treatment within peanut skin on adhesiveness was not significant.

TPA cohesiveness is a secondary textural parameter defined as the ratio of the positive force area during the second compression to area of the first compression; this parameter is difficult to perceive as a sensory rating because of relative insensitivity of the teeth (Szczesniak and others 1963, Bourne 1978). Peanut skin incorporation did not have a significant effect on the cohesiveness of the modified peanut butter formulations, measured instrumentally; these effects did not differ with specific heat treatment within level of incorporation.

Gumminess is a secondary textural attribute calculated as the product of firmness and cohesiveness (Muego and others 1990). As a sensory measure, gumminess is identified as the denseness of the food that lasts throughout chewing (Szczesniak and others 1963). In these peanut butter samples, incorporation of peanut skins (Table 4.4) produced significantly higher levels of gumminess when compared to the control formulations. There were not significant differences in gumminess with an increase in peanut skin incorporation from 2.5% to 5%.

The nested effects of heat treatment within peanut skin incorporation showed an effect of specific heat treatment on gumminess. Blanching the peanut skins incorporated increased gumminess of the peanut butter over the level found in the control, although there were no differences due to level of incorporation within the range evaluated. At 5% peanut skin incorporation, roasting to any extent significantly increased gumminess beyond the increase associated with blanching. At 2.5% peanut skin incorporation, roasting did not increase gumminess to a greater extent than did incorporation of the blanched peanut skins, although there is a trend toward increased gumminess when medium roasted peanut skins are incorporated. However, gumminess of the sample prepared with 2.5% medium roasted peanut skins, did not differ from those samples formulated with 5% incorporation of roasted peanut skins.

To identify relationships, if any, between the two instrumental textural assessments, Pearson product correlation coefficients were calculated between the various textural parameters. Significant ($p<0.1$; $r \geq 0.7$ or -0.7) results (Appendix D; Table D-1) were inconsistent, varying with heat treatment within skin level. Therefore, trends cannot be generalized between the two instrumental assessments. The most appropriate instrumental assessment of texture would require verification with a descriptive sensory panel (Meilgaard and others 1999).

Appearance

Appearance attributes are extremely important to consumer perception of peanut butters. Consumers have had strong reactions to peanut butters based on visual inspection of color, and particulates (McNeil and others 2000). Appearance parameters which were evaluated with trained observers or instrumentally included presence of particulates and color, respectively.

The significant main effect of peanut skin incorporation and the nested effect of heat treatment in peanut skin incorporation on presence of detectable particulates are found in table 4.5. The control samples as well as those in which peanut skins were incorporated, contained detectable levels of particulates. Peanut skin incorporation at either level significantly increased the presence of detectable particulates when compared to 0% peanut skin incorporation. However, increasing the level of peanut skin incorporation from 2.5% to 5% did not significantly increase the detection of the presence of particulates. These data suggest that there is a fairly wide range of particulate levels that can be incorporated before an increase is detectable.

The nested effects of heat treatment in peanut skin incorporation on detection of particulates produced significant differences when compared with the control formulations.

Presence of particulates was less obvious in the formulations that contained blanched peanut skins; incorporation at the 5% level was required before there was a significant difference in the detection of the particulates present.

Table 4.5: Particulate presence [a] of peanut butters as affected by level of peanut skin incorporation and heat treatment within peanut skin incorporation (n=9)

Attribute	**Heat**	**LS-Means ± SEM**			
Skin [b]		**0**	**2.5**	**5**	**StdErr**
		3.7b	4.9a	5.1a	0.15
Heat(Skin) [c]	Blanched	3.7e	4.2de	4.6cd	0.25
	Light	3.7e	5.1abc	5.8a	0.25
	Medium	3.7e	5.3ab	5.0bc	0.25

[a] Data were collected using a particle size distribution scale anchored by commercial peanut butter. Each sample was evenly spread onto particle analysis sheets provided by the USDA covering an area of 4 ½ in x 2 7/8 in per product. Three trained panelists evaluated the formulations against the particle scale created by the commercially available products and gave each peanut butter formulations a grade of 1 – 6; 1 being the least presence of particles and 6 being the highest presence of particles. There were three samples evaluated for each formulation of peanut butter.

[b] LS-means for each parameter followed by different letters within a row are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF

[c] LS-means for each parameter followed by different letters within the heat treatment nested in peanut skin matrix are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF

Increased particulate presence was detectable when 2.5% roasted peanut skins were incorporated regardless of temperature of roasting. However, with roasted peanut skins, the perception of the number of particulates present did not further increase with incorporation at the 5% level, when compared to the 2.5% level of incorporation. It is interesting that at the 5% level, light roasted peanut skin were more detectable than were the medium roasted skins. This likely reflects the uneven distribution or size of the particulates in the peanut butter matrix.

The significant differences in perception of the presence of particulates in the roasted samples when compared with the formulations prepared with blanched peanut skins may be due to the presence of darker particulates. Dark particulates provide a strong visual stimulus which may increase the perception of their abundance (Swanson and others 2005). The increased temperature or length of heating likely increased the extent of Maillard browning which is associated with increased development of melanin (Pattee and others 1991). This perception could explain the significant differences observed between roasted peanut skin formulations and blanched peanut skin formulations when incorporated at the same level. The difficulties in evaluating particulate presence stems from the observer's ability to not only distinguish between relative sizes of the particulates, but also the shape, color, and density of the particulates as well. This task is further compounded by the identification and comparison of irregular areas, and orientation of the individual particulates within the formulation (Swanson and others 2005). Because of these confounding factors, it is difficult to accurately compare particulate presence using visual observation, although the training as was done with these observers results in more consistent responses (Swanson and others 2005).

The color of peanut butters can have important quality implications due to the association of flavor and aroma with roasting of the peanuts. These flavors and aromas are associated with the production and intensity of the characteristic golden brown color, which is attributed to melanoidin produced due to the Maillard browning reaction (Pattee and others 1991). The main effect of level of peanut skin incorporation and the nested effect of heat treatment in peanut skin incorporation on color are presented in Table 4.6. Peanut skin incorporation did not produce significant differences in lightness (L*) when compared with the control formulations. Pattee and others (1991) also observed non-significant differences in lightness between peanut butters prepared with peanuts subjected to with varying degrees of roasting; they further concluded that these effects are not major contributors to differences in flavor perception.

Table 4.6: Significant differences in color [a] of peanut butters as affected by level of peanut skin incorporation and heat treatment within peanut skin incorporation (n=6)

	Parameter	Heat	LS-Means ± SEM			
Skin [b]			**0**	**2.5**	**5**	**StdErr**
	L*		38.1	40.5	36.6	1.25
	a*		6.9ab	7.4a	6.7b	0.17
	b*		26.3a	25.3a	22.4b	0.81
Heat(Skin)	L*	Blanched	39.9	41.1	38.1	2.16
		Light	35.2	39.7	37.4	2.16
		Medium	39.2	40.6	34.3	2.16
	a*	Blanched	7.3	7.9	7.4	0.29
		Light	6.6	7.1	6.6	0.29
		Medium	6.9	7.1	6.1	0.29
	b*	Blanched	27.6	26.6	25.6	1.40
		Light	24.7	24.7	22.0	1.40
		Medium	26.7	24.8	19.7	1.40

[a] Data were collected using a Minolta spectrophotometer (model CM-700d, Minolta Corp., Ramsey NJ). Measurements occurred on two different locations on each sample, and there were three samples in each formulation.

[b] LS-means for each parameter followed by different letters within a row are significantly different ($p<0.05$) according to mixed model analysis of variance (PROC MIXED) and LS-means separation with PDIFF

[c] Represents degree of lightness on a 0- 100 scale where 0 indicates black and 100 indicates white.

[d] Represents red-green axis where negative values trend toward green while positive values trend toward red.

[e] Represents blue-yellow axis where negative values trend toward blue while positive values trend toward yellow.

Previous researchers have not evaluated the effects of heat treatment or peanut skin incorporation on the red-green color or blue-yellow color of peanut butters (Pattee and others 1991). The main effect of peanut skin incorporation on the red-green color axis produced significant differences amongst the modified formulations, although neither modified formulation differed from the control. All samples were in the red range of the opponent color scale.

The main effects of peanut skin incorporation on blue-yellow color axis produced significant differences from the control formulations (Table 4.6); all samples were in the yellow range of the opponent color scale (Pattee and others 1991). Incorporation at 2.5% peanut skins did not produce significant changes in yellowness when compared with the control formulations, whereas 5.0% peanut skin incorporation produced a peanut butter that was significantly less yellow than was found for the control peanut butter. In Table 4.6, the nested effects of heat treatment in peanut skin incorporation on peanut butter color are presented. Specific heat treatment of the peanut skins did not significantly affect lightness, redness, or yellowness of the peanut butter formulations.

Sensory evaluation

Panel Profile

A numerical summary of the panelist responses to all questions on the sensory questionnaire are presented in appendix D; the panel is profiled here. Of the 140 sensory panelists, 94 were female and 46 were male. 57% of the panelists were 18-27 years old, 29% were at least 44 years of age, with the remaining panelists between 28 and 43 years of age. All panelists consumed products containing peanuts, with 94% consuming these products at least several times per month and 66.4% consuming these products either several times a week or daily. All but two panelists consumed peanut butter and 79% of these panelists purchased creamy rather than crunchy peanut butter.

Participants identified which brand names of various peanut butter formulations were purchased most frequently. Consumers older than 35 are reportedly extremely brand loyal, with younger consumers less brand loyal. These younger consumers may be more willing to try a new product if product attributes and other influential factors met expectations (McNeil and others 2000). Among these respondents, 57% were younger than 27. Jif Regular was purchased by 45% of the panelists and was selected most often. Various brand names of “healthy” peanut butter were purchased by 14% of the participants. Among those 20% of the panelists who indicated the peanut butter that he/she purchased was not on the list, nearly 60% selected a natural product.

Because health-related claims are often used to position foods in the marketplace, panelists were asked to rate the importance of specific health claims for foods that they purchase; results are found in Table 4.7. 77% of the panelists indicated that the high in antioxidants claim was somewhat or very important to them. When queried about the impact of an antioxidant claim on purchasing of peanut butter specifically, 48% indicated that they would be more likely to purchase a peanut butter carrying the antioxidant claim rather than their preferred product. It should be noted that willingness to purchase the higher antioxidant product would likely be affected by price of the product that carried the antioxidant claim (Sloan 2009); price was not specified. According to McNeil and others (2000) for consumers younger than 35, price and jar size were strong influences on peanut butter purchase decisions. Nearly 70% of panelists also indicated that the natural claim was somewhat or very important to them in general when purchasing foods, with 12% of panelists indicating consumption of natural peanut butters.

Table 4.7: Panelists profile: importance of potential health claims in food selection (n=140)

How important is each of the following claims when you select FOODS to BUY?	**% of panelists saying:**		
	Not	**Somewhat**	**Very**
Whole-grain	8.0	41.6	50.4
Low/reduced, no sugar	27.7	45.5	26.9
Low/reduced fat	22.4	46.8	30.8
No trans-fat	21.2	32.7	46.1
Low/reduced calorie	28.2	50.8	21.0
Low/reduced sodium	30.5	43.6	25.9
Low carb	44.4	37.7	17.7
Protein-rich	16.5	51.2	32.3
Calcium-fortified	29.9	38.7	31.5
No chemical additives	30.0	43.6	26.4
No Preservative	31.1	45.4	23.5
Natural	30.4	40.9	28.7
Reduces risk of heart disease	26.1	38.6	35.3
Reduces risk of cancer	24.4	38.4	37.2
Reduces risk of hypertension	29.8	34.3	35.9
High fiber	10.0	47.0	43.0
Low glycemic index	48.2	34.9	16.9
High in antioxidants	23.7	45.8	30.5
Prebiotic/probiotics	46.9	41.2	11.8
Organic	56.2	34.1	9.6
Vitamin-fortified	22.4	51.6	26.0

Sensory Results

The acceptability results for the control and modified formulations are found in Tables 4.8.and 4.9. Across all heat treatments, peanut skin incorporation (Table 4.8) produced significant decreases in appearance acceptability as level increased; the control formulation received the highest average acceptability rating.

Table 4.8: Consumer sensory results: effects on acceptability of peanut butters prepared with added peanut skins across heat treatments (n=140)

	LS-Means ± Standard Error [a]		
	Level		
Attribute	0%	2.5%	5.0%
Appearance [b]	6.4 ± 0.1a	6.2 ± 0.1b	5.1 ± 0.1c
Ease of Spreadability [b]	6.7 ± 0.1a	6.5 ± 0.1a	6.0 ± 0.1b
Consistency [c]	6.0 ± 0.1a	6.4 ± 0.1b	6.6 ± 0.1c
Texture [b]	6.5 ± 0.1a	6.3 ± 0.1a	5.9 ± 0.1b
Flavor [b]	6.6 ± 0.1a	6.5 ± 0.1a	6.0 ± 0.1b
Overall Acceptability [b]	6.5 ± 0.1a	6.4 ± 0.1a	5.8 ± 0.1b

[a] LS-means ± standard error within a row followed by different letters differ significantly ($p<0.05$)
[b] Evaluated on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely
[c] Evaluated on a 9-point scale where 1= runny; 9= stiff

Ease of spreadability is an important consumer characteristic included as part of USDA's grading procedures for peanut butters (USDA 1983). Panelists were asked to rate the ease of spreadability after spreading the peanut butter on a cracker. Previous consumer panels have indicated that peanut butters should spread evenly and thickly with a minimum overspreading (McNeil and others 2000). Effect of peanut skin incorporation on ease of spreadability produced ratings within the acceptable range of the scale for all levels of incorporation, although the ratings were less acceptable when 5.0% peanut skin were incorporated.

For consistency, panelists rated formulations as significantly more stiff as level of peanut skin incorporation increased, suggesting the increased stiffness is associated with a decrease in the acceptable ease of spreadability. For overall acceptability as well as acceptability of texture and flavor, only peanut skin incorporation at the 5.0% level produced significantly lower acceptability ratings when compared with the control formulations.

Effect of heat treatment within peanut skin level was also examined (Table 4.9). For appearance, the only formulation not to be rated in the acceptable range of appearance scale contained 5.0% peanut skins subjected to medium roasting. Acceptability of appearance of the peanut butters formulated with 2.5% peanut skins subjected to either blanching or light roasting did not differ significantly from the control. These results suggest that the specific heat treatment as well as level of peanut skin incorporation should be considered when effects on appearance acceptability are evaluated.

Of the modified formulations, 5.0% peanut skin incorporation subjected to light or medium roasting produced significantly less acceptable spreadability ratings when compared to the control formulation; ease of spreadability was in the slightly acceptable range of the scale when peanut skins were incorporated at this level. Ease of spreadability for all remaining samples did not differ in acceptability from the control.

Heat treatment within skin level influenced perceived consistency. Roasted formulations at either level of peanut skin incorporation were significantly stiffer when compared to the control. However, consistency of the blanched formulations at either level of peanut skin incorporation did not differ from the control.

All peanut butter formulations evaluated were rated by consumers as having an acceptable texture (Table 4.9), falling in the slightly to moderately acceptable range of the scale. Only formulations with 5.0% peanut skin incorporation subjected to light or medium roasting were significantly less acceptable in texture when compared with the control formulations; these formulations prepared with roasted skins were also significantly less acceptable in texture when compared with formulations prepared with blanched peanut skins at the 5% level of incorporation. Panelists gave an average rating of 6.6 to flavor acceptability of the control formulations, and rated all modified formulations as having an acceptable flavor as indicated by values above midpoint on the 9-pt scale. Only formulations with 5.0% peanut skin incorporation subjected to roasting at any level differed significantly from control in flavor acceptability

Heat treatment effects within skin level impacted overall acceptability. Overall acceptability of the formulations with 2.5% peanut skins did not differ from the control. Although in the acceptable range of the scale, samples prepared with 5.0% peanut skins subjected to medium roasting were rated significantly less acceptable when compared with all other formulations. Reducing the incorporation level to 2.5% increased the acceptability of the formulations prepared with medium roasted skins; these samples equaled the control in overall acceptability.

In addition to rating formulations on the 1-9 hedonic scale, panelists were also asked to indicate what they liked or disliked in particular about each sample. These qualitative responses can help to explain the overall acceptability of the formulations as well as aid in future reformulation efforts. These responses are presented in tables 4.10 and 4.11. The reasons why panelists dislike formulations (Table 4.10) were of particular interest, because of recommendations for future reformulations.

Table 4.9: Consumer sensory results: acceptability of peanut butters prepared with added peanut skins differing in heat treatment (n=140)

	Skin Level						
	LS-Means ± Standard Error [a]						
	0%	2.5%			5.0%		
Attribute	Control	Blanched	Light Roast	Medium Roast	Blanched	Light Roast	Medium Roast
Appearance [b]	6.4 ± 0.2a	6.5 ± 0.2a	6.2 ± 0.2ab	5.8 ± 0.2bc	5.5 ± 0.2c	5.0 ± 0.2d	4.6 ± 0.2d
Ease of Spreadability [b]	6.7 ± 0.1a	6.8 ± 0.2a	6.3 ± 0.2a	6.3 ± 0.2a	6.5 ± 0.2a	5.8 ± 0.2b	5.8 ± 0.2b
Consistency [c]	6.0 ± 0.1c	6.2 ± 0.2bc	6.4 ± 0.2b	6.4 ± 0.2b	6.0 ± 0.2c	7.0 ± 0.2a	6.9 ± 0.2a
Texture [b]	6.5 ± 0.1a	6.5 ± 0.2a	6.3 ± 0.2ab	6.3 ± 0.2ab	6.4 ± 0.2a	5.8 ± 0.2bc	5.6 ± 0.2c
Flavor [b]	6.6 ± 0.2ab	6.9 ± 0.2a	6.2 ± 0.2bcd	6.4 ± 0.2abc	6.2 ± 0.2bcd	6.0 ± 0.2cd	5.7 ± 0.2d
Overall Acceptability [b]	6.5 ± 0.1ab	6.7 ± 0.2a	6.2 ± 0.2bcd	6.4 ± 0.2abc	6.1 ± 0.2cd	5.9 ± 0.2d	5.4 ± 0.2e

[a] LS-means ± standard error within a row followed by different letters differ significantly ($p<0.05$)
[b] Evaluated on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely
[c] Evaluated on a 9-point scale where 1= runny; 9= stiff

Of the panelists who described issues with appearance, many citied color as a reason for disliking the samples. This reason seemed to be a particular issue with the roasted formulations at 5.0% peanut skin incorporation, for which many panelists cited dark color as a reason for dislike. Dark color has previously been identified as a negative attribute because of the perceived association between dark color and burnt samples. Panelists mainly cited oily or moist appearance as reasons for disliking the control formulation. Previous consumer panelists have identified oiliness as a negative attribute, preferring a glossy sheen in the peanut butter (McNeil and others 2000). Panelists who cited dislikes with mouthfeel mainly described issues with dryness of the formulations. Blanched formulations with 2.5% peanut skin incorporation were the only samples not cited for issues of mouthfeel. Previous panelists indicated mouthfeel as an important attribute in peanut butter, with an ideal peanut butter melting in the mouth and sliding down the throat. Dryness has also been previously identified as a negative attribute (McNeil and others 2000).

The number of specific dislike responses related to flavor/taste was reported by panelists less often than was found for both appearance and textural attributes. Panelists who cited dislikes pertaining to flavor/taste specifically indicated bland and salty notes, particularly with the control formulation. These responses may suggest that incorporation of peanut skins decreased the perception of bland and salty notes. Bland and salty notes have been previously described by consumers as negative attributes (McNeil and others 2000). However, previous consumer panels only indicated issues related to salt when they felt the peanut butter had no salt. The responses by these panelists did not seem to follow this logic as more of them cited reasons for disliking samples due to saltiness rather than no salt (McNeil and others 2000). Perhaps this change in preference is associated with the introduction of lower salt and reduced sodium products in the marketplace. Incorporation of peanut skins did not seem to produce bitter notes or aftertaste, commonly associated with phenolics. Few panelists specifically indicated bitter taste or aftertaste as reasons for specifically disliking the formulations, though only the modified formulations received these responses when given. The small number of bitter responses also suggests that the prescreening criteria for inclusion of specific formulations for consumer evaluation were appropriate.

Panelists cited textural related responses for disliking formulations more than flavor/taste and appearance. Many specific responses for disliking formulations were related to indicators of consistency and graininess with the control formulation receiving the most specific responses. The specific responses related to consistency, including stiffness, thickness, consistency, and spread were indicated in nearly all formulations. Previously, consumer focus groups have identified stiffness and thickness as negative attributes, future assessments of consistency will be needed with additional reformulation. Consumer focus groups also characterize graininess as an attribute associated with natural peanut butters (McNeil and others 2000), suggesting a possible marketing approach for these formulations. General trends from these responses suggested that peanut skin incorporation at 5.0% increases perception of negative textural attributes. Light roasted samples received the fewest textural specific responses for dislike when compared with blanched and medium roasted samples.

In table 4.11, the particular reasons panelists like the control and modified peanut butter formulations are summarized. It should be noted that the overall responses panelists stated for liking the formulations were less specific than reasons they gave for disliking samples. When an array of peanut butter formulations was presented to previous consumer focus groups, they were also better able to identify particular reasons for disliking rather than liking the formulations (McNeil and others 2000).

Of the particular attributes panelists identified that they liked about the formulations, appearance related attributes were identified less often than were flavor/taste or texture. However, many panelists identified color of the control formulation as an attribute that they liked. Of the modified formulations, more panelists identified liking the color of blanched formulations rather than roasted formulations, regardless of level of peanut skin incorporation. Color has been described by previous consumer panels as important in their assumptions of bland or burnt flavor, which are associated with light and dark colors, respectively (McNeil and others 2000).

Panelists liked the flavor/taste of the formulations more than any other general attribute, though few respondents indicated which specific flavor/taste attributes they liked. Previously, panelists were more specific about the product characteristics that they disliked than they were about those that they liked (McNeil and others 2000). Of the formulations evaluated, panelists liked flavor/taste related attributes for the control formulation more than any modified formulation. Specific flavor/taste related attributes that panelists liked about all formulations regardless of heat treatment and peanut skin incorporation were nuttiness and sweetness. Both of these attributes have been previous identified by consumers as positive flavor/taste attributes of peanut butters (McNeil and others 2000).

Of the panelists who provided textural related attributes as reasons for liking formulations, consistency and particle presence dominated the specific responses. Smoothness and creaminess were specifically indicated as positive attributes in nearly every formulation (table 4.11); previous consumer panels also indicated these attributes as positive textural characteristics of peanut butters (McNeil and others 2000). The control formulation received the most textural related responses by panelists; more panelists identified textural related attributes of blanched formulations more often than was found for roasted formulations that they liked.

A stepwise multiple regression analysis revealed that about 81% of the variability in overall acceptability was accounted for by acceptability of flavor, texture, appearance and spreadability. The percentage contribution of each attribute to overall acceptability was flavor, 75%, texture, 5% with spreadability accounting for an additional 0.5%, and appearance, 1%.

Table 4.10: Panelists responses to the open-ended question: what in particular did you **dislike** about the peanut butter formulation? Number in each cell, represents the number panelists giving the associated response.

Category	0%	2.5%			5.0%		
	Control	Blanched	Light	Medium	Blanched	Light	Medium
Appearance							
Appearance	5	3	3	8	6	7	11
Color	4	1	3	4	7	8	11
Color Dark		2	4	4	5	10	15
Color Light	1						
Moist	6				3		
Oily	9	1		1	6	1	
Specks	1	2	2	4		1	1
Mouthfeel							
Mouthfeel			1	2	1		2
Consistency					3		
Dry	3		3	4	3	5	1
Hard to Swallow	1		2	1			
Stuck to Mouth	4		1	1	1	1	
Flavor/Taste							
Flavor	3	1	1	1	1	1	2
Flavor: Roasted							2
Taste	8	1	2	2	2	5	4
Aftertaste		2			1		1
Taste: Mild	2	3			2		1
Taste: Strong				1			
Bitter				1	1	2	
Bland	9	4	8	2	4	7	6
Burnt				1	3		1
Salty	5	2	1				2

No salt		1					
Sweetness	1	1	2		2		
NOT sweet	2	1			2	1	
Texture							
Texture	6	3	2	2	3	3	9
Consistency	4	2	2	3		1	4
Crunchy	4	1		1		4	
Grainy	9	3		6	6	5	9
Smooth	1						
Sticky	2	3	4	1			1
Spread	5			2	3	2	2
Stiffness	4	5	1	2	3	2	5
Thickness	5	1	3	2	2	3	4
Other							
Other	1			1	2	1	2
Smell	1			1	1	1	1

Table 4.11: Panelists responses to the open-ended question: what in particular did you **like** about the peanut butter formulation? Number in each cell, represents the number of panelists giving the associated response.

Category	0%	2.5%			5.0%		
	Control	Blanched	Light	Medium	Blanched	Light	Medium
Appearance							
Appearance	8	1	3	2		1	
Color	26	9	2	3	6	2	1
Color Dark			1		1	2	
Color Light	1		1				
Oily	1						
Mouthfeel							
Mouthfeel	1		1	1	1		
Moist	1						
Flavor/Taste							
Flavor	24	12	5	9	12	13	8
Flavor: Nutty	4	4	2	2	3	1	2
Flavor: Roasted		1		2	2	1	
Taste	20	12	14	9	12	13	9
Aftertaste	1					1	1
Taste: Mild		1		2	1	1	1
Taste: Natural	1	1					
Taste: Strong				1			
Salty	1		2	1			
No salt		1					
Sweetness	3	1	2	3	1	1	2
Texture							
Texture	18	9	13	14	7	5	8
Consistency	16	5	6	2	6	6	7
Creamy	6	3	1	2	4		
Crunchy	3	1	1	1	1	2	
Grainy		1	2		1	1	1

Smooth	9	5	3	5	2		4
Spread	16	5	3	6	8	7	4
Stiffness	3					1	
Thickness	2	1	1	2		1	
Other							
Other	2	3	2	2	2	1	2
Overall	6	1	2		3	2	1
Smell	4		2	4		2	1

Despite the cited negative responses for texture and appearance, their overall effects on acceptability were less influential when compared with the contribution of flavor to overall acceptability. Because less than 100% of the variability in response is explained by this sensory attributes, other unidentified factors also influence the overall acceptability of peanut butters.

Conclusion and implications

Overall, these objective and sensory results suggest that peanut butters can be successfully reformulated with the incorporation of peanut skins at the 2.5% level irrespective of heat treatment; these peanut butters contain 1.5-1.7 times the phenolics found in the traditionally formulated peanut butters. There were no effects of heat treatment on acceptability of any attribute except appearance within this level of incorporation. Appearance of the sample prepared with medium roasted skins at the 2.5% level was less acceptable than was found for the samples prepared with skins subjected to less severe heat treatment at the same level of incorporation. Objective assessment of appearance suggests that the particulates present were more discernable. Previous researchers (McNeill and others 2000) have found that presence of particulates decreases acceptability of peanut butters. These sensory results coupled with the lack of increase in phenolics when medium roasting rather than other heat treatments of the peanut skins were employed, suggests that the medium roasted peanut skin should be eliminated from future reformulation efforts.

Although objective assessments of texture found differences with heat treatment within peanut skin incorporation at the 2.5% level, these differences do not appear to be great enough across the panel as a whole to impact overall acceptability, texture acceptability or acceptability of the ease with which the peanut butter could be spread. Despite these acceptability results, consistency was found to differ, and textural attributes such as consistency and graininess elicited more negative comments when panelists were queried about specific samples than did other attributes including appearance, flavor and taste. Overcoming these identified defects, though apparently minor, may increase the appeal of the product, especially for subgroups of consumers.

Addition of peanut oil to peanut butters has been previously shown to significantly decrease maximum force (firmness) (Ahmed and Ali 1986) and work of shear (spreadability). Addition of peanut oil to reformulated high phenolic peanut butters might decrease the levels of maximum force and work of shear to that of the control formulations. This could also improve sensory perception of texture by decreasing panelist described negative attributes such as stiffness, and thickness, both indicators of consistency. More research will be needed to fully investigate the physical and textural properties of reformulated high phenolic peanut butters with altered levels of peanut oil. The addition of oil to peanut butter has potential to cause marketing concerns because the standard of identity set for peanut butter states, “the fat content of peanut butter cannot exceed more than 55% and peanut butter must contain at least 90% peanuts” (FDA HHS 2009, American Peanut Council 2010). Importance of meeting the standard of identity and the implications for marketing should be reassessed relative to any effects on quality characteristics obtained through the increased addition of peanut oil to the high phenolic peanut butter. Not being able to label the peanut skin fortified product as peanut butter could cause consumer confusion and result in less consumption of the product; this would essentially defeat the purpose of utilizing a commonly known and consumed food for fortification (van Raaj and others 2008). The maximum amount of oil, including as a stabilizer, used in these reformulated peanut butters was 0.016kg per 3kg batch of peanut butter; therefore, these formulations were able to meet the current peanut butter standard of identity by reduction of peanuts in favor of peanut oil incorporation.

At the 5% level of incorporation, phenolics levels were increased 2.3 to 3.6 times the control formulation, with heat level influential. Increasing the severity of the heat treatment decreased the level of phenolics present within this level of skin incorporation. Appearance and textural differences found using objective techniques appear to impact acceptability of the sensory attributes of these reformulated products. At the 5% level of incorporation with either the light or medium roasted peanut skins, the peanut butters exhibited less acceptable appearance, spreadability, texture, flavor and overall acceptability than was found for the traditionally formulated product. The additional increase in the phenolics level and the product characteristics justify additional reformulation efforts at the 5% level with the blanched skins only. Although appearance and overall acceptability (which likely reflected appearance acceptability) of the sample prepared with blanched skins at the 5% level of incorporation differed from the control, other attributes, including consistency, did not. This formulation may be acceptable if consumers were aware of the antioxidant content or if the product carried a natural claim.

Because there are not dietary recommendations for phenolic or antioxidant intake for overall health maintenance or prevention of chronic diseases, reformulation efforts should continue to attempt to maximize consumer acceptability and phenolics levels of the formulations. It appears that levels comparable to those foods found at the top of the USDA list of ORAC levels found in foods and ingredients may be achieved.

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CHAPTER 5: CONCLUSIONS

Polyphenols are compounds associated with positive health effects against chronic diseases such as cancers, cardiovascular diseases, diabetes, neurodegenerative diseases, and osteoporosis due to their effects on inflammation (Scalbert and others 2005, Jensen 2006, Ullah and Khan 2008). Incorporation of these compounds into commonly consumed foods, such as peanut butter, would provide an opportunity to increase dietary consumption of phenolics without the added challenges of changing consumer diets (van Raaj and others 2008). Peanut skins are common by-products of peanut processing and are rich sources of phenolic compounds which have the potential to be a functional food ingredient (Davis and others 2010).

The purpose of this study was to assess the acceptability and quality characteristics of peanut butter that was reformulated by incorporating peanut skins to increase phenolic levels. These resulting formulations met USDA (1972) standard of identity for peanut butter and contained phenolic amounts comparable to top foods and ingredients in the USDA ORAC database (USDA 2010). Increasing peanut skin content resulted in higher levels of phenolics while roasting treatments attenuated these effects. Objective assessments of quality of these formulations included firmness, spreadability, adhesiveness, cohesiveness, gumminess, color, and presence of particulates. These assessments revealed significant differences between the control and modified formulations in firmness, spreadability, gumminess, and presence of particulates, with skin level and heat treatment within skin level influential.

Instrumental textural assessments of the formulations identified effects of peanut skin incorporation and the nested effects of heat treatment within peanut skin incorporation on the resulting peanut butters. Maximum force (firmness) and work of shear (spreadability), when assessed with the TTC spreadability rig were increased with increasing peanut skin incorporation. Lack of consistent correlations between these two parameters across all formulations suggests the necessity of assessing both these textural parameters for texture when using the TTC spreadability rig.

Assessments of texture through texture profile analysis found significant effects of peanut skin incorporation and the nested effects of heat treatment within peanut skin incorporation on the firmness, adhesiveness, cohesiveness, and gumminess of the modified peanut butters. Of the textural parameters measured, there were only significant nested effects of heat treatment within peanut skin incorporation on the gumminess of the peanut butter formulations. The main effect of peanut skin incorporation significantly increased adhesiveness and gumminess; firmness was significantly increased with each increasing level of peanut skin incorporation. Correlations between these TPA parameters and maximum force (firmness) and work of shear (spreadability) obtained with the spreadability rig revealed that these assessments measure different textural properties of the formulations.

The main effects of peanut skin incorporation and the nested effects of heat treatment within peanut skin incorporation on particulate presence found significant differences between the control and modified formulations. Peanut skin incorporation significantly increased particulate presence of the resulting formulations, although increasing the percentage peanut skins from 2.5 to 5.0 did not alter the perception of the relative abundance of particulates. Particulates were visible in all formulations, including the control with values in the upper half of the particulate presence scale. For color, the main effect of peanut skin incorporation was significant for a*b*; no significant differences in lightness were observed when the modified formulations were compared to the control. Peanut skin incorporation at 2.5% produced the reddest formulations, though neither level of peanut skin incorporation was significantly different when compared with 0% incorporation. Yellowness of the formulations was significantly decreased with 5% peanut skin incorporation. Nested effects of heat treatment within peanut skin incorporation were not significant for L*a*b*.

Consumer panelists rated the acceptability of the appearance, texture, flavor, and overall acceptability of these formulations as well as assessing spreadability and consistency. All formulations evaluated were determined to be acceptable in each of those mentioned parameters, though some modified formulations were rated significantly less acceptable than was the control in each category. Panelists found blanched and light roasted formulations with 2.5% peanut skin incorporation equal to the control formulation in appearance, texture, flavor, and overall acceptability. When panelists were asked to specifically indicate their likes and dislikes about the formulations, textural related attributes dominated the dislike responses while flavor/taste related attributes dominated the like responses. Panelists were better able to identify specific attributes as reasons for disliking formulations than liking formulations. The panelists who cited dislike responses related to texture specifically indicated attributes such as consistency and graininess while panelists mainly cited general flavor/taste attributes as reasons for liking the formulations. As a part of the panelist profile, each panelist was asked to rate the importance of 21 potential label claims. Of these, 77% of panelists found high in antioxidant claims to be somewhat or very important to them and nearly 70% of panelists found the claim natural to be somewhat or very important to them.

The creation of consumer acceptable high phenolic peanut butter formulations has significance for both nutrition and the food industry. High phenolic peanut butters can potentially be a great addition to the diet, particularly for younger consumers who were more likely to try different peanut butters. Consumption of high phenolic peanut butter could increase the amount of antioxidants incorporated into the diet, which may play a preventative role in some chronic health diseases such as cancer, arthritis, heart disease, and stroke. This dietary goal could be achieved without a major change in dietary choices, facilitating the incorporation of this high phenolics peanut butter into the meal plan. Peanut skins are by-products of the peanut butter making process, so incorporation of these high phenolic ingredients, which are typically a waste product, would be likely to provide more benefits than cost. If consistency proves to be a barrier to use by consumers, the addition of oil may improve this textural characteristic. Because this formulation adjustment may not fit within the current peanut butter standards of identity, peanut skin fortified peanut butters prepared with additional peanut oil may not meet the requirements necessary to be labeled as peanut butter. Potential benefits on sensory characteristics would need to be weighed relative to the negatives associated with not meeting the standard of identity.

Future studies should investigate the quality effects of peanut skin fortified peanut butters reformulated with 2.5% blanched or light roasted peanut skins, or 5.0% blanched peanut skins in comparison with commercially available peanut butter products. The results from those comparisons can further reveal the changes necessary to make this product competitive in the peanut butter market. In particular, the potential for high phenolics levels to increase oxidation (O'Keefe and Wang 2006) and negatively impact shelflife should be investigated. Because of its potential "natural" product appeal, quality characteristics of peanut skin fortified peanut butters should also be compared with commercially available peanut butters specifically identified as natural. When further tweaking the high phenolic formulations, efforts should assess the quality, acceptability, and nutritional content of the modified formulations. Ultimately, response of consumers to the “better for you” classification of these high phenolic peanut butters will need to be ascertained.

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APPENDIX A: PARTICULATE PRESENCE ANCHORS

Position 2

Position 1

Position 3

Position 4

APPENDIX A: PARTICULATE PRESENCE ANCHORS

Position 5

Position 6

APPENDIX B: SENSORY SCORECARD

Product:________ Panelist Number: __________

Peanut Butter Sensory Scorecard

You will evaluate 4 samples today. Before tasting, please answer the following question about the product's appearance by marking the box (☐) that best reflects your opinion of this product.

How well did you **like or dislike the appearance** of this product?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … **Extremely Like**

Using a clean knife, spread the peanut butter sample on the cracker. How well did you **like or dislike the ease with which you could spread** this product on the cracker?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … **Extremely Like**

Rate the **consistency** this product.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Runny … **Stiff**

Eat the peanut butter cracker and evaluate it by marking the box (☐) that best reflects your opinion of this product.

How well did you **like or dislike the overall texture** of this product?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … **Extremely Like**

How well did you **like or dislike the overall flavor** of this product?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … **Extremely Like**

Overall, how well did you like or dislike this product?

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Dislike … **Extremely Like**

Please drink some water and eat some cracker and carrot to cleanse your mouth.

Comments: Please indicate WHAT in particular you liked or disliked about this product.(USE WORDS NOT SENTENCES)

LIKED	DISLIKED
______________	______________
______________	______________
______________	______________
______________	______________

Please return your tray. This was your last peanut butter sample. You will receive a short Panelist Questionnaire in a moment.

APPENDIX C: PANELIST QUESTIONNAIRE **Panelist Number: ______**

Panelist Questionnaire

Now, we would like to know a little more about you.
Please check the best response for each item below.

1. Your gender: _____male _____female

2. Your age category:

_____18-27 _____44-51
_____ 28-35 _____52-61
_____36- 43 _____62 and above

3. How often do you eat products containing peanuts?

_____daily
_____several times a week
_____several times a month
_____once a month
_____several times a year
_____never

4. How often do you eat peanut butter?

_____daily
_____several times a week
_____several times a month
_____once a month
_____several times a year
_____never

5. If you eat peanut butter, which one brand of peanut butter do you purchase most often (Check ONLY ONE)?

_____ Jif Regular _____ Skippy Regular
_____ Jif Reduced Fat _____ Skippy's Reduced Fat
_____ Peter Pan Regular _____ Smucker's Original
_____ Peter Pan Smart Choice _____ Smucker's Natural Reduced Fat

_____ Peter Pan Whipped _____ Other ____________________
_____ Reese's Regular (please specify)

6. Which type of peanut butter do you purchase most often? (Select only ONE)

_____Creamy _____Crunchy

7. Who in your household would eat this peanut butter product? (Select all that apply)

_____yourself
_____children under 10 years of age
_____children 11-18
______your spouse
______your room or housemates
______ no one

8. How important is each of the following claims when you select FOODS TO BUY?

	Very important	**Somewhat important**	**Not important**
Whole-grain			
Low/reduced, no sugar			
Low/reduced fat			
No trans-fat			
Low/reduced calorie			
Low/reduced sodium			
Low carb			
Protein-rich			
Calcium-fortified			
No chemical additives			
No preservatives			
Natural			
Reduces risk of heart disease			
Reduces risk of cancer			
Reduces risk of hypertension			
High fiber			
Low glycemic index			
High in antioxidants			
Prebiotic/ probiotic			
Organic			
Vitamin- fortified			

9. If a peanut butter other than your preferred peanut butter carried an antioxidant claim, would you be more likely to purchase it rather than your preferred peanut butter?

_____yes _____no

APPENDIX D: PEARSON PRODUCT CORRELATION BETWEEN INSTRUMENTAL ASSESSMENTS OF TEXTURE

Table D-1: Pearson product correlation between instrumental assessments of texture by sample

Rig [a]	TPA [b]	Peanut Skin Sample	r, p [c]
Spreadability	Adhesiveness	0% Medium Roast	-0.8, 0.006
		5% Medium Roast	-0.8, 0.04
	Firmness	0% Medium Roast	0.6, 0.08
		5% Blanched	-0.8, 0.07
	Gumminess	5% Blanched	-0.9, 0.005
Firmness	Adhesiveness	5% Blanched	0.8, 0.04

[a] Data were collected using the texture analyzer (*TAX-T2*, Texture Technologies Corp., Scarsdale, NY, USA/Texture Exponent 32, Stable Micro Systems Lt, Godalming, Surrey, England) with a 5 kg load cell and contact speed of 5 mm/s. Six samples were used from each formulation and each sample was penetrated with the TTC spreadability rig once to a distance of 2mm. Maximum force was extracted as the highest peak in the time/force curve and work of shear was the area above the curve associated with removal of the cone after penetration.

[b] Data were collected using the texture analyzer (*TAX-T2*, Texture Technologies Corp., Scarsdale, NY, USA/Texture Exponent 32, Stable Micro Systems Lt, Godalming, Surrey, England). Six samples were used from each formulation and each sample was compressed twice with a 7.6 cm diameter compression disc. Samples were portioned onto a base-plate raised 25mm and the load cell was 5 kg with a contact speed of 5 mm/s. Values were taken from time/force curve (Bourne, 1978).

[c] Only significant ($r \geq 0.7$ or -0.7, $p \leq 0.1$) correlations are reported.