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Acceptability Of Brownies Supplemented With Black Bean Puree By College Students At Indiana State University

Amanda M. Fleischer
Indiana State University

Acceptability of Brownies Supplemented with Black Bean Puree by

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Amanda M. Fleischer

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COMMITTEE MEMBERS

Committee Chair: Florence Uruakpa, Ph.D., RD, CD

Assistant Professor of Applied Health Sciences

Indiana State University

Committee Member: Maureen K. Johnson, Ph.D., MCHES

Assistant Professor of Applied Health Sciences

Indiana State University

Committee Member: Eliezer Bermúdez, Ph.D., CP-FS

Associate Professor of Applied Health Sciences

Indiana State University

ABSTRACT

Studies have shown that legumes can be an effective fat replacer in baked goods. However, little research has been conducted addressing black beans as a fat replacer in brownies. The purpose of this study was to determine the overall acceptability, palatability, and nutrient content of brownies made using black bean puree as a replacement for shortening. Using black beans as fat replacers in baked goods reduces total calories and fat content yielding a more nutritionally acceptable product. Today's obesity epidemic justifies exploring lower calorie options for baked products. Black beans were chosen due to their dark color which will unlikely alter the color of the brownies. Black beans were used to replace 30%, 60%, and 90% of the shortening by weight in a control brownie formula. One hundred sixty seven untrained students from Indiana State University evaluated the product using a 9-point hedonic scale. One-way ANOVA revealed significant differences in appearance, odor, mouthfeel, taste, and total score when replacing shortening with black beans ($p<0.05$). For all tested sensory characteristics, Bonferroni post hoc testing indicated that 30% fat replacement was not significantly different from the control. Also, 30% fat replacement compared with the control showed a reduction in 12 calories and 1.52g fat per 1.15 ounce serving. Using an acceptability level of 20 for total score, the control, 30, 60, and 90% fat replacement were rated as acceptable. This study showed that pureed black beans can replace as much as 90% of the fat (by weight) in brownies, while yielding an acceptable and more nutritious product. However, overall acceptability, determined by total score, was lower in brownies with higher concentrations of fat replacement.

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CHAPTER 1

INTRODUCTION

Justification

Overweight and obesity due to energy imbalanced between calories consumed and calories expended are the fifth leading risk for global deaths (World Health Organization [WHO], 2011b). An increased intake of energy-dense foods that are high in fat, salt and sugars, but low in vitamins, minerals and other micronutrients are the primary dietary causes of overweight and obesity worldwide. According to the World Health Organization (WHO, 2011a), other primary causes include a decrease in physical activity due to the increasingly sedentary nature of many forms of work, changing modes of transportation, and increasing urbanization. WHO (2011b) defines overweight and obesity as abnormal or excessive fat accumulation that may impair health, which is measured by body mass index (BMI). BMI, a simple index of weight-for-height commonly used to classify overweight and obesity in adults, is defined as a person's weight in kilograms divided by his/her height in meters squared (kg/m^2) (Center for Disease Control and Prevention [CDC], 2011).

Obesity is the second leading preventable cause of death in the United States. Obesity rates (33.8%) have risen to an all-time high of one out of every three adults (WHO, 2011b). According to Mokdad et al. (1999) the greatest increases in overweight and obesity occur in persons between the ages 18 and 29 years and in those with some college education. A survey administered by the American College Health Association (ACHA, 2011), found that 32.4% of college students are categorized as overweight or obese.

Diet recommendations to prevent chronic diseases such as overweight and obesity are designed to achieve energy balance and a healthy weight. They also include limiting energy intake from total fats, while decreasing saturated and trans fat consumption. Furthermore, an increase of the consumption of fruits, vegetables, legumes, whole grains and nuts is recommended, while added sugars and salts are not advised (WHO, 2011a).

There are many different fat replacers that can be used in baking. However, few fat replacers yield a comparable result to non-modified foods while reducing calories and increasing nutritional value. Legumes have been shown as effective fat replacers in baked products that decrease fat and increase nutritional value (Rankin & Bingham, 2000). Chocolate brownies substituted with black bean puree for shortening may be a good choice for college students.

United States Department of Agriculture (USDA, 2011), states that black beans have a high carbohydrate (62.36%) content which gives the potential for being a successful fat replacer. Black beans are low in fat (1.41%), and high in protein (21.60%), dietary fiber (15.5%), B vitamins, zinc, potassium, magnesium, calcium, and iron (USDA, 2011). Also, they are an inexpensive, readily available food. An additional benefit is that dietary fat absorption is reduced in the presence of considerable dietary fiber. According to Rankin and Bingham (2000), legumes may be used as a fat replacer in baked products.

Statement of the Problem

The objectives of this study are to 1) determine the palatability and overall acceptability of chocolate brownies prepared using pureed black beans as a replacement for 30, 60, and 90% of shortening, and 2) compare their sensory attributes with those of brownies made with a traditional amount of 100% shortening. Black beans were used specifically because their dark color would be unlikely to affect the color of the brownies.

Research Questions & Hypothesis

General Statement of the Problem

Do chocolate brownies made with black bean puree as a fat replacer at levels of 30, 60, and 90% have acceptable sensory characteristics when compared with traditional chocolate brownies prepared without fat replacement?

Hypothesis

Chocolate brownies prepared with 30, 60 and 90% black bean puree fat replacement will yield a baked product with acceptable sensory attributes when compared with a traditional chocolate brownie prepared with shortening.

Null Hypothesis

Chocolate brownies prepared with 30, 60 and 90% black bean puree fat replacement will yield a baked product without acceptable sensory attributes when compared with a traditional chocolate brownie prepared with shortening.

Limitations

The following factors are considered possible limitations to the current study:

1. The temperature and heat distribution in the ovens used to bake the samples.
2. The time brownies were baked to achieve doneness.
3. The freshness of the brownies at each tasting session.
4. The overall likability of the original brownie recipe.
5. The accuracy and reliability of the sensory evaluation methods.

6. The order in which brownies were tasted.
7. The consistency of the samples given to the panelists based on end or center pieces.
8. The untrained panelists may not have taken this study seriously.
9. The individual preferences of each panelist for brownie characteristics.

Delimitations

This study was delimited to college students enrolled at Indiana State University in Terre Haute, Indiana. To be included in the study, participants were to be enrolled in AHS 111 – Personal Health Science and Wellness class in which the professor agreed to allow students to partake in analysis. Students with food allergies were excluded from the study. The data were collected during the fall semester of 2012. Sensory analysis of brownies was available during hosted sessions only with guided instruction.

Assumptions

It was assumed that all participants could read and understand instructions and survey materials and that they responded in an open and honest manner. Also, it was assumed that all participants took the analysis seriously and were observant and thoughtful towards their responses.

Definition of Terms

Ester: Organic compound having a carbonyl-oxygen-carbon system, present in fruits and responsible for characteristic flavors and aromas (Murano, 2003).

Fat Mimetic: Substances that imitate organoleptic or physical properties of triglycerides but which cannot replace fat on a one-to-one basis (Institute of Food Technologist [IFT], 1998).

Fat Replacer: An ingredient that can be used in food to provide some or all of the functions of fat, while yielding fewer calories than fat (IFT, 1998).

Fat Substitute: Macromolecules that physically and chemically resemble triglycerides, or fats and oils, and can theoretically replace the fat in foods on a weight-to-weight basis (IFT, 1998).

Flavor: Overall impression combining taste, odor, mouthfeel factors, and trigeminal perception (Murano, 2003).

Hedonic Test: Relating to pleasure, consumers are tested for their preferences rather than their evaluation of differences. They are often provided a form to record their likes or dislikes of a particular sample (Murano, 2003).

Hydrogenation: The forced addition of hydrogen atoms to the unsaturated bonds in an unsaturated fat (Murano, 2003).

Methylation: Adding a methyl group (CH_3).

Mouthfeel: The perceived sensation of food by the epithelial lining within the oral cavity, which includes tactile sensation as well as thermal response (Murano, 2003).

Odor: The sensation derived from food as interpreted through the olfaction (sense of smell or odor perception) mechanism (Murano, 2003).

Organoleptic: Perceived by a sense organ or capable of detecting a sensory stimulus (Murano, 2003).

Palatability: The level of acceptable or agreeable taste, mouthfeel, texture, etc., to the palate (Murano, 2003).

Pasteurization: A food preservation process that heats liquids to 160°F for 15 seconds, or 143°F for 30 minutes, to kill bacteria, yeasts, and molds (Murano, 2003).

Taste: The sensation derived from food as interpreted through the tongue-to-brain sensory system (Murano, 2003).

Transesterification: A reaction between an ester of one alcohol and a second alcohol to form an ester of the second alcohol and an alcohol from the original ester, as that of methyl acetate and ethyl alcohol to form ethyl acetate and methyl alcohol; interesterification (Murano, 2003).

Triacylglycerols or triglycerides: Esters of glycerol and three fatty acids (Murano, 2003).

CHAPTER 2

REVIEW OF RELATED LITERATURE

Overweight and Obesity

The National Institutes of Health (National Institute of Health [NIH], 2000) definition of obesity is “a complex, multifactorial disease that develops from the interaction between genotype and the environment; it involves the integration of social, behavioral, cultural, physiological, metabolic, and genetic factors (p. 5).” According to WHO (2011), a BMI of 25 or higher is overweight and a BMI of 30 or higher is obese. Other methods of defining obesity used by the Centers for Disease Control and Prevention (CDC, 2010) include body fat percent, waist-to-hip ratios, and techniques such as ultrasound, computed tomography, and magnetic resonance imaging. According to NIH (2000), the most important measurements when assessing body fat are BMI and waist circumference. BMI can have restrictions when measuring persons (e.g., older adults) who have a high amount of muscle or who have lost an abundant amount of muscle mass (NIH, 2000). Overweight and obesity have a strong association with balancing intake of calories with exhumed energy through diet and exercise (WHO, 2011).

According to WWEIA/NHANES data from 2007-2008, the overall prevalence of overweight and obesity for adults was 68% (National Heart Lung and Blood Institute, 2011). The greatest increases in overweight and obesity are in persons between the ages 18 and 29 years, and those with some college education (Mokdad et al., 1999). According to the National College

Assessment, Spring 2011, conducted by the American College Health Association (ACHA, 2011), 32.4% of college students are categorized as overweight or obese. A recent study (Racette, 2005) has also shown that within the first two years of college, 50%-70% of students gained weight, contributing to the large obese population. Other studies (Vella-Zarb & Elgar, 2009; Holm-Denoma, Joiner, Vohs & Heatherton, 2008) have found that on average, college students gain between 3.5 and 4.0 lbs between their freshman and senior years of college. Still another study (Gropper et al, 2009) consisting of 240 students found that two thirds of freshman gained weight during their first year of college with one third gaining more than 5 lb.

Overweight and obesity acquired at early ages can lead to future consequences including, but not limited to, an increase in the risk for developing: coronary heart disease, type 2 diabetes mellitus, cancers (endometrial, breast, and colon), hypertension, dyslipidemia, stroke, liver and gallbladder disease, sleep apnea, respiratory problems, osteoarthritis, and gynecological problems (NIH, 1998). A higher body weight is also associated with an increase in mortality from all causes. Other consequences that obese individuals may experience are social stigmatization and discrimination (NIH, 2000).

The rise of overweight and obesity is linked to 1) an increased intake of energy-dense foods that are high in fat, salt and sugars but low in vitamins, minerals and other micronutrients and, 2) decrease in physical activity caused by the increasingly sedentary nature of many forms of work, changing transportation, and increasing urbanization. These changes in dietary and physical activity patterns are often result of environmental and societal changes associated with development and lack of supportive policies in sectors such as health, agriculture, transport, urban planning, environment, food processing, distribution, marketing and education (WHO, 2011). A survey conducted by ACHA (2011) showed that 58% of students only eat 1-2 servings of fruits and vegetables per day and only 6.2% of students eat 5 or more servings per day. Additionally, 38.5% of students do not do any vigorous-intensity cardio or aerobic exercise for at least 20 minutes any day of the week (ACHA, 2011).

In order to prevent overweight and obesity, WHO (2011) recommends a diet that limits energy intake from total fats and emphasizes the consumption of fruits, vegetables, legumes, whole grains, and nuts. They also recommend limiting the intake of sugars and engaging in regular physical activity to achieve energy balance and maintain a healthy weight (WHO, 2011). Fat replacement in brownies using black beans may be a successful ingredient to aid in meeting these dietary recommendations.

Standards for Fat Replacers

Fat replacers are defined as ingredients that can be used in food to provide some or all of the functions of fat, while yielding fewer calories than fat. It is necessary that fat replacers be able to mimic all or some of the functional properties of fat in a fat-modified food. Fat functions include: flavor, calories, food texture, satiety, plasticity, structure, stability, and quality in many foods. In baking, fats contribute to tenderness, aeration, flavor compounds, color compounds, and the mouthfeel (Murano, 2003). The Institute of Food Technologists (IFT, 1998) stated that fat also contributes to physiological benefits because it carries fat soluble vitamins, essential fatty acids, precursors for prostaglandins, and is a carrier for lipophilic drugs. Additionally, fat is the most concentrated source of energy in the diet, providing 9 kcal/g compared to 4 kcal/g for proteins and carbohydrates (IFT, 1998). A large majority of consumers enjoy the taste, texture, and aroma that fat gives to foods. The use of a fat replacer in which consumers do not have to sacrifice these traits is essential.

Research (Calorie Control, 2011) has found that people who consume low-fat foods, that meet the American Dietetic Association (ADA) recommendations of 30% or less of the overall diet, have a more varied and nutritious diet, and show, on average, have a higher intake of vitamin A, carotene, folate, calcium, and iron compared to those who did not consume low fat foods. Fat replacers can also benefit in that they help to reduce fat, saturated fat, and cholesterol, a recommendation by the ADA in the Dietary Guidelines for Americans (USDA & U. S Department of Health and Human Services, 2010). People utilizing fat replacers in their recipes should ensure that the fat replacer does not only lower the amount of fat in the product, but that it also lowers the amount of calories the product will yield. By reduction of fat in the diet by 10-percent, one can reduce the amount of energy intake by 238 kilocalories per day (ADA, 2005).

In addition to replacing fat in baked goods, fat replacers are intended to emulsify, provide cohesiveness, tenderize, carry flavor, replace shortening, prevent stalling, prevent starch retrogradation, condition dough, retain moisture, and texturize (Swanson, 2003). For these purposes, the use of a lipid-based, carbohydrate-based, or protein-based fat replacer may be appropriate.

Types of Fat Replacers

Fat Mimetics

Fat mimetics are substances that imitate organoleptic or physical properties of triglycerides but which cannot replace fat on a one-to-one basis. They are compounds that help to replace the mouthfeel of fats by contributing a greater viscosity to the liquid phase in the mouth (Swanson, 2003). These are often carbohydrate or protein based fat replacers that are frequently chemically modified to mimic the function of fat. In most cases, successful incorporation of lipophilic flavors when using fat mimetics requires the use of an emulsifier. These are not suitable for frying because they bind to water and denature at high temperatures but are typically better used in baked products (IFT, 1998).

Protein-based Fat Replacers

Protein-based fat mimetics are typically acceptable for use in dairy products, salad dressings, frozen desserts and table spreads (Murano, 2003). They are not an acceptable fat replacer for oils or foods that need to be fried because at high temperatures the protein will denature which results in losing the creamy texture. These will have a nutritional value of 4 kcal/g since they are absorbed in the body as a protein. Protein-based fat mimetics are used in cooking processes such as baking, retorting, and ultra-high temperature processing. These mimetics are often produced from egg, milk, whey, soy or wheat proteins by microparticulation (a process which involves heating proteins to produce a gel structure). If processed correctly, they are perceived to have similar mouth feel (creamy, smooth) and taste as perceived in fat (Lucca & Tepper, 1994).

An example of a protein-based fat mimetics is Simplesse® which is made by microparticulation of whey protein concentrate through homogenization, pasteurization, and dehydration processes (Cheung, Gomes, Ramsden, & Roberts, 2002). It is typically used in frozen dessert products but can also be used in yogurt, soft cheeses, cheese spreads, sour cream, dips, frostings, sauces, mayonnaise, salad dressings, and baked goods. Simplesse® provides body, texture, and mouth feel by contributing to creaminess, viscosity, and opacity of food (O' Connor & O' Brien, 2002).

Carbohydrate-based Fat Replacers

Carbohydrate-based fat mimetics ingredients are polysaccharides and have a variety of uses that can fall into the sub-category of: maltodextrins or dextrins, polydextrose, cellulose derivatives, starch derivatives, and oat flour derivatives. They thicken foods by adding bulk. These function as a fat replacer by stabilizing water in the food product in a gel-like matrix. The gel-like matrix creates an increased viscosity and body as well as a creamy mouth feel that reflects fat properties. Carbohydrate-based mimetics are not suitable for frying applications because of the high water activity. The high water activity also contributes to an increase in potential microbial growth which would reduce shelf life. As a result, they are good for applications such as baked goods, candy, dairy products, salad dressings, processed meats, dips, cheese, chocolates, chips, and ice cream (Lucca & Tepper, 1994; Murano, 2003).

Gums are a carbohydrate-based fat mimetic that provide thickening and sometimes gel formation that are often times freeze-thaw, heat, and acid stable depending on the particular gum. They are often extracted from beans, sea vegetables, or other sources and are used in dairy products, salad dressings, soups, sauces, ice cream, icings, glazes, and baked foods. Examples of gums include: xanthan, guar, locust bean, gum arabic, carrageenan, and pectins (Murano, 2003). Gums can be used on their own or in addition to other fat replacers to increase viscosity and act as stabilizers and gelling agents (Lucca & Tepper, 1994; O' Connor & O' Brien, 2002; IFT, 1998).

Maltodextrins and dextrins are categorized as generally recognized as safe (GRAS). They are non-sweet starch hydrolysates that have a dextrose equivalence and are usually produced by partial hydrolysis of corn or potato starch (IFT, 1998). They increase viscosity and contribute to mouth feel and body in a product by providing a flavor closely resembling that of butter (Murano, 2003). They are typically derived from products such as oat, rice, corn, wheat, or tapioca and are used in products such as table spreads, margarine, imitation sour cream, salad dressings, baked goods, frostings, fillings, sauces, processed meat and frozen dessert (Domagala, Sady, Grega, & Bonczar, 2005; Crehan, Hughes, Troy, & Buckley, 2000). They function as a fat replacer by building solids and viscosity while binding to control water and contributing to a smooth mouthfeel. . An aqueous solution of 20-30% is considered suitable for a fat mimetic and can reduce calories by as much as 8 kcal/g (Lucca & Tepper, 1994; O' Connor & O' Brien, 2002).

Polydextrose is a randomly bonded polymer of glucose, sorbitol, and citric acid and is only partially metabolized in the body which allows it to only contribute 1 kcal/g. Only 50% of the ingested portion of polydextrose is metabolized by the body causing the remaining amount to be excreted undigested. The main use for polydextrose is as a bulking agent, but it is also used in baked goods, frozen dairy desserts, salad dressings, puddings, and frostings (Martínez-Cervera, Sanz, Salvador, & Fiszman, 2012; Auerbach, Craig, Howlett, & Hayes, 2007; Kocer, Hicsasmaz, Bayindirli, & Katnas, 2007). A side effect that can sometimes occur when consuming polydextrose is that it can have a laxative effect in larger quantities (Lucca & Tepper, 1994; O' Connor & O' Brien, 2002).

Cellulose is another carbohydrate-based fat mimetic that is used in combination with other hydrocolloids. Microcrystalline cellulose can mimic the body, mouth feel, and viscosity of fat in an aqueous system while contributing 0 kcal/g. These microcrystallines are not water-soluble but are dispersed in solution and held together by other ingredients such as gums. This makeup of gums and microcrystals creates a creamy mouth feel and body that reflects that of fat

(Lucca & Tepper, 1994; O' Connor & O' Brien, 2002; Primo-Martín et al., 2010; Karahan, Kart, Akoglu, & Cakmakc, 2011).

There are many different modified starches that are available in the market today. These can act as fat mimetics because they enhance creaminess and retain moisture in foods. Some examples are potato, maize, oat, rice, wheat, and tapioca starches. They work well in conditions that have high moisture content such as salad dressings, sauces, baked goods, frostings, and sausages. Starches do not perform well in a freeze/thaw or acidic environments. Also, they have a tendency to mask the flavor of foods in which they are incorporated. Starches are inexpensive and readily available as a fat mimetic (O' Connor & O' Brien, 2002).

Fat Substitutes

There are two different categories in which fat replacers fall: fat substitutes and fat mimetics. Fat substitutes are macromolecules that physically and chemically resemble triglycerides, or fats and oils, and can theoretically replace the fat in foods on a weight-to-weight basis (IFT, 1998). In most cases, fat substitutes are lipid- or fat-based fat replacers. These are also either chemically synthesized or derived from fats by enzymatic modification. Most of these substitutes are stable at cooking and frying temperatures. They can be less flavorful than fats and carry water soluble compounds instead of lipid soluble compounds. Fat substitutes are typically synthetic molecules which can be mixtures of sucrose esters formed by chemical transesterification of sucrose with six to eight fatty acids (IFT, 1998). The process of transesterification involves hydrolyzing and methylating fatty acids to form fatty acid methyl esters.

There are a wide variety of fat substitutes that have been developed and are commercially available as well as others that are still in the developmental, noncommercial phase. The best known sucrose fatty acid polyester is Olestra, which would be categorized under fat substitutes (Food and Drug Administration [FDA], 1996). Olestra® is a synthetic fat molecule that contains 6, 7, or 8 fatty acids and is produced by the Procter and Gamble Company of Cincinnati, OH. It is modified from a triglyceride fat molecule with its fatty acids attached to sucrose rather than glucose (Figure 1). This modification inhibits the body's ability to absorb it in the digestive tract by blocking digestive enzymes, which categorizes it as a non-caloric fat replacer (Murano, 2003). The mouth feel, appearance, flash point, heat stability, and oxidative stability of Olestra® resemble that of conventional fats. Also, Olestra® is suitable for deep fat frying or baking application with respect to its flavor-carrying ability. Olestra® was approved by the FDA in 1996 as a food additive with the ability to replace up to 100% of the fat in snack foods such as chips and crackers, as well as for frying savory snack foods. Its inability to be absorbed results in some complications (O' Connor & O' Brien, 2002) including gas, diarrhea, and abdominal cramping (Cheskin, Miday, Zorich, & Filloon, 1998). The FDA (1996) requires any product containing Olestra to have a warning on the label that reads, "This product contains olestra. Olestra may cause abdominal cramping and loose stools. Olestra inhibits the absorption of some vitamins and other nutrients. Vitamins A, D, E, and K have been added" (FDA, 1996, p. 49). The FDA (1996) concluded that, based on the available data, Olestra is not toxic, genotoxic, carcinogenic, or teratogenic. In general, consumers must weigh the benefits with the side effects to decide if a product containing Olestra will be a good fit for them.

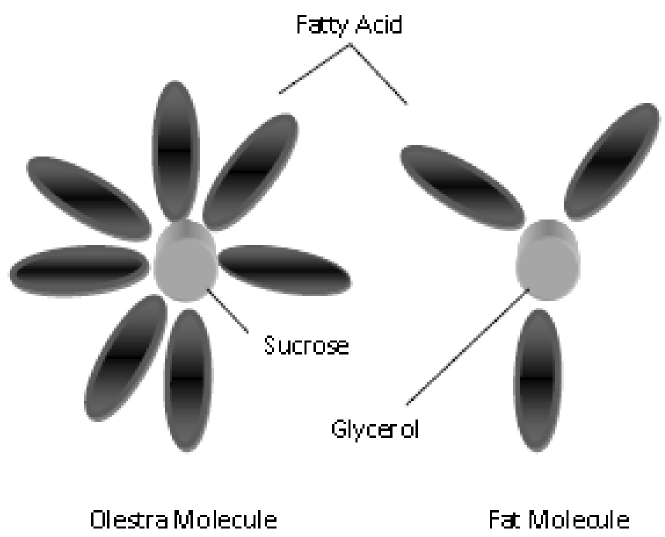

Figure 1. A representation of Olestra Molecule (Adapted from Murano, 2003).

Another fat substitute that is classified as a structured lipid and is made of short and long chain fatty acids is Salatrim. The short and long chain triglycerides are randomly attached to a glycerol. The amounts of short and long chain fatty acids influence the functional properties of the product, specifically hardness (Sorensen, et al., 2008). Common applications for Salatrim include, chocolate flavored coatings, fillings for confectionery and baked goods, savory dressings, dips, and sauces, and dairy products, including frozen dairy desserts, cheese, and sour cream. In one study (Sorensen, et al., 2008) it was found that Salatrim increased fullness and decreased hunger more than a regular fat meal. Its caloric value is similar to that of Caprenin which contributes 5 kcal/g (O' Connor & O' Brien, 2002; Sorensen et al., 2008).

Caprenin (caprocaprylobehenic triacylglycerol) is also a popular fat substitute which is classified as a structured lipid. Caprenin contains short- and medium-chain fatty acids and is produced by the Procter and Gamble Company (Murano, 2003). Caprenin, which consists of caprylic, capric, and behenic fatty acids attached to a glycerol, has 5 kcal/g compared to the 9 kcal/g that fats contribute. It is used for confections and candies because of its cocoa butter like properties and because it is solid at room temperature (O' Connor & O' Brien, 2002; Wardlaw et al., 1995; Webb, Wood, Bertram, & Fortier, 1993).

Although there are several other fat substitutes that have been patented, they are still undergoing investigation to achieve regulatory approval. These include but are not limited to: dialkyl dihexadecylmalonate and esterified propoxylated gylcerols (O' Connor & O' Brien, 2002).

Legumes

Legumes are defined as dry beans categorized as a large family of plants which are distinguished by their seed-bearing pods. Common kinds of legumes include black, pinto, navy, lima, fava, and kidney beans, as well as lentils and chickpeas which are known scientifically as *Phaselous vulgaris*, or common bean. Legumes (other than soy and peanuts) originated in parts of Central and South America and were introduced to Europe in the 15th century by Spanish explorers. Now, legumes are grown in many countries worldwide including India, Brazil, China, Mexico, Indonesia, and the United States and in countries in Central and South America. They are an important economical crop in North America because their production and export has increased significantly in recent years (Anton, Ross, Beta, Fulcher, & Arntfield, 2008).

Legumes are a high in protein, complex carbohydrates, and fiber; and are low in saturated fat. Some recent studies (Kushi, Meyer, & Jacobs, 1999; Anderson, Smith, & Gustafoson, 1994; Messina, 1999; Geil & Anderson, 1994) have established the health benefits of legumes. Some of the potential health benefits that legumes can have include reducing the risk of cancer, heart disease, and osteoporosis as well as lowering blood cholesterol and helping in managing diabetes mellitus. One study (Bazzano & Ogden, 2001) showed that there is a significant inverse relationship between legume intake and risk of coronary heart disease (CHD). Legume intake may play an important part in diet therapy to prevent CHD. They can also help relieve menopausal symptoms due to their high content of isoflavones (Messina, 1999). More research is needed to determine the actual effect that legumes have on prevention and treatment of chronic disease.

In three different studies (Adair, Knight, & Gates, 2001; Szafranski, Allen & Whittington, 2005; Rankin & Bingham, 2000) evaluating the sensory results of substituting legumes for fat in a baked product, it was shown that using legumes for a substitution of 25% of the fat would receive similar sensory score as the control product that had no fat replacement (Rankin & Bingham, 2000). Areas that were tested include appearance, color, flavor, texture and overall acceptability (Adair et al., 2001). In one study (Szafranski et al, 2005) where cannellini beans were substituted for shortening in brownies, it was found that the sensory characteristics were not significantly different when comparing the control brownies (with no fat substitution) with the 50% cannellini bean substitution brownie. Using legumes as fat replacers which resembles sensory characteristics of fats can cost up to 80% less than shortening (Sandlin, Finely, & Zheng, 2010). They are good sources of fiber, plant sterols, beneficial oligosaccharides, antioxidants, lignans, phenolic acids, phytoestrogens and other phytochemicals, as well as a variety of vitamins and minerals (Brandstetter, 1999).

CHAPTER 3

METHODOLOGY AND PROCEDURES

Four variations of brownies made with black beans were analyzed and ranked on a 9-point hedonic scale based on six sensory characteristics. Chocolate brownies that were analyzed included a control (0% shortening replacement), 30, 60 and 90% shortening replacement with black bean puree. Compositions of the four brownie samples are shown in Table 1.

Table 1 Chocolate Brownie Formulas (USDA, 1998).

Variable	Control	30%	60%	90%
Ingredient				
Shortening	255.2 g	178.6 g	102.1 g	25.5 g
Black Bean Puree	0 g	76.5 g	153.1 g	229.6 g
Sugar	737.1 g	737.1 g	737.1 g	737.1 g
Salt	7.1 g	7.1 g	7.1 g	7.1 g
Vanilla	7.1 g	7.1 g	7.1 g	7.1 g
Fresh, Large Eggs	7	7	7	7
Enriched all-purpose flour	425.2 g	425.2 g	425.2 g	425.2 g
Cocoa	170.8 g	170.8 g	170.8 g	170.8 g
Baking Powder	14.2 g	14.2 g	14.2 g	14.2 g

Formulas and Procedures

The formulation of the black bean brownies was adapted from the USDA (2011) website (http://www.fns.usda.gov/tn/Resources/all_numerical.pdf). The original recipe was used as the control without fat replacement then altered by percentage to accommodate black bean puree as a fat replacer at three different concentrations. The recipe was originally expressed in ounces but was converted into grams to be more accurate as well as adhere to international metric system requirement (Technology, 2006).

Procedure for Preparing Control and Variations

The brownies were prepared the Tuesday afternoon before the sensory evaluations which took place the following Wednesday, Thursday, and Friday in Applied Health Sciences 111 classes. All ingredients, except the eggs, were held at room temperature until use. Eggs were held in the refrigerator. For preparation of the brownies, all ingredients were gathered and the oven was preheated to 350° F. To prepare the black bean puree, canned black beans were strained of the liquid in the sink and rinsed twice to remove excess sodium. To begin the batter preparation, shortening and/or black bean puree were creamed with the sugar, salt, and vanilla in a mixer for 2 minutes on medium speed. Then the eggs were added and beaten for 3 minutes on medium speed. The flour, cocoa, and baking powder was then added and mixed at medium speed until completely incorporated. Batter was then spread into 2 disposable aluminum pans (11-3/4"L × 9-3/8"W × 2-5/16"H) which had been previously lightly coated with pan release spray and labeled with the appropriate three-digit sample number representing the brownies proportions(Table 3). Brownies were then baked in a conventional oven at 350° F for 20-30 minutes. Each pan of brownies was tested with a tooth pick to reassure that they were cooked through before removing. The tooth pick came out clean when done. Each pan of brownies was left out to cool at room temperature and then cut into 100 pieces and placed in cups on tables labeled with their corresponding three-digit numbers. Water was provided to the panelists to cleanse palates in-between tasting each brownie. Brownies were stored at room temperature in plastic wrap covered containers until the tasting period.

Nutritional Information

Nutritional information has been gathered about each chocolate brownie product through the USDA (2011) database. Each ingredient was entered separately into the database to obtain its nutritional makeup. After gathering the nutritional makeup of each individual ingredient, the nutrients were added together to get the total content for that brownie. This step was repeated with each black bean brownie formula used for comparison (Table 2).

Table 2 Nutritional Information for Chocolate Brownies (USDA, 2011).

Variable	Control	30%	60%	90%
Nutrient Content				
Calories	152.00	140.00	128.00	117.00
Protein (g)	2.43	2.56	2.70	2.83
Carbohydrate (g)	23.35	23.72	24.08	24.44
Total Fat (g)	6.98	5.46	3.99	2.42
Cholesterol (mg)	26.04	26.04	26.04	26.04
Vitamin A (IU)	37.80	37.90	38.00	38.10
Iron (mg)	1.03	1.06	1.10	1.13
Calcium (mg)	26.58	26.98	27.36	27.79
Sodium (mg)	96.58	96.54	96.50	96.46
Dietary Fiber (g)	1.36	1.50	1.63	1.77

Note: Sodium content may be less than indicated amount due to canned black beans being rinsed prior to use.

After the nutritional information was calculated, a 2-tailed t-Test was done for the combined samples of the control and 30% brownies as well as the combined samples of the 60% and 90% brownies, using the Statistical Package for the Social Sciences Software PASW Student Version 18 (SPSS) (Norusis, 2012). Results of this test were not significant (p=0.1) possibly due to the fact that the values were only estimates from the USDA nutrient database. It is possible that the results would have been significant (p<0.5) between the two groups (control and 30% brownies; and 60% and 90% brownies) if exact values with more precise means and standard deviations were determined in the lab.

Overall, the total calories and fat per serving decreased as the percentage of black bean puree increased. Additionally, the nutritional value in protein, vitamin A, iron, calcium, and dietary fiber all increased with the percentage of black bean puree. Nutritionally, the brownie with 90% black bean replacement is the healthiest option of the brownies.

Testing

After obtaining approval from the Institutional Review Board at Indiana State University (Appendix A), overall acceptability and palatability of the control and three variations of brownies were evaluated by 167 untrained panelists (students enrolled in AHS 111 during the fall 2012 semester) at Indiana State University during their class period. The brownies were tasted by five different sets of classes which took place the Wednesday, Thursday, and Friday after the brownies were made (Tuesday). To determine whether the freshness of the brownies had any effect on the sensory properties of the brownie, score sheets were labeled one through five to represent the time that they were tasted. Tasting one took place at 1pm on Wednesday, two at 2pm Wednesday, three at 9:30am on Thursday, four at 2:00pm on Thursday, and five at 2:00 on Friday. Tasting periods took 15-20 minutes each depending on how long the panelists spent analyzing the brownies. During the tasting periods, panelists evaluated the brownies blindly by using a three-digit number. Panelists were asked to taste the brownies in random order to minimize positional error (Charley & Weaver, 1998). Panelists were also asked to carefully match the three-digit number of the brownie with the corresponding column on the scoring sheet. Three-digit numbers were used to eliminate biases that could potentially be associated with certain numbers (Charley &Weaver, 1998). The scoring sheet allowed panelists to rank each brownie using a 1-9 scale relating to key characteristics such as appearance, odor, mouthfeel, taste and total score. The total score represents each sensory characteristic added together. A one-through-nine point hedonic scale has also been used in similar studies to show acceptability and palatability of similar products (Nasser, Dine, & Olabi, 2009; Cordonnier & Delwiche, 2007; Greene, Bratka, Drake & Sanders, 2005; Rankin & Bingham, 2000; Adair et al., 2001; Szafranski et al., 2005). A rating scale of 1-9 (explained in score card shown in Table 3) was used. Panelists were asked to remain silent during the tastings and not to discuss opinions or ratings about the brownies with other panelists. Based on the nine-point hedonic scale, an acceptability level has been generated using a score of five or higher (neither like nor dislike) for each individual sensory characteristic. For total score, an acceptability level of twenty or higher (average of neither like nor dislike) has been generated. The acceptability levels represent the point at which the product is liked enough to be used on average in everyday baking without yielding a product that is disliked. Additionally, the higher the value of the acceptability level the more the product is liked for either the individual characteristic or the overall liking (total score).

Table 3 Chocolate Brownies Score Card.

9-Like Extremely
8- Like Very Much
7-Like Moderately
6-Like Slightly
5-Neither Like nor Dislike
4- Dislike Slightly
3-Dislike Moderately
2-Dislike Very Much
1-Dislike Extremely

Brownie sample identification code number*

Characteristics	***472***	***698***	***327***	***763***
Appearance				
Odor (Aroma)				
Mouthfeel (Texture)				
Taste (Flavor)				
Total				

*472: 60%, 698: Control, 327: 90%, 763: 30%

Statistical Analysis

An analysis of variance (ANOVA) was used for data analysis to determine the differences in the means of the groups. Alpha level for statistical significance was set a priori at $p<0.05$. ANOVA was also used in similar studies to analyze results (Szafranski et al., 2005; Adair et al., 2001; Rankin & Bingham, 2000). This was followed by the Bonferonni multiple comparison post hoc test which compared specific pairs of means (Tables 5, 6, 7, 8, 9). Statistical analysis was executed with a PC computer by using the Statistical Package for the Social Sciences Software PASW Student Version 18 (SPSS) (Norusis, 2012).

CHAPTER 4

RESULTS AND DISCUSSION

Brownie Freshness

Effect of brownie freshness was measured since brownies were tasted in five different sessions which was based on when each class was available. Tastings were labeled one through five with one being the first and having the freshest brownies. There was no significant difference ($F=0.000$, $p>0.05$) in all brownie scores relating to the freshness of the brownies; therefore, no post hoc analysis was conducted.

Table 4 Analysis of Variance (ANOVA) for the Sensory Characteristics and Total Score of Chocolate Brownies Made with Different Levels of Black Bean Fat Replacement.

		Sum of Squares	df	Mean Square	F	Sig.
Freshness of Brownies	Between Groups	0.000	3	0.000	0.000	1.000
	Within Groups	1350.419	664	2.034		
	Total	1350.419	667			
Appearance	Between Groups	48.107	3	16.036	5.504	0.001*
	Within Groups	1919.950	659	2.913		
	Total	1968.057	662			
Odor (Aroma)	Between Groups	193.239	3	64.413	22.258	0.000*
	Within Groups	1918.707	663	2.894		
	Total	2111.946	666			
Mouthfeel (Texture)	Between Groups	471.539	3	157.180	37.165	0.000*
	Within Groups	2803.993	663	4.229		
	Total	3275.532	666			
Taste (Flavor)	Between Groups	670.234	3	223.411	54.567	0.000*
	Within Groups	2714.497	663	4.094		
	Total	3384.732	666			
Total Score	Between Groups	4555.849	3	1518.616	46.332	0.000*
	Within Groups	21600.097	659	32.777		
	Total	26155.946	662			

*Statistically Significant, $p<0.05$

Appearance

Analysis with One-way ANOVA (Table 4) indicated significant differences in appearance between fat replacement groups (F=5.504, $p<0.05$). Post hoc analysis (Table 5) showed a significant difference in the comparisons between the control and 90% groups (μ_d = 0.575, $p<0.05$) and between the 30% and 90% groups (μ_d=0.590, $p<0.05$). However, no significant differences were indicated between the control and the 30% groups (μ_d= -0.16, $p>0.05$), the control and 60% groups (μ_d= 0.478, $p>0.05$), the 30% and 60% groups (μ_d = 0.494, $p>0.05$), or the 60% and 90% groups (μ_d=0.096, $p>0.05$). This suggests that appearance does not differ in brownies at a fat replacement of up to 60%. Similar results were found in another study using legumes where appearance was not affected by percent of fat replacement (Szafranski et al., 2005). In another study using legumes as fat replacers, no significant difference was found at 25% fat replacement (Rankin & Bingham, 2000).

Table 5 Bonferroni Multiple Comparisons Post Hoc Analysis for Appearance

Fat Replacement	Fat Replacement	Mean Difference	Std. Error	Sig.
Control	30%	-0.016	0.188	1.000
Control	60%	0.478	0.188	0.066
Control	90%	0.575*	0.188	0.014
30%	60%	0.494	0.187	0.051
30%	90%	0.590*	0.187	0.010
60%	90%	0.096	0.187	1.000

*Statistically Significant, $p<0.05$

Odor (Aroma)

Analysis with one-way ANOVA (Table 4) indicated significant difference in odor between fat replacement groups (F=22.258, $p<0.05$). Post hoc analysis (Table 6) showed significant differences in the comparisons between the control and 60% groups ($\mu_d = 0.836$, $p<0.05$), control and 90% groups ($\mu_d = 1.447$, $p<0.05$), 30% and 90% groups ($\mu_d = 1.060$, $p<0.05$), and 60% and 90% groups $\mu_d = 0.611$, $p<0.05$) However, no significant differences were indicated between the control and 30% groups ($\mu_d = 0.387$, $p>0.05$), or the 30% and 60% groups ($\mu_d = 0.449$, $p>0.05$). This suggests that odor is not significantly different from the control at 30% black bean fat replacement.

Table 6 Bonferroni Multiple Comparisons Post Hoc Analysis for Odor (Aroma)

Fat Replacement	Fat Replacement	Mean Difference	Std. Error	Sig.
Control	30%	0.387	0.186	0.231
Control	60%	0.836*	0.186	0.000
Control	90%	1.447*	0.186	0.000
30%	60%	0.449	0.186	0.097
30%	90%	1.060*	0.186	0.000
60%	90%	0.611*	0.186	0.007

*Statistically Significant, $p<0.05$

Mouthfeel (Texture)

Analysis with One-way ANOVA (Table 4) indicated significant differences in mouthfeel between fat replacement groups (F=37.165, p<0.05). Post hoc analysis (Table 7) showed significant differences between control and 60% groups (μ_d = 1.787, p<0.05), control and 90% groups (μ_d = 1.721, p<0.05), 30% and 60% groups (μ_d = 1.635, p<0.05), and 30% and 90% groups (μ_d = 1.569, p<0.05). However, no significant differences were indicated between the control and 30% groups (μ_d = 0.152, p>0.05) or the 60% and 90% groups (μ_d = -0.066, p>0.05). This suggests that mouthfeel is not significantly different from the control at 30% black bean fat replacement. Similar results were found in a study using legumes as fat replacement where no significant differences were found until 75% fat replacement (Szafranski et al., 2005). Another study showed that at 25% fat replacement with legumes that there were no significant differences (Rankin & Bingham, 2000).

Table 7 Bonferroni Multiple Comparisons Post Hoc Analysis for Mouthfeel (Texture)

Fat Replacement	Fat Replacement	Mean Difference	Std. Error	Sig.
Control	30%	0.152	0.225	1.000
Control	60%	1.787*	0.225	0.000
Control	90%	1.721*	0.225	0.000
30%	60%	1.635*	0.225	0.000
30%	90%	1.569*	0.225	0.000
60%	90%	-0.066	0.225	1.000

*Statistically Significant, p<0.05

Taste (Flavor)

Analysis with one-way ANOVA (Table 4) indicated significant differences in taste between fat replacement groups (F=54.567, p<0.05). Post hoc analysis (Table 8) showed significant differences in the comparisons between the control and 60% groups (μ_d = 2.160, p<0.05), control and 90% groups (μ_d = 2.196, p<0.05), 30% and 60% groups (μ_d = 1.778,

p<0.05), and the 30% and 90% groups (μ_d = 1.814, p<0.05). However, no significant differences were indicated between the control and 30% groups (μ_d = 0.381, p>0.05) and the 60% and 90% groups (μ_d = 0.036, p>0.05). This suggests that taste is not significantly different from the control at 30% black bean fat replacement. Similar results were found in another study using legumes as fat replacement (Rankin & Bingham, 2000) where significant differences were found in the 50% and 75% bean brownies but not in the 25%. Another study showed no significant difference until 75% bean replacement (Szafranski et al., 2005).

Table 8 Bonferroni Multiple Comparisons Post Hoc Analysis for Taste (Flavor)

Fat Replacement	Fat Replacement	Mean Difference	Std. Error	Sig.
Control	30%	0.381	0.222	0.516
Control	60%	2.160*	0.222	0.000
Control	90%	2.196*	0.222	0.000
30%	60%	1.778*	0.221	0.000
30%	90%	1.814*	0.221	0.000
60%	90%	0.036	0.221	1.000

*Statistically Significant, p<0.05

Total Score

Analysis with One-way ANOVA (Table 4) indicated significant differences in total score between fat replacement groups (F=46.332, p<0.05). Post hoc analysis (Table 9) showed significant differences in the comparisons between the control and 60% groups (μ_d = 5.296, p<0.05), the control and 90% groups (μ_d = 6.000, p<0.05), the 30% and 60% groups (μ_d = 4.355, p<0.05), and the 30% and 90% groups (μ_d = 5.060, p<0.05). However, no significant differences were indicated between the control and 30% groups (μ_d = 0.940, p>0.05) or the 60% and 90% groups (μ_d = 0.705, p>0.05). This suggests that the total score of black bean brownies is not significantly different at 30% compared with the control chocolate brownie. A study using legumes found that significant differences occurred with as little of fat replacement as 25%

(Rankin & Bingham, 2000). Another study using legumes as fat replacement did not indicate significant differences between brownies until 75% (Szafranski et al., 2005).

Table 9 Bonferroni Multiple Comparisons Post Hoc Analysis for Total Score

Fat Replacement	Fat Replacement	Mean Difference	Std. Error	Sig.
Control	30%	0.940	0.629	0.814
Control	60%	5.296*	0.629	0.000
Control	90%	6.000*	0.629	0.000
30%	60%	4.355*	0.628	0.000
30%	90%	5.060*	0.628	0.000
60%	90%	0.705	0.628	1.000

*Statistically Significant, $p<0.05$

Acceptability Level

The control brownie was favored for appearance, odor, mouthfeel, taste, and total score. Brownies prepared with 30% fat replacement were disliked slightly more than the control brownie but not enough to show significance. On all measurements except appearance, the brownies with less or no black bean replacement are liked on average more than brownies with greater levels of black bean replacement. All four brownies would be considered acceptable for appearance and odor, using a minimum hedonic score of 5 (neither like nor dislike) as acceptable (Figures 2, 3). Using the same score for acceptability, the control and 30% brownies would be considered acceptable for mouthfeel and taste. Both the 60% and 90% brownies were not considered acceptable for mouthfeel and taste but were close candidates with means from 4.49 to 4.653 (Figures 4, 5). A hedonic score of a minimum of 20 was considered acceptable for total score and showed that all four brownies would be considered acceptable (Figure 6). Therefore, this study showed that it is possible to substitute up to 90% pureed black beans for fat in chocolate brownies and still yield an acceptable product. However, the control brownie was preferred by tasters over the black bean substituted brownies and as the percent of black bean fat replacement increase the total score decreased. These results were similar to those found in another legume fat replacement studies (Rankin & Bingham, 2000, Szafranski et al., 2005).

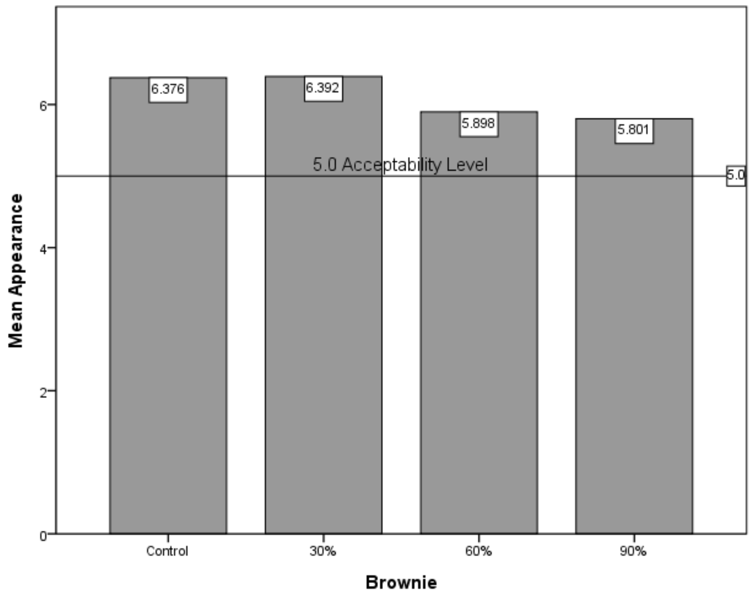

Figure 2. Comparison of Mean Scores for Appearance of Chocolate Brownies Made with Black Bean Puree Fat Replacement.

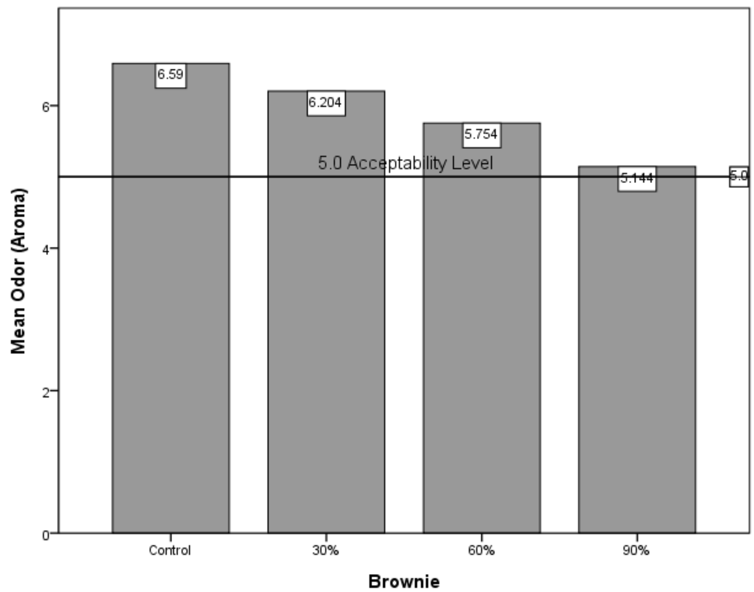

Figure 3. Comparison of Mean Scores for Odor of Chocolate Brownies Made with Black Bean Puree Fat Replacement.

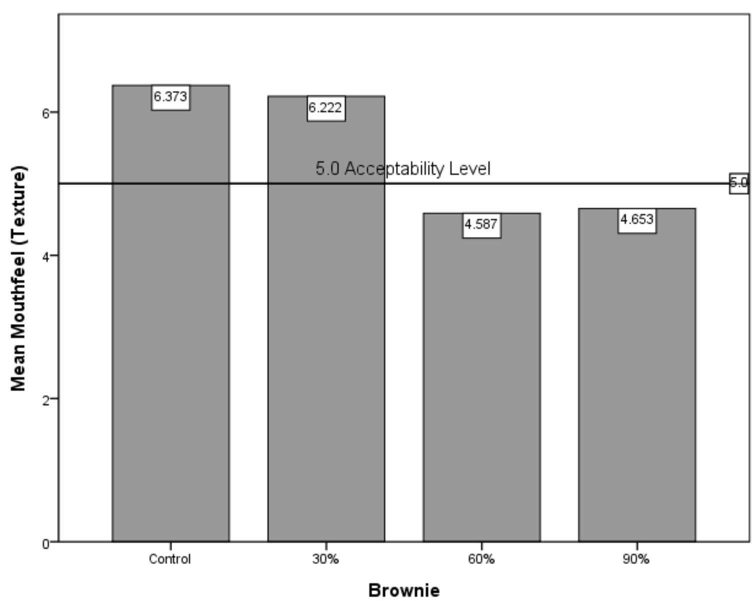

Figure 4. Comparison of Mean Scores for Mouthfeel of Chocolate Brownies Made with Black Bean Puree Fat Replacement.

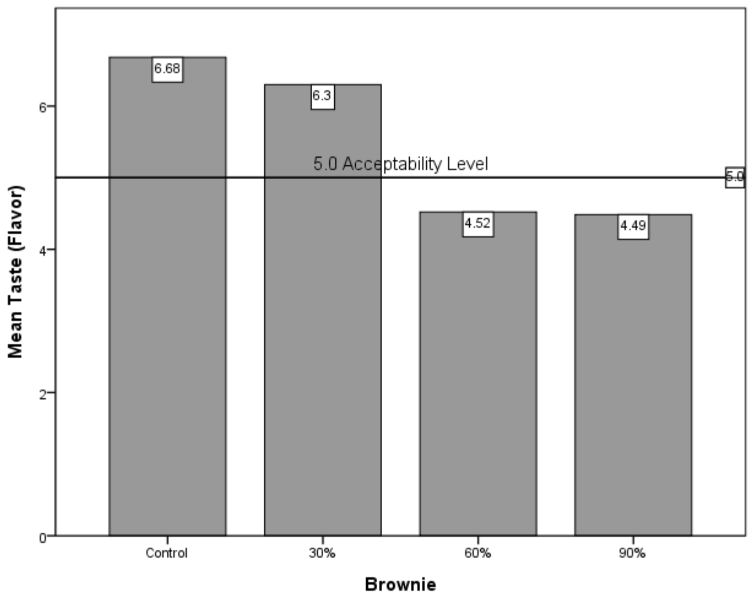

Figure 5. Comparison of Mean Scores for Taste of Chocolate Brownies Made with Black Bean Puree Fat Replacement.

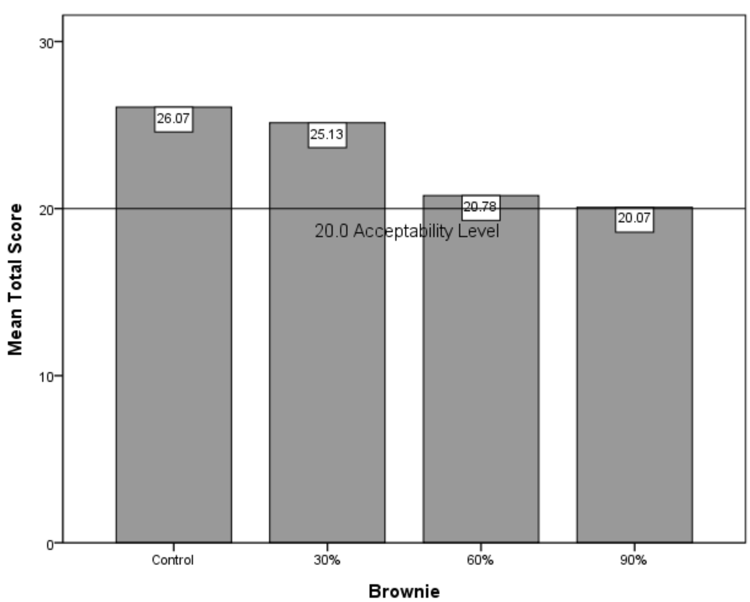

Figure 6. Comparison of Mean Scores for Total Score of Chocolate Brownies Made with Black Bean Puree Fat Replacement.

Discussion

Substituting pureed black beans for shortening also improved nutritional content. The greatest improvements were seen in the reduction of kilocalories and fat. A decrease of 12 kcal and 1.52g total fat were seen in the 30% black bean brownie compared with the control and a decrease of 24 kcal and 2.99g total fat were seen in the 60% black bean brownie compared with the control for a 1.15 ounce serving. The use of legumes as fat replacers in food products could possibly lead to a reduced saturated fat consumption recommended by the WHO (2011). Future studies are needed to determine the effects of substituting black beans for fat in other baked products.

CHAPTER 5

SUMMARY

The objective of this study was to determine the palatability and overall acceptability of chocolate brownies prepared using black beans as a fat replacer for shortening. Four variations of brownies were analyzed including a control (0%), 30, 60, and 90% fat replacement groups with black bean puree for shortening. All four brownie variations were then tested for appearance, odor, mouthfeel, and taste using a 9-point hedonic scale. The ratings scale consisted of 9 (like extremely), 8 (like very much), 7 (like moderately), 6 (like slightly), 5 (neither like nor dislike), 4 (dislike slightly), 3 (dislike moderately), 2 (dislike very much), 1 (dislike extremely).The score from all sensory characteristics was then added together to obtain a total acceptability score. The same untrained panelists evaluated all four brownies during a 20-min period which took place during one of five scheduled tasting sessions.

Statistical Analysis of Variance (ANOVA) followed by Bonferroni multiple comparison post hoc test was used to analyze the data obtained from the study. Statistical analysis was done using a PC computer by using the Statistical Package for the PASW Social Sciences Software Student Version 18 (SPSS) (Norusis, 2012).

Statistical analysis of data suggests that brownies made with 30% black bean fat replacement are not statistically different from brownies made with 100% shortening for all tested characteristics. However, brownies with 60% and 90% fat replacement showed significantly lower ratings than the brownies made with shortening for odor, taste, mouthfeel, and total score. Only 90% brownies showed a significantly lower score from the control for appearance.

Using acceptability mean score of five or higher, all four brownies would be considered acceptable for appearance and odor. Using the same score, the control and 30% brownies were considered acceptable for all characteristics. This suggests that black bean fat replacement would be effective and acceptable for brownies made with 30% black bean fat replacement. Using a mean acceptability score of 20 for total score, all four brownies would be considered acceptable.

Conclusions

Based on the findings of this study, it is concluded that black bean puree is acceptable at 30, 60 and 90% replacement for shortening. However, substituting a smaller concentration of black beans with shortening may be a viable option for fat replacement in brownies given that they yield a product that is easy to make (simply drain, rinse, and puree), have an improved nutritional content, and cost about the same (compared to shortening). Black bean puree should be considered as a viable option for fat replacement in brownies both at home and in the foodservice industry. Overall, these findings are consistent with the findings in similar studies. One study showed that brownies made with pureed cannellini beans as a fat replacer at 25% and 50% did not have a significant difference from the control brownie (0% fat replacement) (Szafranski et al., 2005). Cannellini beans achieving no significant difference at 50% may be due to the 10% difference in fat replacement between the two studies and the possibility that cannellini beans possess a milder taste due to the low presence of tannins, compared to black beans (Wang et al., 2010). Two other studies, one using white beans for replacement, the other using mungbean paste for replacement in cookies, showed that at the lower concentration of fat replacement (25%) there was not a significant difference from the control. However, at 50% and higher there was a significant difference (Adair, Knight, & Gates, 2001; Rankin & Bingham, 2000).

Recommendations

Further research is needed to determine the acceptability of brownies made with different beans as fat replacers. Additionally, further research is needed to determine the acceptability of different baked goods using black beans as fat replacement. Trained panelists may be more reliable than untrained panelists in the event that chocolate brownies made with black bean puree fat replacement were to go into commercial production. It may be achievable to divide the data by brownie taste and/or mouthfeel preferences (i.e. chewy, chocolaty, crunchy, etc.) by leaving a comment section at the bottom of the survey where panelists are to leave an explanation of why certain scores were given. Dividing the data based on panelist preferences may help to better understand the relationship of the given scores to the individual preferences. Lastly, it may be viable to require panelists not to eat for a period of time prior to the tasting to eliminate variation due to fullness. Another option would be to have a section at the bottom of the scorecard for each panelist to indicate their degree of fullness which would help to divide the data accordingly.

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