CONSUMER SENSORY CHARACTERISTICS OF BUTTER CAKE MADE FROM WHEAT AND RICE FLOURS

A Thesis

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DEDICATION

I would like to dedicate my research to my grandmother. Thank you for everything you have done for me. I will always treasure my memories of you. I wish you could have seen me graduate, but I think this is the next best thing.

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ABSTRACT

Rice is an important commodity in Louisiana and throughout the world. During the milling process, about 15% of rice kernels become broken. Louisiana produced approximately 2,011,000 hundred weights of broken rice kernels in 2002. Converting broken rice into rice-based products adds dollars back to broken rice. The market potential for rice in processed foods is huge. In the refrigerated and frozen baked foods category, it is approximately $14.3 billion; while in the baked snack foods and wholesale bakery foods category, it is approximately $31.4 billion. Approximately 1-2% of the United States population suffers from Celiac Spruce Disease, which is a result of the malabsorption of certain proteins in the diet, specifically gluten. Gluten can be found in almost all cereal grains, including wheat, rye, oat, and barley. Rice, however, does not contain gluten, which makes it an ideal food for individuals with this disease.

A butter cake product was formulated using predominantly rice flour. Consumer studies were performed to determine 1) attributes critical to product acceptance and purchase decision, 2) the optimal formulation of the butter cake product, and 3) whether or not consumers were able to correctly differentiate between butter cake samples made either from wheat, rice, or a mixture (50:50) of wheat and rice. Logistic regression analyses identified overall liking, taste and texture as attributes critical to overall acceptance and purchase decision. Predictive discriminant analysis also identified if overall liking, taste, moistness, and texture contribute significantly to overall differences among the three butter cake formulations. Superimposition of the optimal response surface areas of overall liking, taste and texture revealed that formulations containing 50-95% wheat, 0-50% rice and 0-40% pre-gelatinized rice flours would yield a product with acceptability scores greater than 6.0. Consumers were able to correctly discriminate between the different formulations of butter cake (100% rice flour, 50/50 wheat/rice flours) when compared

to the labeled control formulation containing 100% wheat. Consumers would be willing to compromise certain attributes in order to gain a potential health benefit from consuming this product, especially if they are not able to consume wheat products.

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

1.1 Gluten and Celiac Spruce Disease

Celiac Spruce Disease is a problem of malabsorption of certain proteins in the diet, mainly gluten. Roughly 1 to 2 percent of the US population suffers from this disease (Suszkiw, 2002). However, some feel that the occurrence of this condition is severely underestimated. A mere decade ago, this disease was considered by many to be an uncommon disorder (Schober *et al.*, 2003). New and better screening procedures have allowed for more diagnoses of this disease. In fact, it has been estimated that roughly 1 in 250 people in the United States are currently living with this disease (American Gastroenterological Association, 2001).

Gluten is composed of about 75-86% protein, while the other components are carbohydrates and lipids; however, these are held within the gluten-protein matrix (Bloksma and Bushuk, 1998). Also, gluten is made up of the protein fractions, glutenin and gliadin. Glutenin is a tough and rubbery mass upon hydration, while gliadin becomes a viscous, fluid mass. This is what allows gluten to exhibit both elastic and viscous properties in dough and lends to its properties of extensibility, resistance to stretch, mixing tolerance, and gas holding ability (Gallagher *et al.*, 2004).

Individuals with Celiac Spruce Disease have a lifelong intolerance to the gliadin fraction of wheat as well as the prolamins secalin (rye), hordeins (barley), and avidins (oats) (Murray, 1999). The primary method treatment of this disease is through the complete omission of foods containing gluten. Celiac Spruce Disease impairs intestinal absorption and can lead to severe malnutrition (Sanchez *et al.*, 2002). Celiac Spruce Disease affects the small intestine which, in turn, prevents in the absorption of several important nutrients including iron, folic acid, calcium and fat soluble vitamins (Gallagher *et al.*, 2004). The only way to ensure a life free of complications is to adhere strictly to a 100% gluten-free diet (Gallagher *et al.*, 2003).

The main structure forming protein in flour is gluten, and it is responsible for the elastic properties desired in high quality baked goods. Therefore, the removal of gluten results in a challenge because it is one of the main structural forming proteins in baking (Gallagher *et al.*, 2004). When gluten is removed from bakery products, it negates the quality desired. Therefore, the use of polymeric substances that mimic the viscoelastic properties of gluten must often be added to the product (Gallagher *et al.*, 2003). Most gluten-free products currently available in the market are of inferior quality to those containing gluten (Arendt *et al.*, 2002). Many types of gluten-free baked goods may exhibit both technological problems and poor sensory qualities because of their lack of this protein (Torres *et al.*, 1999).

In recent years, there has been an increased demand by health professionals and consumers for healthier food products. However, food companies have met this challenge with relatively limited success because consumers often view healthy food choices to be in direct conflict with enjoyable eating (Tuorila and Cardello, 2002). It is a challenge for both food scientists and bakers to develop gluten-free cereal based products. In fact, a limited number of publications exist on the formulation of such products. This reflects extraordinary challenges of preparing such products as well as the general lack of awareness of the number of people that require such products (Gallagher *et al.*, 2004). However, in recent years there has been an increase in research and development of gluten-free products. This research involves use of starches, dairy products, gums, hydrocolloids, and other non-gluten proteins in order to improve the texture and overall acceptability of these products (Gallagher *et al.*, 2004). This, in turn, has led to an increase in a number of gluten-free products available in supermarkets for consumers

(Gallagher *et al.*, 2004). Unfortunately, the quality of these products are often well below acceptable standards.

According to Turcsik (2004), the need for flours that are free of gluten (such as rice, tapioca, potato, soy, flax, etc.) is becoming progressively more popular in the mainstream supermarket, therefore offering new sales potential for food companies. In fact, an increasing number of food companies are developing alternatives to wheat flours because gluten intolerance is one of the largest growing segments of medical conditions linked to the diet (Turcsik, 2004).

Tuorila and Cardello (2002) pointed out that the undesirable off-taste/texture often imparted by health-improving ingredients often emphasizes the fact that consumers are willing to trade taste for health benefits. Likewise, it has been shown that health improving benefits are often capable of motivating consumers to increase in the overall liking of a product, which ultimately increases the purchase intent of consumers for a particular product (Kahkonen *et al.*, 1996).

1.2 Rice

Farmers in the United States consistently produce a dependable supply of some of the highest quality rice in the world. In fact, rice (*Oryza sativa*) is second only to wheat in the tonnage produced (Bean 1983). In 2003, the average national yield of rice was 6,645 pounds per acre. Also, according to the United States Department of Agriculture, the average price of the crop was between $7.00 and $7.50 per hundredweight (Figure 1); this is noteworthy because it increased from only $4.22 per hundredweight just one year earlier (Helton, 2004). Rice farmers were faced with extremely low farm prices in 2002, where cash rice prices had fallen dramatically to levels not seen in decades (Figure 2). However, in 2003, rice prices began steadily increasing for several reasons.

Table 1. Marketing Year U.S. Monthly Average Farm Prices

Year	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July
	Dollars per cwt											
1994-1995	6.87	6.82	6.52	6.63	6.60	6.83	6.74	6.67	6.75	6.87	7.06	7.19
1995-1996	7.77	8.01	8.84	9.21	9.45	9.36	9.19	9.20	9.35	9.73	9.77	9.81
1996-1997	10.10	10.00	9.66	9.41	9.82	9.95	10.10	10.20	10.30	10.20	9.90	10.00
1997-1998	9.94	9.92	10.00	9.82	9.77	9.57	9.75	9.67	9.40	9.38	9.58	9.58
1998-1999	9.01	9.42	9.31	9.02	9.10	9.09	9.02	8.93	8.49	8.21	8.25	8.26
1999-2000	6.91	6.17	5.91	5.96	6.01	5.98	5.82	5.64	5.75	5.62	5.69	5.59
2000-2001	5.72	5.53	5.57	5.72	5.69	5.86	5.72	5.66	5.68	5.40	5.14	5.32
2001-2002	5.01	4.67	4.39	4.25	4.29	4.30	4.16	3.99	3.94	3.98	3.92	3.81
2002-2003	3.72	3.94	3.69	3.70	4.13	4.29	4.03	4.14	4.33	4.58	5.04	5.09
2003-2004	5.27	6.13	6.44	6.99	7.25							

Source: USDA/NASS Agricultural Prices, United States Monthly Average Farm Prices and Marketings

Figure 1: U.S. Average Farm Prices of Rice (Coats, 2004)

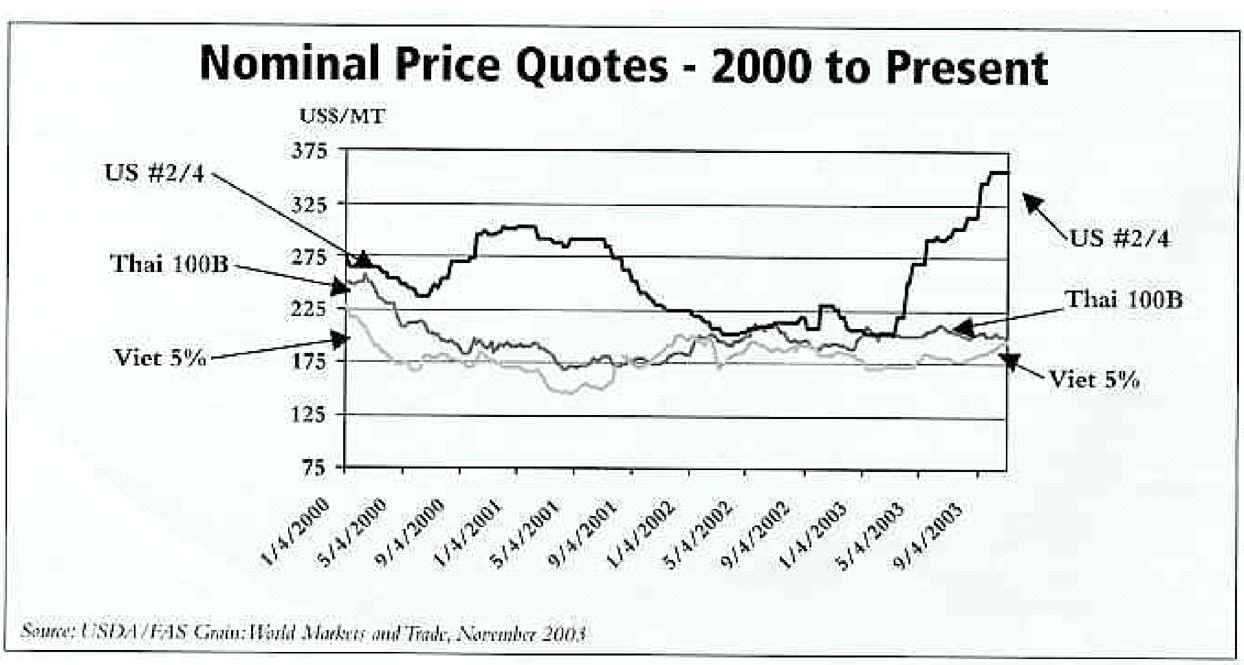


Figure 2: Nominal Rice Prices (Coats, 2004)

First, United States rice producers are capitalizing on improving the global economy. Second, rice supplies in the western hemisphere were enhanced by the negative impact of global weather occurrences. Finally, rough rice exports were in high demand (Coats, 2004). The reason for the increased demand of rough rice is because competing rice exporters protect their rice by not exporting this commodity. Subsequently, the United States is able to charge a premium because supply is diminished and demand is high (Coats, 2004). In the mid-1990's, global economy projections were predicted that, if maintained, would allow the rice industry to make a complete transition to producing rice for the global market by 2003; however, the global economy is only recently coming out of a recession, which makes the aforementioned projections both unrealistic and unattainable (Coats, 2004).

About 90% of the rice consumed in the United States is grown within its borders; in fact, the nation's per capita consumption of rice is 27 pounds annually (Suszkiw, 2002). According to the USA Rice Foundation, the United States is the 3rd largest exporter of milled rice. Total United States rice production for 2003-2004 is 6.204 million metric tons. In fact, the USDA has projected that the 2003-2004 global milled production of rice will exceed 2002-2003 production by 10.3 million metric tons (Coats, 2004). However, the full potential of this staple crop has not been utilized, especially its derivatives and byproducts such as flour, starch, protein, bran, hull, and oil. After the milling process, about 15 percent is either broken or immature, which is sold for less than whole rice. Because this broken/immature rice is not aesthetically pleasing, it is most often used for making beer, flour, or pet food.

Characteristics of rice that distinguish it from other grains include its small particle size, range of gelatinization temperatures, and amylose / amylopectin ratios. When compared with other grains, rice is free of gluten and has a mild flavor which does not mask other important ingredients. The gluten in wheat is the protein that binds water which allows for an elastic dough in baked goods. Rice can not form a dough without an added thickening agent. Wheat flour contains individual starch granules after milling; however, rice flour has clumps of starch granules (Kohlwey *et al.*, 1995). The age of the rice affects how the rice is cooked. In fact, a freshly harvested rice will be moister than an aged rice (Kohlwey *et al.*, 1995).

Rice is an optimal food ingredient in entrees, sides, soups, snacks, baby foods, health foods, confections, and beverages. Rice is both versatile and economical. It is a complex carbohydrate, and is fat, cholesterol, and sodium free (USA Rice Federation, 2003). It is also non-allergenic, which is good for people with Celiac Spruce Disease.

Rice products such as protein and flour are useful as an ingredient because it works as an emulsifier, a leavening balancer, a thickener, a texture enhancer, and a fat-reducing agent. One of the most important macronutrients of rice is protein due to its ability to bind starch and form starch granules, which influences the pasting properties of rice flour. The content of lipids in rice is about 1%. The lipids are bound very tightly to the proteins and starch in the endosperm of the rice. This results in the formation of an amylose-lipid complex, which affects the pasting properties of rice flour.

An evaluation of rice varieties available throughout the world shows a broad spectrum of both physical and chemical properties. Riviana Foods, Inc. has done research centered on methods of utilization of these properties by new processing methods. These new processing methods are created to find new applications for both rice flours and starches (Kohlwey *et al.*, 1995). These flours and starches can be used in the food industry to create new and better food products available to individuals. These products can also help to improve the quality of food products that are free from gluten.

1.3 Rice Flour

Products made from rice flour have become increasingly popular due to the fact that foods from plant sources have been recognized to be more nutritious than those from animal sources (Anonymous, 1998). Also, rice is readily available in large quantities; the protein and starch found in rice are both hypoallergenic and easily digestible (Shih, 1999). Success in converting products to those containing only rice flour is difficult because the components of rice have unique properties, specifically in the absence of gluten (Shih, 2002). Rice flour is made from ground and polished rice by grinding through various types of mills (Nishita, 1982). Rice flour is mainly starch and is completely gluten free. The differences among flours made from rice (*Oryza sativa* L.) are due to the variations among cultivars, more specifically the starch component of the rice, the milling methods, and the pretreatments of either rice or flour (Bean, 1986).

One of the most popular forms of rice in the United States is regular-milled white rice. This type of rice has the hull, bran, and germ layers removed and the rice is polished (Kuntz, 2002). It is during this milling process, however, that many of the rice kernels become broken, leaving them unappealing to consumers. Rice flour is made mainly from these broken kernels. Rice varieties are identified in the United States as either long, medium, or short grain length. Each of these types of rice has different properties with respect to textural attributes. These differences are directly related to the properties of rice starch, particularly the amylose content (Bean, 1986). The appearance of rice flour is white to creamy white, which is relatively free from specs. It has a typical rice aroma, free from sour, musty, or other objectionable odors. The flavor is bland, with typical rice flavor with no rancid or off flavors (Anonymous, 2003).

According to Bean (1986), the milling process has an effect on the properties of the starch in rice flour, which, in turn, affects its functionality. In the United States, most of the rice flour is produced from broken rice kernels. In fact, the type of mill used to manufacture the rice flour has an effect on the particle size of the flour.

Rice flour can be used in many applications. For example, it can be used in snack processing to increase the crispiness of chips and crackers. It also reduces cracker hardness. In breakfast cereals, rice flour can improve the texture of the product, reduce breakage, and extend the shelf life. It can also be added to cookies to obtain the cake-like texture (USA Rice Federation, 2003).

When a liquid is added to rice flour, the viscosity is not as high as other types of grain flours. For this reason, rice flour batters can contain a high degree of solids. These solids act as a buffer in the cooking process to absorb liquids. Therefore, a wheat batter with the same solids content would form a product with a gummy texture, whereas the rice flour batter would produce a dry texture. This dry texture can be a problem in baked goods. Therefore, when a moister texture is desired, a gum or low percentage of gelatinized material (such as pre-gelatinized rice flour) can be added. The viscosity of a rice flour batter increases with the solids content in a logarithmic pattern, which make it difficult to control product formulation. However, when two different grains are being mixed (such as wheat and rice), the rate of change is linear in the batter mixture (Kohlwey *et al.*, 1995).

Most flour slurries, including rice and other flours, decrease in apparent viscosity with time. This is important because most industrial processes need to have some degree of tolerance to mixing as well as a stability over time. It is important to note that the cooking quality of the rice flour is altered when the flour is moistened or steeped (Kohlwey *et al.*, 1995). Wheat flour has the lowest gelatinization temperature and peak viscosity, and rice flour (long-grain) has the highest gelatinization temperature and peak viscosity after cooking (Kohlwey *et al.*, 1995).

The particle size of the rice flour greatly affects how quickly the product will cook. In the United States, the particle size for rice flour is generally less than 300 microns in size. The finest type of rice flour is rice starch, which is usually less than 16 microns in size (Kohlwey *et al.*, 1995). In the United States, the use of rice flour in making both cakes and breads is still relatively new. There is enough interest in the market by patients of Celiac Spruce Disease to keep the demand for these products.

1.4 Pregelatinized Rice Flour

Different types of starches and hydrocolloids are available for use in the baking industry for the improvement of the texture and appearance of baked goods. In fact, rice starches are widely available and are extremely useful for products not containing gluten (Gallagher *et al.*, 2004). When acetylation and gelatinization are used to modify rice flour, both the cold-swelling and the pasting properties are improved. Therefore this modification can increase the ability of rice flour to hold moisture thus increasing the moisture content of the finished product (Shih, 2001). Pregelatinized rice flour has often been used in the food industry as a bulking or thickening agent; for this reason, it is possible that addition of this product to gluten-free baked goods may improve the texture of the finished product. This type of flour is traditionally produced from grinding roasted rice kernel from raw or parboiled rice (Lai, 2001). Different types of pregelatinized rice flour are available with differing functional properties. The physiochemical properties of the starch change when thermal treatment occurs during the processing of the pregelatinized rice flour. The starch granules change in different ways depending on the temperature and/or moisture levels during processing (Lai, 2001). These changes affect the cold swelling and thickening power of the batter, as well as the resistance to shearing, the ability to puff, and the texture after baking (Kohlwey *et al.*, 1995).

1.5 Baking Industry

According to Salzman (2001), the snack cake category of the baking industry represents approximately a 600 million dollar industry, and the trend is growing. This is due to consumers' increased demand for goods that can be consumed with little or no home preparation. Although the production of baked goods, most notably cakes, is considered by many to be an art, it is also a product of science. Therefore, it is extremely important for those developing new baked goods to understand each different ingredient and its purpose in the mixture of the product (Goldstein, 2001). There are several essential ingredients important in the formulation of baked goods: flour, eggs, milk, sweeteners, fat, and leavening agents.

The main structure of baked goods is composed of flour. Flour also binds and absorbs moisture from the mixture (Goldstein, 2001). Different types of flour have different properties which are applicable to different types of baked products. However, most flours do contain wheat, which contain varying proportions of glutenin and gliadin proteins. For this reason, it is a challenge to develop a cake product that does not contain gluten for individuals who are intolerant to this protein.

In some cake batters, eggs could account for as much as 70% of the cost of the ingredients in the batter (Goldstein, 2001). In baked goods, eggs impart binding, shortening, leavening capabilities as well as aid in coloring and browning during the baking process. Milk is also an integral part of a cake batter. Because it contains protein, sugar, and butterfat, it adds color, nutritional value, and moistness to the product (Goldstein, 2001).

The type of sweetener (brown, white, corn syrup) depends on both the degree of desired sweetness and the type of cake product being produced. The purpose of adding the sugars and sweeteners is to aid in coloring and browning, bulking, creaming/aeration, and moisture retention capability of the desired batter (Goldstein, 2001).

According to Goldstein (2001), the purpose of the fat in the cake is to provide tenderness to the product. Also, the major point of differentiation of the type of fat used is whether it is a solid or liquid at room temperature. During the mixing process, air is incorporated into the fat at a stage called creaming. This creates pockets where both air and moisture occur, thus creating texture that is light and airy. This stage, where gas bubbles are incorporated into the mixture, is directly linked to the final texture and volume of the cake which is related to the final quality of the cake product (Sahi and Alava, 2003).

Leavening agents provide both volume and structure to the finished product. These agents help to aerate the mixture through the release of air, steam, and/or carbon dioxide during the process. The expansion of trapped water and air during the baking process causes a leavening action, which affects the texture of the finished product. Some leavening agents, such as baking powder, baking soda, and cream of tartar, react to form gases during the baking process (Goldstein, 2001). During the whipping process, air is incorporated into the batter. When the acids and bases of leavening agents react with the moisture and heat during the baking process, small bubbles are formed in the product which results in a honeycomb of small air spaces (Goldstein, 2001).

Many different types of cake products are made with batters that have been whipped to incorporate air including sponge, roll, and layer cakes (Nielsen, 2002). These items are often produced on a large scale basis with continuous mixing, baking, and procession lines. In fact, several important steps go into the commercial preparation of baked goods (Figure 3). The first step involves the combination or pre-mixing of ingredients. Next, the batter is stabilized in a feed tank. After this step, the air is incorporated into the batter at a controlled rate. Next, the batter is deposited into containers, baked, cooled and packaged. As with all commercially produced items, it is vital that these processing parameters remain the same to make certain that the batter density and final crumb structure is the same in every cake and batch (Nielsen, 2002).

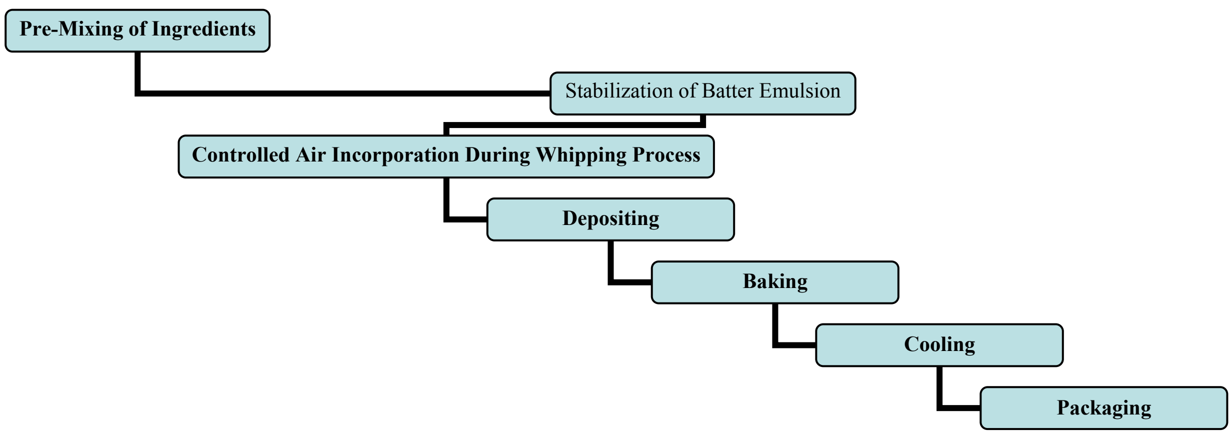


Figure 3: Industrial Cake Production Processing Steps (Nielsen, 2002)

1.6 Product Development

The development of new food products in today's food industry is becoming increasingly challenging due to the changing trends and competitive products. Consumers are expecting newer and better products that are an alternative to take-out but without the in-home preparation (Moskowitz, 1999). Therefore, it is increasingly important for product developers to come up with products that are desirable to consumers. Companies must identify an opportunity for the creation of a product and then create a concept to fit the opportunity. Next, the company must create a product to fit the concept, and then perform all of the necessary consumer studies before the product is launched. Many times, optimization studies must be performed during this process. This means that a product is created and refined with a particular feature in mind, for example the development of a gluten-free butter cake product.

Several stages compose a product life cycle: concept development, product development, growth and maturity (Koeferli, 1998). In the concept development phase, many times focus groups are utilized to determine what products are desired from individuals with similar interests. These focus groups allow food researchers to determine target market and provide information on the need of the specific concept. In today’s market, a new challenge exists for the food industry where consumers require products for a specific need. Therefore, food companies must be able to create new products for unique consumer segments which are identified through the sensory behavior of consumers (Sidel and Stone, 1993). Once a concept has been determined, the product development phase begins. During this integral process, the product in question is prepared and optimized in order to achieve a maximum acceptance level when the product is launched (Koeferli, 1998). When performing an optimization of a product, it is extremely important to bring the consumer into the process at as early a stage as possible (Palomar, 1994). This allows consumers to be a part of the process and provide input at early stages of development.

It is at this point that sensory evaluation techniques become critical in order to determine both acceptance levels as well as the ultimate purchase decision of the consumer. When developing a new food product, it is extremely important that products can be produced both economically and easily while still maintaining standards of quality, and the product developed is acceptable to consumers while still at its earliest stages (Prinyawiwatkul, 1993). The final stages of the product life cycle are the growth and maturity stage. At this point, sensory analysis can be used in order to determine acceptance and quality with respect to processing parameters or changes in ingredients. Also, these techniques can be used to formulate line extensions of the original product. According to Koeferli and others (1998), a product should be designed in order to meet the needs of the consumer both consistently and continuously in order to be successful in the future. Because consumers' tastes and perceptions are constantly changing, it is becoming increasingly important that sensory scientists and product developers are able to adapt to these changes.

CHAPTER 2. DEVELOPMENT AND CHARACTERIZATION OF CONSUMER SENSORY QUALITY OF A BUTTER CAKE PREPARED FROM WHEAT AND RICE FLOURS

2.1 Introduction

2.1.1 Celiac Spruce Disease

Celiac Spruce Disease is a problem of malabsorption of certain proteins in the diet, mainly gluten. Celiac Spruce Disease severely impairs intestinal absorption that can lead to severe malnutrition and is caused by a severe sensitivity to gluten (Sanchez *et al.*, 2002). Roughly 1 to 2 percent of the US population suffers from this disease (Suszkiw, 2002). These individuals are intolerant to cereals such as wheat, oats, rye, and barley. The only way to ensure a life free of complications is to adhere strictly to a 100% gluten-free diet (Gallagher *et al.*, 2003). The main structure forming protein in wheat flour is gluten, which is responsible for the elastic properties desired in high quality baked goods. When gluten is removed from bakery products, the result is a lower quality product. Therefore one of the main objectives of this study is to characterize the sensory quality of a non-wheat butter cake product made predominately from rice flour.

2.1.2 Rice

The United States produces a dependable supply of some of the highest quality rice in the world. About 90% of the rice consumed in the US is grown within its borders; in fact, the nation's per capita consumption of rice is 27 pounds annually (Suszkiw, 2002). According to the USA Rice Foundation, the US is the 3rd largest exporter of milled rice. The US rice and rice products market was valued at $1.5 billion in 1994, and a projected increase by 5 or 6 percent is expected to reach nearly $2.0 billion by 1999 (USA Rice Federation, 2003). However, the full potential of this staple crop has not been utilized, especially its derivatives and byproducts such as flour, starch, protein, bran, hull, and oil.

After the milling process, about 15 % of rice is either broken or immature, which is sold for a lower price than whole rice. Because the broken rice is not aesthetically pleasing to consumers, it is most often used for making beer, flour, or pet food. An evaluation of rice varieties available throughout the world shows a broad spectrum of both physical and chemical properties. Riviana Foods, Inc. has done research centered on methods of utilization of these properties by new processing methods. These new processing methods were created to find new applications for both rice flours and starches (Kohlwey *et al.*, 1995).

Rice is an optimal food ingredient in entrees, sides, soups, snacks, baby foods, health foods, confections, and beverages. One advantage of using rice as a food ingredient is its versatility. Another important advantage, particularly to food processors, is that rice is very economical. Along with being a complex carbohydrate, it is also fat, cholesterol, and sodium free (USA Rice Federation, 2003). It is also non-allergenic, which is especially important for individuals with Celiac Spruce Disease. Also, rice is useful as an ingredient because it works as an emulsifier, a leavening balancer, a thickener, a texture enhancer, and a fat-reducing agent.

2.1.3 Rice Flour

Rice flour is made from ground and polished rice, is mainly starch and is completely gluten free. The appearance of rice flour is white to creamy white, which is relatively free from specs. It has a typical rice aroma without sour, musty, or other objectionable odors. The flavor is bland and is of typical rice flavor with no rancid or off flavors (Anonymous, 2003). The differences between flours made from rice (*Oryza sativa* L.) are due to the variations among cultivars, more specifically the starch component of the rice, the milling methods, and the pretreatments of either the rice or the flour (Bean, 1986).

When a liquid is added to rice flour, the viscosity is not as high as other types of grain flours. For this reason, rice flour batters can contain a high degree of solids. These solids act as a buffer in the cooking process to absorb liquids. Wheat batter with this same solids content would form a product with a gummy texture, while the rice flour batter would produce a dry texture. This dry texture can be a problem in baked goods. Therefore, when a moister texture is desired, a gum or low percentage of gelatinized material (such as pre-gelatinized rice flour) can be added (Kohlwey *et al.*, 1995).

The particle size of the rice flour greatly affects how quickly the product will cook. In the US, the particle size for rice flour is generally less than 300 μ in size. The finest type of rice flour is rice starch, which is usually less than 16 μ in size (Kohlwey *et al.*, 1995). In the US, the use of rice flour in making both cakes and breads is still relatively new. There is enough interest in the market by patients of Celiac Spruce Disease to keep the demand for these products. Therefore, the objective of this study was to determine and characterize the consumer sensory quality of a non-wheat butter cake product made from rice flour.

2.2 Materials and Methods

2.2.1 Cake Preparation

Three different butter cake formulations were prepared: one made from 100 % wheat flour (WBC), one made from 100 % rice flour and whipped (WRBC), and one made from 100% rice flour but not whipped (NWRBC). The reason that one of the rice flour cakes included whipped egg whites was to improve both the visual puffiness as well as the texture of the product. Also, in the WRBC formulation, high fructose corn-syrup was added to the product in order to help improve the moistness of the cake. The NWRBC formulation had a very grainy texture and was extremely dense and dry in initial trials. In a study conducted by Bean (1983), vegetable oil was preferred over other forms of fat because it gave cakes made with rice flour a finer texture that was not crumbly. In this study butter was melted before adding to the batter to give a more desirable texture to the finished product.

The butter cake made entirely from wheat flour (WBC) contained the following percentages: 25% sugar, 22% butter, 18% wheat flour, 18% eggs, 15% milk, 0.6% baking powder, and 0.3% vanilla. First, the butter was melted and then combined with sifted flour, sugar, and baking powder. Next, the whole eggs, vanilla and milk were added to the mixture. The mixture was beaten on level 6 (medium speed) with the paddle attachment in a Kitchen Aid® stand mixer for 2 minutes. Next, the batter was transferred to a greased 9 X 5 loaf pan and baked in a preheated 350°F Hotpoint electric oven for 40-50 minutes. The cake was considered done when it obtained the desired golden brown color.

The butter cake made from 100% rice flour (WRBC) contained 24.8% rice flour, 23.0% high fructose corn syrup, 17.4% butter, 14.5% eggs, 11.9% milk, 7.44% sugar, 0.682% baking powder, 0.207% vanilla, and 0.155% cream of tartar. This mixture was beaten for 3 minutes with the paddle attachment on level six in a Kitchen Aid® stand mixer and was set aside. The five egg whites that were separated from the yolks were then combined with 1 tsp cream of tartar and beaten with the wire whisk attachment for four minutes in a Kitchen Aid® stand mixer. The two mixtures were then folded together very gently until all of the egg whites were incorporated into the batter. The batter was then placed into a greased 9 X 5 loaf pan and baked for 40-50 minutes in a 350°F Hotpoint electric oven.

The butter cake made from 100% rice flour (NWRBC) was prepared identically to the WBC formulation, except that the egg was added directly to the mixture (egg white was not whipped separately). The butter and sugar were combined first, then the sifted flour and baking powder were added, followed by eggs, vanilla, and milk. The mixture was beaten on level 6 (medium speed) with the paddle attachment in a Kitchen Aid® stand mixer for 2 minutes. Next, the batter was transferred to a greased 9 X 5 loaf pan and baked in a preheated 350°F Hotpoint electric oven for 50-60 minutes.

2.2.2 Consumer Acceptance Test

One hundred untrained consumers participated in this study. Consumers were randomly selected from the Baton Rouge, LA, area. Criteria for recruitment included the following: (1) they had to be at least 18 years of age, (2) they were not allergic to wheat, rice, butter, sugar, corn syrup, eggs, milk, vanilla, and cream of tartar, and (3) they were available for the required 20 minutes to complete the survey.

Consumers were presented with coded samples following the Randomized Block design. This design was described by Cochran and Cox (1957). Consumers were served a 2 X 2 inch slice of each of the three cakes, which were coded according to their formulation as follows: sample A was the NWRBC, sample B was the WBC, and sample C was the WRBC. Participants were also served plain crackers (without salt) and room temperature water in order to cleanse their palettes between samples. Each consumer evaluated the 3 samples for visual puffiness, appearance/color, odor/aroma, taste, overall texture/mouthfeel, moistness, and overall liking on a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely). This scale is useful in consumer testing because it defines psychological states of 'like' and 'dislike' on a linear scale. It is important to note that this scale is bipolar, which means that the descriptive adjectives at either end of the scale may not be opposite in sensory meaning (Gacula and Singh, 1984).

Consumers also rated the sandiness of the product and indicated if the sandiness was acceptable using the 2-point hedonic scale (yes/no). Overall acceptance and purchase decision were also rated using the 2-point hedonic scale. 100 observations were collected for each of the 3 formulations.

2.2.3 Statistical and Data Analysis

All analyses used SAS software version 9.00, 2002 (SAS Institute., Cary, NC). The analysis of variance test (ANOVA) was used to determine consumers' perceptions and acceptability of each sensory attribute as well as the overall liking of each butter cake. Analysis of variance is used for separating the combined variation in the observed data set into components with respective causes for variation. Next, the reason, or source, for the variation is identified and tested for significance as a source of variation in the overall data set (Gacula and Singh, 1984). However, when using the ANOVA technique, certain assumptions are made: (1) observations follow a normal distribution, (2) independently distributed error terms with a mean of zero, and (3) common variance σ^2 (Gacula and Singh, 1984). According to Smith *et al.,* (2003), one of the drawbacks of using the ANOVA technique is that it only examines interaction effects; however, it does not give insight into the nature of the interactions. Therefore, many have begun using a two-staged approach to analyze sensory data, such as the principal component analysis (PCA) technique. Therefore, it is possible to determine the potential causes of the interaction in the data (Smith *et al.*, 2003).

Descriptive discriminant analysis (DDA) was also used to determine the most discriminating attributes in terms of consumer perceptions. Predictive discriminative analysis

(PDA) was used to determine both product acceptance and purchase decision with prediction intervals based on individual attributes according to consumers. Both logistic regression analysis and predictive discriminative analysis can be used to determine both product acceptance and purchase decision. Logistic regression is used to predict both acceptance and purchase decision using the odds ratio estimate. The odds are a nonnegative number with a value that is greater than 1.0 when a success is more likely to occur than a failure (Agresti, 1996). In this case, a "success" was either acceptable product or intent to purchase product. When values of θ (odds ratio) are farther from 1.0 in any given direction, this represents stronger levels of association.

2.2.4 Principal Component Analysis

Principal component analysis (PCA) is a variable reduction technique which is used to simplify and describe interrelationships between dependent sensory attributes and samples through the use of multivariate techniques (McNeill *et al.*, 2002). The PCA technique simplifies data structure and aids in interpretation by forming the original dependent attributes into new uncorrelated dimensions which results in a data map that graphically illustrates interrelationships among variables (Lawless and Heymann, 1998). In sensory data, it is possible that several descriptors actually describe the same characteristics in the product (an example is aroma and flavor descriptors can be redundant in measuring the same characteristics). However, PCA transforms the data into a set of variables known as principal components, thus eliminating the aforementioned redundancies (Lawless and Heymann, 1998).

PCA takes *n* variables $X_1, X_2, \ldots, X_p$ and finds combinations of these variables to produce indices $Z_1, Z_2, \ldots, Z_p$ that are uncorrelated. A lack of correlation between the variables means that the indices are measuring different dimensions in the data (Manly, 1986). These indices are ordered where the largest amount of variation is displayed by Z_1, and so forth. The Z_i

are called the principal components. If the variances of most of the indices are extremely low, then the variation in the data can be described by only a few Z variables that are not negligible. According to Manly (1986), when the original variables are highly correlated (either positively or negatively), then the best results are obtained with principal component analysis because this means that the important principal components measure the underlying dimensions in the data set.

2.3 Results and Discussion

2.3.1 Mean Acceptance Scores

The mean consumer acceptance scores are presented in Table 1. According to the mean overall liking scores, consumers preferred formulation 2 (WBC) with a mean overall liking score of 7.07. The NWRBC formulation had a mean overall liking score of 4.95, and the WRBC formulation had an overall liking score of 4.12. The WBC sample, which was made of 100% wheat flour, had higher ratings in sensory attributes such as taste, texture, moistness, and overall liking.

Table 1: Mean Consumer Acceptance Scores for Sensory Attributes and Overall Liking of Three Butter Cake Formulations*

Formulation Number	Mean Consumer Acceptance Score						
	Visual Puffiness	Appearance/ Color	Odor/ Aroma	Taste	Texture	Moistness	Overall Liking
1 NWRBC	6.30 ab (1.40)	6.81 a (1.25)	6.59 a (1.45)	5.06 b (2.20)	4.33 b (1.96)	4.78 b (2.13)	4.95 b (2.00)
2 WBC	6.50 a (1.41)	6.85 a (1.18)	6.65 a (1.42)	6.94 a (1.35)	7.24 a (1.19)	7.36 a (1.02)	7.07 a (1.24)
3 WRBC	5.97 b (1.83)	5.97 b (1.74)	5.89 b (1.46)	4.18 c (1.65)	4.37 b (1.76)	4.55 b (1.91)	4.12 c (1.70)
Range**	0.53	0.88	0.76	2.76	2.91	2.81	2.95

*Numbers in parentheses represent standard deviation of 100 consumer responses.
**Range = the highest score minus the lowest score.
a, b, c Means within the same column followed by different letters are significantly different ($p<0.05$)

2.3.2 Overall Product Differences – Pooled Within Canonical Structure r's

In order to determine if the formulations differed considering all of the sensory attributes simultaneously, the multivariate analysis of variance (MANOVA) method was used (Table 2). This technique is extremely useful because it reveals whether significant differences exist between treatments when all attributes are compared simultaneously (Lawless and Heymann, 1998). According to Koeferli *et al.* (1998), the use of this technique greatly expanded the field of sensory analysis. It can be used to correlate, reveal patterns, and classify data collected from consumers.

Table 2: Multivariate Statistics and F Approximations

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 2 M = 2 N = 143.5					
Statistic	**Value**	**F Value**	**Numerator DF**	**Denominator DF**	**Pr > F**
Wilks' Lambda	0.458	19.72	14	578	<0.0001
Pillai's Trace	0.619	18.59	14	580	<0.0001
Hotelling-Lawley Trace	1.014	20.88	14	459.05	<0.0001
Roy's Greatest Root	0.803	33.28	7	290	<0.0001

The Wilks's lambda value is used in assessing the influence of all sensory attributes at the same time (Lawless and Heymann, 1998). The Wilks's Lambda P-value of <0.0001 (Table 2) indicates that all of the three formulations were different when all seven sensory attributes were considered simultaneously.

In order to determine which attributes were responsible for the underlying differences among the three formulations, descriptive discriminant analysis (DDA) was used. According to the pooled within canonical structure in the first dimension (Can 1), texture (0.9123), moistness (0.8103), overall liking (0.7884), and taste (0.6846) did contribute significantly to overall differences among the three butter cake formulations, resulting in 79% cumulative variance explained (Table 3).

Table 3: Canonical Structure r's Describing Group Differences Among Butter Cake Formulations[a]

Variable	Can1**	Can2**
Visual Puffiness	0.1203	0.2043
Appearance / Color	0.1593	0.5446
Odor / Aroma	0.1398	0.4454
Taste	0.6847*	0.5087
Texture	0.9123*	0.0495
Moistness	0.8103*	0.1832
Overall Liking	0.7884*	0.5101
Cumulative Variance Explained (%)	79%	100%

[a] Based on Pooled Within-Group Variances.
* Indicates sensory attributes which largely account for group differences in the first dimension.
** The pooled within canonical structure in the first and second dimensions.

2.3.3 Logistic Regression Analysis vs. Predictive Discriminant Analysis (PDA) for Acceptance and Purchase Intent

Using predictive discriminative analysis, product acceptance can be predicted with 87% and 82% accuracy based on overall liking and taste alone, respectively (Table 4). Based on logistic regression analysis for consumer acceptance of the butter cake product, overall liking is the most important attribute with an odds ratio estimate of 3.511 (Table 5). Appearance and moistness are the next most important attributes with odds ratio estimates of 1.403and 2.272, respectively. Therefore, for every one point increase in overall liking, appearance, and moistness on the 9- point hedonic scale, overall product acceptance will be increased by 251.1%, 40.3%, and 127%, respectively.

Table 4: % Hit-Rate for Acceptability and Purchase Intent of Butter Cake Product

Attributes	**% Hit Rate**		
	Acceptability	**Purchase Intent**	**Purchase Intent Celiac Spruce**
All 7 Combined	86.9	82.6	76.2
Visual Puffiness	59.3	58.3	61.0
Appearance / Color	60.0	55.7	60.0
Odor / Aroma	64.3	59.3	56.0
Taste	82.3	76.0	72.3
Texture	78.3	78.0	72.7
Moistness	79.5	78.2	71.5
Overall Liking	86.7	76.3	76.3

Purchase decision can be predicted with 78.2%, 78.0%, and 76% accuracy based on moistness, texture, and overall liking, respectively (Table 4). In this study, overall liking, texture, and taste were identified as critical attributes for both product acceptance as well as purchase decision for a butter cake product made predominately from rice flour (Table 4). Odds ratio estimates were also determined for purchase intent of a butter cake product not containing wheat flour (Table 5). The most important attributes for purchase intent are taste and texture (Odds ratio estimates of 4.654 and 3.221, respectively).

Table 5: Prob>X^2 and Odds Ratio Estimates for Consumer Acceptance and Purchase Intent of Butter Cake Product

Consumer Acceptance			
Independent Variable	**Prob>X^2 (full)**	**Odds Ratio Estimate (full)**	**Odds Ratio Estimate (single)**
Visual Puffiness	0.4101	1.165	1.359
Appearance/Color	0.0172	0.632	1.403
Odor	0.1214	1.269	1.576
Taste	0.9077	1.021	2.481
Texture	0.7731	1.048	2.494
Moistness	0.0211	1.372	2.272
Overall Liking	<0.0001	2.988	3.511
Purchase Intent			
Independent Variable	**Prob>X^2 (full)**	**Odds Ratio Estimate (full)**	**Odds Ratio Estimate (single)**
Visual Puffiness	0.5215	0.880	1.402
Appearance/Color	0.3974	0.813	1.620
Odor	0.9155	1.020	1.602
Taste	0.0005	2.516	4.654
Texture	0.0077	1.828	3.221
Moistness	0.1828	1.307	2.862
Overall Liking	0.1286	1.647	5.673
Purchase Intent Celiac Spruce			
Independent Variable	**Prob>X^2 (full)**	**Odds Ratio Estimate (full)**	**Odds Ratio Estimate (single)**
Visual Puffiness	0.4081	1.123	1.437
Appearance/Color	0.2009	1.235	1.635
Odor	0.1213	0.815	1.364
Taste	0.2352	1.202	1.976
Texture	0.6457	0.938	1.850
Moistness	0.0106	1.370	1.952
Overall Liking	0.0224	1.571	2.204

Purchase decision after being informed about the benefits for individuals with Celiac Spruce Disease can be predicted with 76.3%, 72.7%, 72.3%, and 71.5% accuracy based on overall liking, taste, texture, and moistness, respectively (Table 4). Odds ratio estimates were also determined for purchase intent of a butter cake product not containing wheat flour (Table 5). The most important attributes for purchase intent are overall liking and moistness (odds ratio estimates of 2.204 and 1.952, respectively). This means that for every one point increase in overall liking and moistness on the 9-point hedonic scale, consumer purchase intent (Celiac Spruce) will be increased by 120.4% and 95.2%, respectively. For this reason, these attributes must be focused on when refining the product for the optimization study.

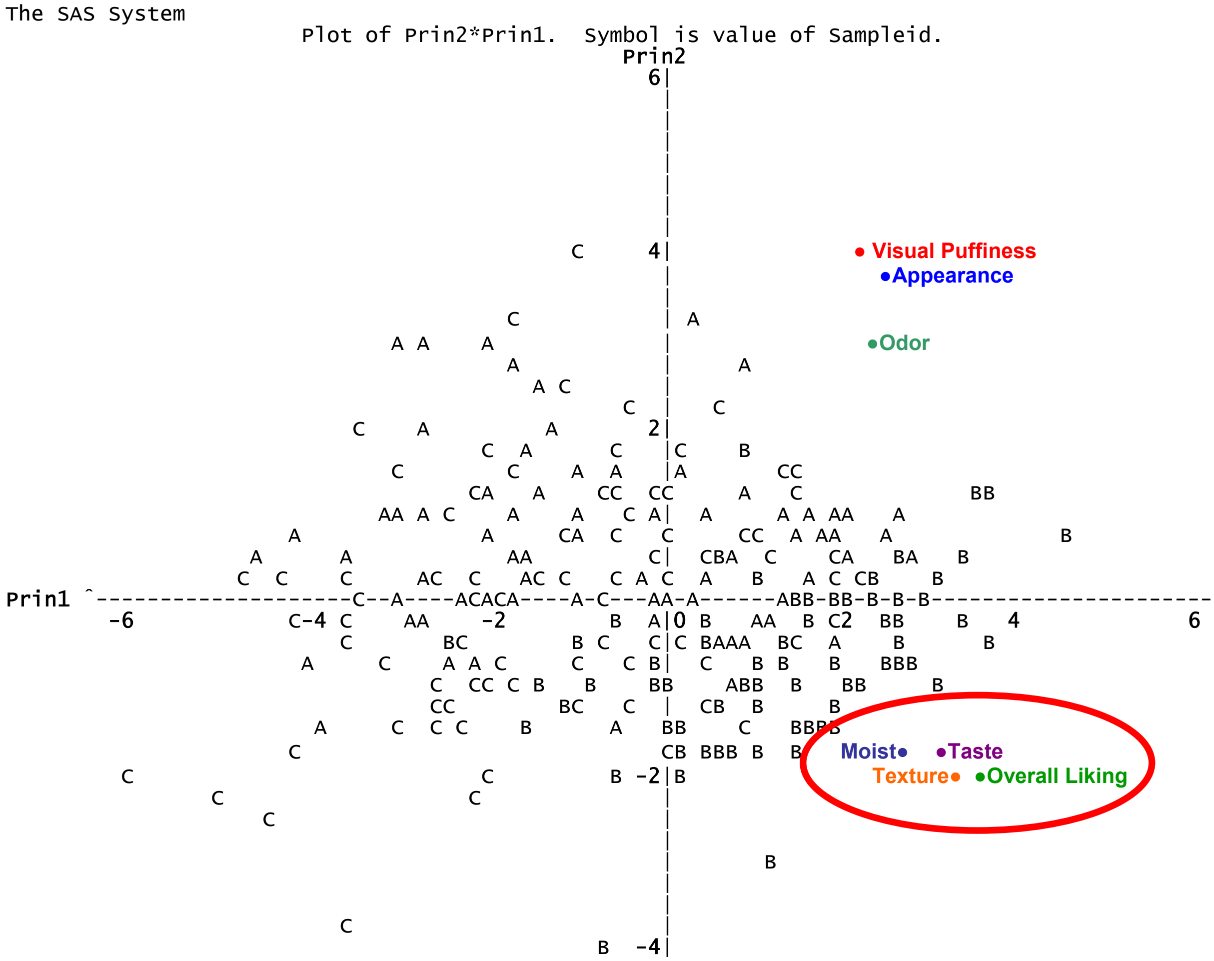
2.3.4 Principal Component Analysis

The bi-plot (product – attribute) space using principal components 1 and 2 is shown in Figure 4. It is evident that the attributes discriminating the butter cakes containing rice flour from the formulation containing only wheat flour are moistness, taste, texture, and overall liking. According to Figure 4, the quadrant with the discriminating factors contains mainly the B (WBC) formulation. This is a verification of the descriptive discriminative analysis (DDA) result, where the pooled within canonical structure in the first dimension, texture (0.9123), moistness (0.8103), overall liking (0.7883), and taste (0.6846) did contribute significantly to overall differences among the three butter cake formulations (Table 3). However, the plots comparing principal components 1 and 3 and principal components 2 and 3 were not able to determine any specific discriminating factors (See Appendix).

2.4 Conclusions

Consumers preferred the 100% wheat flour formulation. According to descriptive discriminative analysis, logistic regression analysis, and principal component analysis, the attributes that separated the wheat flour butter cake from those containing rice flour were texture, moistness, overall liking, and taste. For this reason, the formulation was adjusted, and then an optimization study followed.

The SAS System



NOTE: 2 obs had missing values. 79 obs hidden.

Figure 4: PCA bi-plot (product attribute) involving Principal Component 1 and Principal Component 2

CHAPTER 3. OPTIMIZATION OF A BUTTER CAKE PRODUCT MADE PREDOMINANTELY FROM RICE FLOUR

3.1 Introduction

The full potential of rice has not been utilized, especially its derivatives and byproducts such as flour, starch, protein, bran, hull, and oil. Because broken rice is not aesthetically pleasing to consumers, it is most often used for making beer, flour, or pet food.

Rice is an optimal food ingredient in entrees, sides, soups, snacks, baby foods, health foods, confections, and beverages. The reason rice is so useful is that it is both versatile and economical. It is a complex carbohydrate and is fat, cholesterol, and sodium free (USA Rice Federation, 2003). It is also non-allergenic, which is good for individuals with Celiac Spruce Disease. The US rice and rice products market was valued at $1.5 billion in 1994, and a projected increase by 5 or 6 percent is expected to reach nearly $2.0 billion by 1999 (USA Rice Federation, 2003).

Rice flour can be used in many food applications. For example, it can be used in snack processing to increase crispiness of chips and crackers. It also reduces cracker hardness. In breakfast cereals, rice flour can improve the texture of the product, reduce breakage, and extend the shelf life. It can also be added to cookies to obtain the desired cake-like texture (USA Rice Federation, 2003). In the US, the use of rice flour in making both cakes and breads is still relatively new. There is enough interest in the market by patients of Celiac Spruce Disease to keep the demand for these products.

The purpose of this study was 1) to identify and develop a rice cake product and 2) to determine the optimal formulation of a butter cake product using a 3 component mixture design experiment, and 3) to determine a consumer sensory profile for the product acceptance and purchase decision.

3.2 Materials and Methods

3.2.1 Butter Cake Preparation

After concluding the first study, the 100% rice flour cake was reformulated. An optimization study was performed using differing proportions of wheat, rice, and pre-gelatinized rice flours. The pre-gelatinized flour was used in an attempt to improve the texture of the butter cake product. However, it was not possible to make a cake entirely from pre-gelatinized rice flour. Each mixture had advantages and disadvantages, the 100% pre-gelatinized rice flour cake was too moist making it impossible to cut into portions for the consumer study. A mixture of 25% wheat flour, 25% rice flour, and 50% pre-gelatinized rice flour did not rise during the baking process, which left the final product dense and heavy. This formulation was not as moist as the 100% pre-gelatinized rice flour cake, which made it possible to slice. However, it was decided that 50% pre-gelatinized rice flour was the maximum amount that could be used in the formulations. Therefore, ten different mixtures were formulated using the triangular coordinate graph paper for plotting three-component coordinates. The control sample was the 100% wheat flour butter cake.

Rice flour was obtained from Rivland Foods, Houston, TX. All-purpose wheat flour (Gold Medal Flour, General Mills Sales, Inc., Minneapolis, Minnesota) was purchased from the local grocery store. Pre-gelatinized rice flour , PGR, (Remyflo R 500P) was obtained from A&B Ingredients, Inc., Fairfield, NJ. All other ingredients were obtained locally. The total flour content in each of the 10 cake formulations was 24.8%. All other ingredients (75.2%) remained the same throughout the process. Details about percentages of ingredients in the formulations are shown in Figure 5 and Table 6.

The first step in the baking process included melting the butter and combining it with the sugar and corn syrup. Next, the flour and baking powder were sifted together and then added to the mixture. The mixer (KitchenAid 6 quart Stand Mixer, KitchenAid, U.S.A) was turned on the stir setting just to combine the ingredients. Next, the yolks and whites of the eggs were separated. The egg yolks were added one at a time to the mixture, followed by the vanilla and milk. It was mixed for 3 minutes on level 6 with the flat beater. This mixture was set aside for later use. The next step in the process involved beating the egg whites with cream of tartar into stiff peaks. This was done using the wire whip attachment and mixing for 4 minutes on level 10. The egg white mixture was subsequently folded into the mixture gently so as not to break up the air bubbles in the meringue. Next, the batter was poured into two 5 x 9 inch pans (greased with cooking oil spray) and baked at 350 °F for 40-50 minutes until golden brown.

Table 6 shows each of the individual formulations for the butter cake product as well as the percentages of each type of flour contained. The rest of the ingredients remained the same for each different formulation. Formulation 1 served as the control sample, which used only wheat flour. Formulation 2 contained a 50:50 ratio of wheat to rice flour. Formulation 3 contained 100% rice flour, while formulation 4 contained 75% rice flour and 25% PGR flour. Formulation 5 contained a 50:50 ratio of rice to PGR flour, and formulation 6 contained a ratio of 25:25:50 of wheat, rice, and PGR flours, respectively. Formulation 7 contained a 50:50 ratio of wheat and PGR flours, while formulation 8 contained 75% wheat and 25% PGR flours. Formulation 9 contained a 50:25:25 ratio of wheat to rice to PGR flours. Finally, formulation 10 contained a 25:50:25 ratio of wheat to rice to PGR flours.

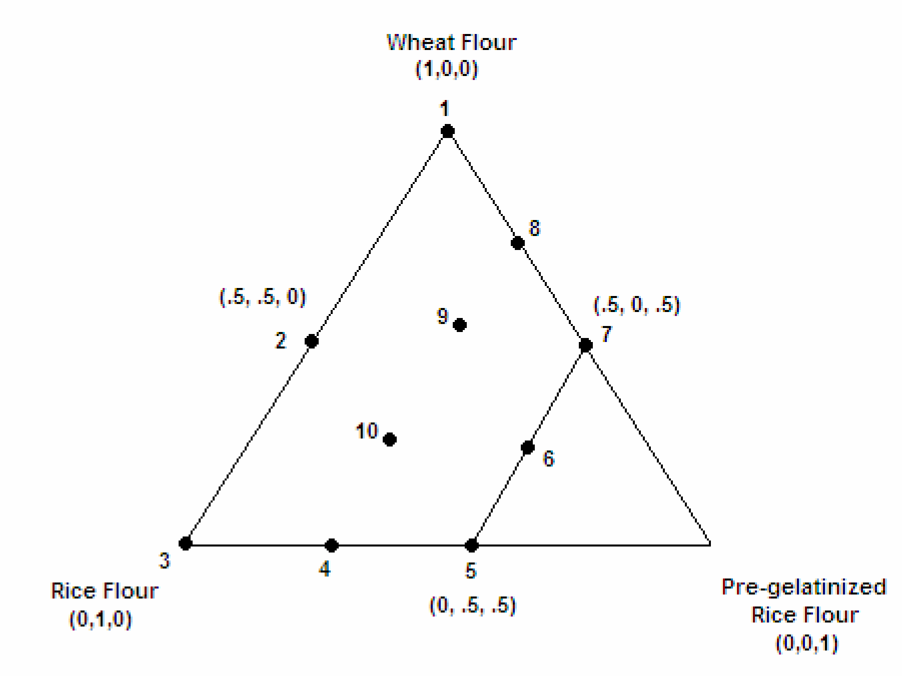


Figure 5: The constrained region in the simplex coordinate system defined by the following restrictions: $0.0 \leq X1 \leq 1.0$, $0.0 \leq X2 \leq 1.0$, $0.0 \leq X3 \leq 0.5$. X1 = wheat flour, X2 = rice flour and X3 = Pre-gelatinized rice flour. Numbers 1-10 represent the 10 formulations and correspond to the numbers in Table 6.

Table 6: Ten Formulations of Butter Cakes[a]

Formulation[b]	% Wheat Flour	% Rice Flour	% Pre-gelatinized Flour (PGR)
1	100	0	0
2	50	50	0
3	0	100	0
4	0	75	25
5	0	50	50
6	25	25	50
7	50	0	50
8	75	0	25
9	50	25	25
10	25	50	25

[a] The flour component system (100% in the mixture design) was 24.8% of the total composition. 23.0% corn syrup, 17.4% butter, 14.5% eggs, 11.9% milk, 7.44% sugar, 0.682% baking powder, 0.207% vanilla, and 0.155% cream of tartar comprised the remaining part of the formulation.
[b] Formulation numbers correspond to the numbers shown in Figure 5.

3.2.2 Experimental Design

A three component constrained simplex lattice mixture design was used (Cornell, 1986). The mixture design consisted of wheat flour (X1), rice flour (X2), and pre-gelatinized rice flour (X3). The flour mixture comprised 24.8% of the total formulation, and was the only component that was changed during the experiment. Each formulation contained the same amounts of butter (17.4%), sugar (7.44%), corn syrup (23.0%), eggs (14.5%), milk (11.9%), baking powder (0.682%), cream of tartar (0.155%), and vanilla (0.207%). The proportions of the components were expressed as fractions of the mixture. The sum of the component proportions (X1 + X2 + X3) equaled 1.0 or 100%.

3.2.3 Consumer Acceptance Test

Three hundred untrained consumers participated in this study (Figure 6). Consumers were randomly selected from the Baton Rouge, LA, area. Criteria for recruitment included the following: (1) they had to be at least 18 years of age, (2) they were not allergic to wheat, rice, butter, sugar, corn syrup, eggs, milk, vanilla, and cream of tartar, and (3) they were available for the required 20 minutes to complete the survey.

Demographic information was collected from the 300 consumers before they began the taste test. The information collected included age, gender, ethnicity, education level, and 2003 household income. Product information was also collected from these participants. They were asked if they normally consumed rice or rice-based products as well as butter cake products. Consumers were also asked to identify the most important quality attribute when eating butter cakes. Choices included taste, texture (puffiness), texture (sandiness), appearance/color, texture (mouthfeel), odor/aroma, texture (moistness), or other. They were also asked if they would buy a non-wheat butter cake product made from rice flour. Likewise, they were asked if they were

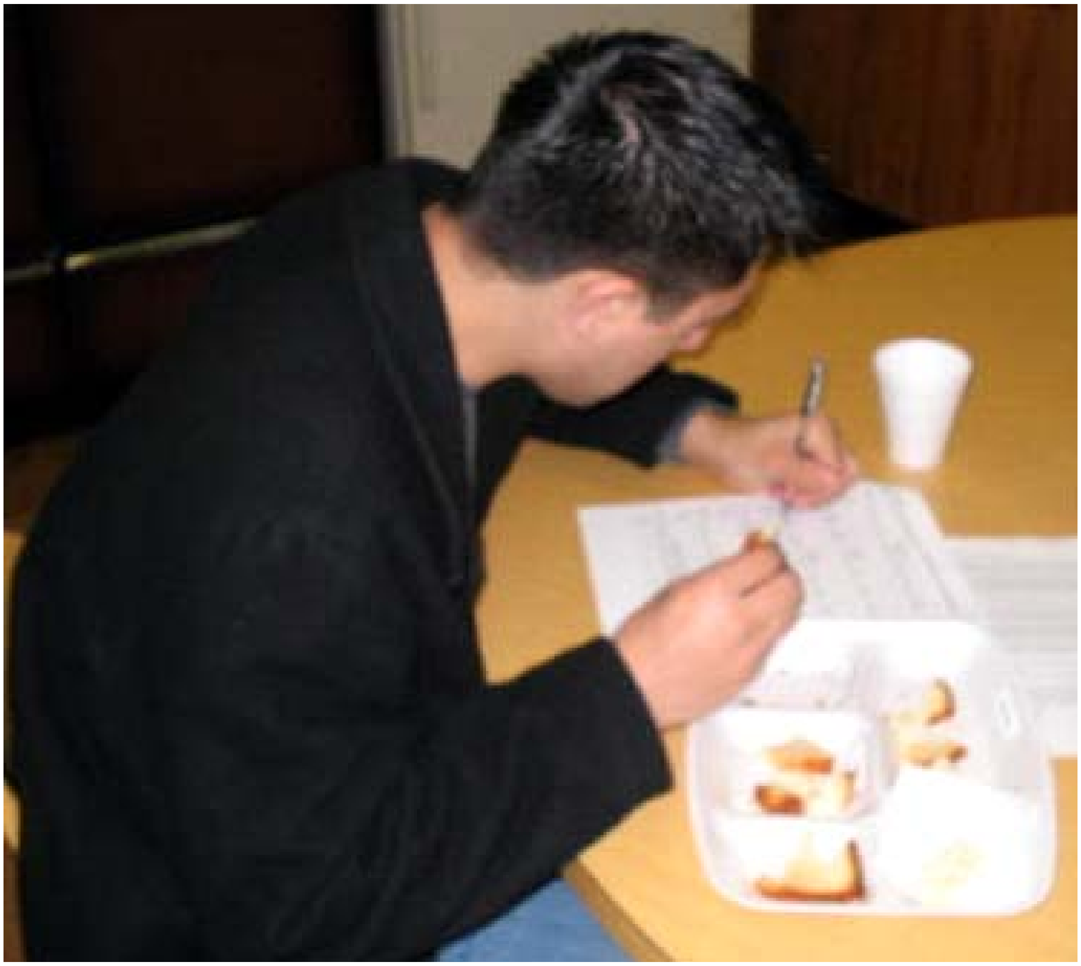


Figure 6: Panelist Evaluating Butter Cake Product

allergic to wheat (Celiac Spruce Disease) would they buy a non-wheat butter cake product. Finally, they were asked what their most favorite flavor would be for a butter cake product. Choices included plain, chocolate, berry, coffee, or other.

Consumers were presented with coded samples (Figure 6) following the Balanced Incomplete Block design Plan 11.21 ($t = 13$, $k = 3$, $r = 6$, $b = 26$, $\lambda = 1$, $E = 0.72$, Type III) (Cochran and Cox, 1957). This design was chosen because part of the objective of this study was to determine how numerous sensory attributes vary over the ten formulations. Also, the number of samples was too large for any consumer to evaluate at one time (Meilgaard *et al.*, 1999). Therefore, each consumer was able to evaluate only 3 out of the 10 samples for visual puffiness, appearance/color, odor/aroma, taste, overall texture/mouthfeel, moistness, and overall liking on a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, 9=like extremely). This scale is useful in consumer testing because it defines psychological states of 'like' and 'dislike' on a linear scale. It is important to note that this scale is bipolar, which means that the descriptive adjectives at either end of the scale may not be opposite in sensory meaning (Gacula and Singh, 1984).

Consumers also rated the sandiness of the product and indicated if the sandiness was acceptable using the 2-point hedonic scale (yes/no). Overall acceptance and purchase decision were also rated using the 2-point hedonic scale. Three replications were performed, and therefore, 90 observations were collected for each of the 10 formulations.

3.2.4 Statistical and Data Analysis

3.2.4.1 ANOVA

All analyses were conducted using SAS software version 9.00, 2002 (SAS Institute., Cary, NC). The analysis of variance test (ANOVA) was used in order to determine consumers' perceptions and acceptability of each sensory attribute and in overall liking of each butter cake formulation. Analysis of variance is used for separating the combined variation in the observed data set into components with respective causes for variation. The source of variation in the overall data set is identified and tested for significance (Gacula and Singh, 1984). However, when using the ANOVA technique, certain assumptions are made: (1) observations follow a normal distribution, (2) independently distributed error terms with a mean of zero, and (3) common variance σ^2 (Gacula and Singh, 1984). Post-hoc comparisons are test for which specific hypotheses are tested based on the observed differences among the sample means (Freund and Wilson, 2003). Tukey's honestly significant difference (HSD) is a multiple comparison procedure which can be applied regardless of whether the overall test for differences is significant among the samples (Meilgaard *et al.*, 1999). Tukey's HSD can be calculated using the studentized range, which is a sampling distribution calculated by dividing the sample range by the estimated standard deviation. The studentized range depends on the number of means being compared, the mean square error degrees of freedom, and the significance level. It is then possible to calculate Tukey statistic and declare if the samples are significantly different (Freund and Wilson, 2003).

3.2.4.2 MANOVA, DDA, and PDA

The multivariate analysis of variance (MANOVA) technique can be used as an extension of the ANOVA procedure. However, in this process, more than one variable is tested to detect differences in groups across multiple dependent variables at the same time (Pavon, 2003).

Descriptive discriminant analysis (DDA) was also used to determine the most discriminating attributes in terms of consumer perceptions. Predictive discriminative analysis (PDA) was used to determine both product acceptance and purchase decision with prediction intervals based on individual attributes according to consumers. Both logistic regression analysis and predictive discriminative analysis can be used to determine both product acceptance and purchase decision.

3.2.4.3 Logistic Regression

Logistic regression is used to predict both acceptance and purchase decision by using the odds ratio estimate. The odds are a nonnegative number with a value that is greater than 1.0 when a success is more likely to occur than a failure (Agresti, 1996). In this study, a "success" was either acceptable product or intent to purchase product. When values of θ (odds ratio) are farther from 1.0 in any given direction, this represents stronger levels of association.

3.2.4.5 McNemar Test

In order to determine if a change in the probability of the purchase intent of consumers before and after they tasted the butter cake product occurred, the McNemar test was performed. The McNemar test is one way of comparing proportions from dependent samples using binary response variables. The test follows a Chi-square distribution with df=1 (Agresti, 1996). Consumers were asked about their purchase intent of the product (before tasting), and then were asked about their purchase intent after tasting. The purpose of this test was to determine if the consumers' purchase intent changed after they tasted the butter cake product made predominately from rice flour. A 95% confidence interval was also calculated using marginal sample proportions ($p_{+1} + p_{1+}$), which can be used to estimate the actual differences in the means. In order to calculate the sample proportions, the following equation was used:

$$p_{ij} = n_{ij}/N$$

where n_{ij} is the number of consumers making response i before and response j after tasting, and N represents the total number of responses from consumers. Next, the 95% confidence interval for the difference in proportions was calculated using the following formula:

$$(p_{+1} + p_{1+}) \pm z_{\alpha/2}(ASE)$$

where ($p_{+1} + p_{1+}$) represents the difference in proportions between consumers who answer yes after tasting (p_{+1}) and those who answered yes before tasting (p_{1+}). The term $z_{\alpha/2}$ equals 1.96 and represents the standard normal percentile having a right-tail probability of $\alpha/2$. ASE is the estimated standard error for the proportion difference and was calculated using the following equation:

$$ASE = \{[p_{1+}x(1 - p_{1+}) + p_{+1}x(1 - p_{+1}) - 2x(p_{11}p_{22} - p_{12}p_{21})]/N\}^{1/2}$$

where p_{11} indicates the number of subjects who answered yes both before and after tasting, p_{22} indicates the number of subjects who answered no both before and after tasting, p_{12} indicates the number of subjects who answered yes before and no after tasting, and p_{21} indicates the number of subjects who answered no before and yes after tasting the product. By determining the 95% confidence interval, we know that the calculated difference of proportions is correct 95% of the time.

3.2.4.5 Proportional Odds Models

According to Meullenet *et al.* (2003), the proportional odds model has several advantages. First, it can be applied to ordinal categorical data. Second, it can be used to model the frequencies and estimate the mean scores of the categorical responses. Third, it has the quality of invariance to the choice of response categories; this means that it holds with the same effects when collapsing over any of the response categories (Agresti, 1996). Because logit transformations using the proportional odds model can amplify the differences at the end of the hedonic scale (notably extremely dislike, extremely like), this suggests that differences in the middle of the scale are more subtle, while the more influential differences lie at the ends of the scale (Meullenet *et al.*, 2003). This can actually be advantageous because the two ends of the scale represent consumers who either like or dislike the product, while the middle represents consumers who are undecided. One of the limitations of this model is that it requires a large number of observations in order to model the response (Meullenet *et al.*, 2003). For a predictor X, the proportional odds model:

$$\text{Logit}\ [P(Y \leq j)] = \alpha_j + \beta x, \qquad j = 1,\ldots, J-1,$$

has β describing the effects of X on the log odds of the response in category j or below (Agresti, 1996). In this model, β does not have a j subscript, thus assuming that X has an identical effect for all J – 1 collapsings of the response into binary outcomes. This model is interpreted using odds ratios for the collapsed response scale for any fixed j (Agresti, 1996). The odds ratio for this model uses cumulative probabilities and their complements for two values x_1 and x_2 of X,

$$\frac{P(Y \leq j \mid X = x_2) / P(Y > j \mid X = x_2)}{P(Y \leq j \mid X = x_1) / P(Y > j \mid X = x_1)}.$$

The difference between the cumulative logits at the two values of x is the log of the odds ratio which is equal to $\beta(x_2 - x_1)$ and is proportional to the distance between the x values (Agresti, 1996). The same value β applies to each j value for the collapsing. For $x_2 - x_1 = 1$, the odds of the response below any given category is multiplied by e^{β} for each unit increase in X. X and Y are statistically independent when the model holds with $\beta = 0$.

3.2.5 Mixture Experiments

According to Cornell (1983), when conducting a mixture experiment, the varying ingredient proportions are controlled so that the characteristics of the product depend completely upon the relative percentages of the ingredients in the blend (not on the total amount of the mixture components). The variables controlled in a mixture experiment represent proportional amounts of the mixture. The proportions are expressed in grams, and the proportions sum to 1.0, or unity (Cornell, 1983).

$$X1 + X2 + \ldots + Xn = 1.0$$

In a simplex coordinate system, the values of the mixture proportions are written as (X1, X2, …, Xn). A three component system can be represented using a triangle, with the vertices representing the single-component mixtures where Xi = 1 and Xj = Xk = 0 for i, j, k = 1, 2, and 3 and $i \neq j \neq k$ (Cornell, 1983). The vertices of the triangle are denoted by (1, 0, 0), (0, 1, 0), and

(0, 0, 1), respectively. Any interior points in the triangle represent mixtures that contain all three of the components, and the center (or centroid) of the triangle represents a mixture containing equal proportions (1/3, 1/3, 1/3) of each of the three components (Cornell, 1983).

The data collected from a mixture experiment serves to become a model of the blending surface using a mathematical equation. This model will yield predictions of consumer responses for any combination of the three components involved. It also serves, to some degree, as a measure of the influence on the response of each component as well as the components blended (Cornell, 1983).

3.2.6 Response Surface Methodology

One way to represent the mathematical equation mentioned above is through a response surface. Response surface methodology (RSM) allows one to find various combinations of experimental factors which will ultimately lead to optimum consumer responses (Gacula and Singh, 1986). Analysis of variance (ANOVA) and residual plots are used in order to determine the fit of the model (Sanchez *et al.*, 2004). The function is a continuous function and is represented as a second-degree polynomial (n=3).

$$\eta = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3$$

In an experiment consisting of N trials, the observed value (Y_u) of the consumer response for the u^{th} trial varies about the mean of η and has a common variance σ^2 for all u = 1, 2, …, N observations (Cornell, 1983). It also contains an experimental error ε_u.

Once N observations are obtained, the parameters of the coefficients in the model can be estimated by the least squares method, and, once calculated, can be applied into the model for use in predicting consumer response values (Cornell, 1983). This function can then be graphed as a function of independent variables, resulting in a response surface plot (Gacula and Singh, 1986).

3.2.7 Attaining the Optimal Formulation

Product optimization was performed using the three-component mixture design experiment in conjunction with the logistic regression. The predictive models were obtained using a restricted regression analysis (without intercept) and used to plot the mixture response surface (Prinyawiwatkul, 1997). These contour plots are extremely useful because they allow for the study of the mixture response surface as well as optimal formulations of a product (Rustom, 1991). Logistic regression analysis was used to identify which attributes were critical to overall acceptance and purchase decision. Once determined, these attributes were identified as the limiting factors to obtain optimal formation of the butter cake product. The area within the MRS plots having a score equal to or greater than 6.0 were selected. The superimposition of the MRS plots for which the limiting factors were identified yielded the optimal formulation of the product.

3.3 Results and Discussion

3.3.1 Demographic Information

It is important that all of the information about potential consumers is collected during a consumer study. For this reason, participants in this study were presented with questions about both demographic and product information. These details are incredibly important when determining the target population for a product. It is evident from Table 7 that most of the participants were in the category of ages 18-24 with 66.67%. As the age increased, the frequency decreased, with no participants coming from the age group of greater than 64 years of age.

One hundred fifty-five (52.19%) of the consumers were male and 142 (47.81%) were female (Table 8). Therefore, the consumers surveyed were practically equal in proportion of males to females. The participants in this study were largely Caucasian (67.00%). The next largest group was Asian in descent, with 14.48% participating in the study (Table 9). A large percentage (61.99%) of the consumers who participated in this study had completed some college (Table 10). Graduate level participants were the next largest group with 20.55% (Table 10). A large percentage (41.64%) of the participants in this study had a household income under $9,999 (Table 11). This fact is not surprising as most of the consumers were college-aged.

3.3.2 Product Information

The frequency of consumers who consume rice or rice-based products and butter cakes is presented in Table 12. Most of the participants reported that they do consume rice and/or rice based products. In fact, over 97% of consumers reported that they consume rice and rice based products. However, the number of consumers who consume butter cake products is lower, with only 71.14% responding positively. One of the most important questions that consumers answered about the product information was naming the most important quality attribute when they eat butter cake products. This is an extremely important question specifically in this study because of the different textural properties that rice flour imparts on the cake product. Many different attributes were named, included taste, appearance, odor, and different textural attributes. Consumers were also able to specify if they found another attribute (other) to be more important than any of the aforementioned qualities. Only four participants indicated another attribute to be most important, most asking for a cake made for health-conscious consumers such as a fat-free or sugar-free product.

Table 7: Frequency of Consumer Age

Age	Frequency	Percent	Cumulative Frequency	Cumulative Percent
18-24	200	66.67	200	66.67
25-34	52	17.33	252	84.00
35-44	24	8.00	276	92.00
45-54	14	4.67	290	96.67
55-64	10	3.33	300	100.00
Over 64	0	0	300	100.00

Table 8: Frequency of Consumer Gender

Gender	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Male	155	52.19	155	52.19
Female	142	47.81	297	100.00

Table 9: Frequency of Consumer Ethnicity

Ethnicity	Frequency	Percent	Cumulative Frequency	Cumulative Percent
African American	25	8.42	25	8.42
Hispanic/Spanish	15	5.05	40	13.47
Asian	43	14.48	83	27.95
White (Caucasian)	199	67.00	282	94.95
Other	15	5.05	297	100.00

Table 10: Frequency of Consumer Education Level

Education Level	Frequency	Percent	Cumulative Frequency	Cumulative Percent
High School	8	2.74	8	2.74
Some College	181	61.99	189	64.73
Completed College	43	14.73	232	79.45
Graduate (MS, MA, Ph.D, Ed.)	60	20.55	292	100.00

Table 11: Frequency of Consumer 2003 Household Income

2003 Household Income ($)	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Under 9,999	117	41.64	117	41.64
10,000-19,999	41	14.59	158	56.23
20,000-29,999	25	8.90	183	65.12
30,000-39,999	16	5.69	199	70.82
40,000-49,999	12	4.27	211	75.09
50,000-59,999	13	4.63	224	79.72
60,000-69,999	13	4.63	237	84.34
70,000-79,999	11	3.91	248	88.26
80,000-89,999	8	2.85	256	91.10
90,000-99,999	2	0.71	258	91.81
Over 100,000	23	8.19	281	100.00

Table 12: Frequency of Consumers' Consumption of Rice or Rice-based Products and Butter Cake Products

Consume Rice	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Yes	292	97.33	292	97.33
No	8	2.67	300	100.00
Consume Butter Cake	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Yes	212	71.14	212	71.14
No	86	28.86	298	100.00

According to consumers responses, 62.29% indicated that taste was the majority of responses indicated that taste was the most important attribute (Table 13). The second most important attribute was texture, or more specifically, moistness of the product (16.85%). The mouthfeel of the product is also an important quality attribute for a butter cake product, with 5.62% of consumers choosing this option. However, less than 1 percent of consumers felt that the sandiness of the product was the most important quality attribute. This could be due to the fact that they typically do not consume baked products made from rice flour which tends to impart a sandy or grainy texture to the cake product. Thirty-three observations were missing because many consumers mistakenly selected more than one response as being the most important quality attribute. Therefore, these responses had to be discarded during data analysis.

Another vital question that consumers were asked about product information was whether or not they would purchase a non-wheat butter cake product made entirely from rice flour. They were also asked whether or not they would buy a butter cake product made entirely from rice flour if they were allergic to wheat, a condition more commonly known as Celiac Spruce Disease.

Table 13: Frequency of Consumers' Perception of Most Important Quality Attribute

Quality Attribute	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Taste	185	69.29	185	69.29
Texture (Puffiness)	10	3.75	195	73.03
Texture (Sandiness)	1	0.37	196	73.41
Appearance/ Color	4	1.50	200	74.91
Texture (Mouthfeel)	15	5.62	215	80.52
Odor/ Aroma	3	1.12	218	81.65
Texture (Moistness)	45	16.85	263	98.50
Other	4	1.50	267	100.00

Table 14: Frequency of Consumers' Intention to Purchase a Non-wheat Butter Cake Product and Their Intention After Being Informed About Celiac Spruce Disease

Buy Non-Wheat Butter Cake	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Yes	260	87.84	260	87.84
No	36	12.16	296	100.00
Buy Celiac Spruce	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Yes	252	85.42	252	85.42
No	43	14.58	295	100.00

These two questions were important to determine consumer perceptions before they tasted the product (Table 14). Also, they played a role in determining whether consumer perceptions and purchase intent changed after tasting the product. Interestingly enough, most of the consumers responded that they would purchase a non-wheat butter cake product. The decision to hypothetically purchase a non-wheat butter cake product differed by only approximately 2% when informed about Celiac Spruce Disease before tasting the product

Another important question that consumers answered was what their most favorite flavor of a butter cake product would be (Table 15). Approximately forty-five percent of people responded that the plain flavor would be their favorite. However, 34.36% of people did report that a chocolate flavor would be desirable for this type of product. The berry and coffee flavors were preferred by 9.28 and 7.22% of consumers, respectively. Only 4.12% of participants reported another flavor. Some interesting suggestions included peanut butter and lemon flavors.

Table 15: Frequency of Consumers' Flavor Preferences

Buy Non-Wheat Butter Cake	Frequency	Percent	Cumulative Frequency	Cumulative Percent
Plain	131	45.02	131	45.02
Chocolate	100	34.36	231	79.38
Berry	27	9.28	258	88.66
Coffee	21	7.22	279	95.88
Other	12	4.12	291	100.00

3.3.3 Consumer Acceptability

The mean overall liking scores are presented in Table 16 for each of ten formulations of the butter cake product. The formulation with the highest overall liking score was formulation 8. This contained 75% wheat flour and 25% PGR flour. However, formulation 2 had the next highest overall liking score (6.13). This formulation consisted of 50% wheat flour and 50% rice flour. Finally, formulation 9 (50% wheat, 25% rice, 25% PGR flours) had an overall liking score of 6.09. However, in order to determine the best possible formulation for this product, product optimization was subsequently performed.

3.3.4 Acceptability and Purchase Intent

Each of the ten butter cake formulations was evaluated separately using a 2-point hedonic scale (yes/no) for consumer acceptance, purchase intent, and purchase intent if unable to consume wheat (Celiac Spruce). The percent (%) of positive responses for the aforementioned questions is shown in Table 17. The formulations with the highest acceptability were numbers 8 (85.6%) and 2 (83.3%). Formulation 8 contained 75% wheat flour and 25% pre-gelatinized flour, while formulation 2 contained 50% wheat flour and 50% rice flour. Formulation 8 also rated highest for purchase intent (53.3%) followed by formulation 9 (52.2%). Formulation 9 was made up of 50% wheat flour and 25% of both rice and PGR flours. When consumers were asked about purchase intent if they were not able to consume wheat gluten, the purchase intent increased for all of the different formulations. Formulations 8, 9, and 2 had the highest percentage (63 – 69.7) of positive responses for purchase intent after being informed about Celiac Spruce Disease. These results correspond directly to the mean consumer acceptance scores, where the three above formulations had the highest overall liking of all of the different formulations.

Table 16: Mean Consumer Acceptance Scores for Sensory Attributes and Overall Liking of Ten Butter Cake Formulations*

Formulation Number**	Mean Consumer Acceptance Score						
	Visual Puffiness	**Appearance/ Color**	**Odor/ Aroma**	**Taste**	**Texture**	**Moist**	**Overall Liking**
1	5.67 cde (1.78)	6.27 bcd (1.73)	6.47 ab (1.52)	5.81 ab (1.77)	6.27 ab (1.62)	6.78 a (1.67)	5.90 ab (1.71)
2	6.91 a (1.28)	7.09 a (1.10)	6.90 a (1.37)	5.83 ab (1.76)	6.04 abc (1.78)	6.57 ab (1.59)	6.13 a (1.45)
3	6.80 a (1.48)	7.26 a (1.30)	6.88 a (1.36)	5.59 ab (2.01)	5.20 cd (2.08)	5.78 b (1.89)	5.57 ab (1.89)
4	6.52 ab (1.51)	6.79 ab (1.43)	6.68 ab (1.32)	5.34 b (2.16)	5.04 d (2.07)	6.21 ab (1.81)	5.22 b (2.08)
5	5.79 bcde (1.55)	6.16 bcde (1.60)	6.26 ab (1.66)	5.16 b (1.95)	5.42 bcd (1.91)	5.84 b (2.08)	5.20 b (1.87)
6	5.46 de (1.65)	5.65 de (1.69)	6.07 b (1.44)	5.47 ab (1.98)	5.60 abcd (1.91)	6.17 ab (1.68)	5.59 ab (1.75)
7	5.10 e (1.90)	5.41 e (1.96)	6.06 b (1.60)	5.54 ab (2.00)	5.66 abcd (2.23)	6.14 ab (1.86)	5.58 ab (1.91)
8	5.96 bcd (1.52)	5.93 cde (1.67)	6.42 ab (1.37)	6.28 a (1.78)	6.34 a (1.95)	6.57 ab (1.60)	6.17 a (1.76)
9	5.63 cde (1.69)	5.72 de (1.72)	6.39 ab (1.48)	6.01 ab (1.78)	6.28 ab (1.72)	6.52 ab (1.55)	6.09 a (1.63)
10	6.34 abc (1.49)	6.56 abc (1.49)	6.36 ab (1.38)	5.93 ab (1.66)	5.90 abcd (1.70)	6.28 ab (1.48)	5.87 ab (1.71)
Range***	1.81	1.85	0.84	1.12	1.30	1.00	0.97

*Numbers in parenthesis represent standard deviation of 90 consumer responses.
**Formulation numbers are shown in Table 1 and Figure 1.
***Range: highest score minus lowest score
a, b, c, d, e Means within the same column followed by different letters are significantly different ($p<0.05$)

Table17: Positive (Yes) Responses for Product Acceptability and Purchase Intent of Butter Cake Formulations[a]

Formulation[c]	Acceptability	Purchase Intent	Purchase Intent after CS[b]
1	68 (75.6%)	33 (36.7%)	52 (58.4%)
2	75 (83.3%)	34 (37.8%)	62 (69.7%)
3	66 (73.3%)	34 (37.8%)	46 (51.7%)
4	58 (64.4%)	25 (27.8%)	43 (48.9%)
5	56 (62.9%)	28 (31.5%)	42 (47.2%)
6	67 (74.4%)	30 (33.3%)	48 (53.9%)
7	60 (66.7%)	34 (37.8%)	41 (45.6%)
8	77 (85.6%)	48 (53.3%)	56 (63.6%)
9	72 (80.0%)	47 (52.2%)	57 (64.0%)
10	67 (75.3%)	38 (42.7%)	52 (59.1%)
Overall	666 (74.2%)	351 (39.1%)	499 (56.2%)

[a] Each formulation was evaluated 90 times
[b] Consumers were asked if they would purchase the product if allergic to wheat (Celiac Spruce)
[c] Table 6: Differing formulations of butter cakes shown

3.3.5 Overall Product Differences – Pooled Within Canonical Structure r's

In order to determine if the formulations differed considering all of the sensory attributes simultaneously, the multivariate analysis of variance (MANOVA) method was used. The Wilks' Lambda p-value of less than 0.0001 (Table 18) indicated that all ten formulations were significantly different considering all sensory attributes at the same time. Descriptive discriminant analysis (DDA) was used in order to determine among the ten formulations which attributes underlying differences. According to the pooled within canonical structure in the first dimension (Can 1), visual puffiness (-0.668), appearance / color (-0.725), and odor / aroma (-0.317) did contribute significantly to overall differences among the ten butter cake formulations (Table 19).

Table 18: Multivariate Statistics and F Approximations

MANOVA	Test Criteria and F Approximations for the Hypothesis of No Overall Form Effect				
H = Type III SSCP Matrix for Forms E = Error SSCP Matrix S = 7 M = 0.5 N = 437					
Statistic	**Value**	**F Value**	**Numerator DF**	**Denominator DF**	**Pr > F**
Wilks' Lambda	0.71985	4.71	63	4939.8	<0.0001
Pillai's Trace	0.30480	4.46	63	6174	<0.0001
Hotelling-Lawley Trace	0.35618	4.94	63	3327.4	<0.0001
Roy's Greatest Root	0.24565	24.07	9	882	<0.0001

Table 19: Canonical Structure r's Describing Group Differences Among Butter Cake Formulations[a]

Variable	**Can1**[**]	**Can2**[**]	**Can3**[**]
Visual Puffiness	-0.668*	0.697	0.079
Appearance / Color	-0.725*	0.397	0.484
Odor / Aroma	-0.317*	0.381	0.272
Taste	0.112	0.728	-0.052
Texture	0.293	0.831	0.402
Moistness	0.156	0.545	0.549
Overall Liking	0.132	0.849	0.123
Cumulative Variance Explained (%)	68.97	80.52	88.37

[a] Based on Pooled Within-Group Variances.
* Indicates sensory attributes which largely account for group differences in first dimension.
** The pooled within canonical structure in the first, second and third dimensions.

3.3.6 Logistic Regression Analysis vs. Predictive Discriminant Analysis (PDA) for Acceptance and Purchase Intent

Based on logistic regression analysis for consumer acceptance of the butter cake product, overall liking is the most important attribute with an odds ratio estimate of 3.920 (Table 20). Therefore, for every one point increase in overall liking on the 9-point hedonic scale, overall product acceptance will be increased by 292.0%. Taste and texture are the next most important attributes with odds ratio estimates of 2.776 and 2.480, respectively. This means that for every one point increase in taste and texture on the hedonic scale, overall product acceptance will increase 177.6% and 148.0%, respectively. Using predictive discriminative analysis (PDA), product acceptance can be predicted with 83% and 80% accuracy based on overall liking and taste, respectively (Table 21).

Odds ratio estimates were also determined for purchase intent of the butter cake product (Table 20). It is important to note that the attributes critical to purchase intent are the same attributes which are critical to consumer acceptance. They are as follows: Overall liking, taste, and texture (Odds ratio estimates of 6.915, 3.499, and 3.240, respectively). Therefore, purchase intent will increase by 591.5%, 249.9%, and 224.0% for every one point increase in overall liking, taste, and texture (respectively) on the 9-point hedonic scale. Purchase decision can be predicted using PDA with 84% and 81% accuracy based on overall liking and texture, respectively (Table 21).

Likewise, odds ratio estimates were also determined for purchase intent of the butter cake product if individuals were allergic to wheat (Table 20). They are overall liking, and moistness (Odds ratio estimates of 2.353 and 1.793, respectively).

Table 20: Prob>X^2 and Odds Ratio Estimates for Consumer Acceptance and Purchase Intent

Consumer Acceptance			
Independent Variable	**Prob>X^2 (full)**	**Odds Ratio Estimate (full)**	**Odds Ratio Estimate (single)**
Visual Puffiness	0.9473	0.993	1.442
Appearance/Color	0.2069	1.144	1.429
Odor	0.8939	1.012	1.656
Taste	0.0019	1.361	2.776
Texture	0.0870	1.181	2.480
Moistness	0.3561	1.078	1.952
Overall Liking	<0.0001	2.496	3.920
Purchase Intent			
Independent Variable	**Prob>X^2 (full)**	**Odds Ratio Estimate (full)**	**Odds Ratio Estimate (single)**
Visual Puffiness	0.9412	0.993	1.490
Appearance/Color	0.8834	0.985	1.405
Odor	0.3650	0.919	1.622
Taste	0.0170	1.331	3.499
Texture	<0.0001	1.568	3.240
Moistness	0.8894	1.014	2.361
Overall Liking	<0.0001	4.019	6.915
Purchase Intent Celiac Spruce			
Independent Variable	**Prob>X^2 (full)**	**Odds Ratio Estimate (full)**	**Odds Ratio Estimate (single)**
Visual Puffiness	0.7877	0.979	1.348
Appearance/Color	0.3188	1.084	1.342
Odor	0.8896	1.010	1.469
Taste	0.5264	1.054	1.899
Texture	0.4007	1.065	1.836
Moistness	0.0277	1.160	1.793
Overall Liking	<.0001	1.914	2.353

Therefore, purchase intent will increase by 135.3% and 79.3% for every one point increase in overall liking and moistness (respectively) and the 9-point hedonic scale. Purchase decision can be predicted with 74.9%, 72.8%, and 72.7% accuracy based on overall liking, taste and texture, respectively, using PDA (Table 21). In this study, overall liking, texture, and taste were identified as critical attributes for both product acceptance as well as purchase decision for a butter cake product made predominately from rice flour. These attributes are considered as critical limiting attributes which will be subsequently used to obtain the optimum formulation.

Table 21: % Hit-Rate for Acceptability and Purchase Intent of Butter Cake Product

Attributes	% Hit Rate		
	Acceptability	**Purchase Intent**	**Purchase Intent CS**
All 7 Combined	85.5	80.9	74.0
Visual Puffiness	65.7	64.0	61.5
Appearance / Color	58.2	59.2	59.2
Odor / Aroma	64.0	63.0	62.8
Taste	80.4	72.3	72.8
Texture	78.1	80.7	72.7
Moistness	76.4	72.6	69.4
Overall Liking	83.3	84.3	74.9

3.3.7 Consumer Sensory Profiling Critical to Product Acceptance and Purchase Decision

The most discriminating attributes were appearance and texture (canonical correlation = -0.63 and 0.60, respectively), as shown in Table 19. Overall liking, texture and taste were significantly critical to both product acceptance and purchase decision (Prob>χ^2 less than 0.05) using logistic regression analysis (Table 20). Using predictive discriminative analysis (Table 21), product acceptance can be predicted with 83% and 80% accuracy based on overall liking and taste, respectively. In this study, overall liking, texture, and taste were identified as critical attributes for both product acceptance as well as purchase decision for a butter cake product made predominately from rice flour.

3.3.8 Change in Probability of Purchase Intent

In order to determine if a change in the probability of the purchase intent of consumers before and after they tasted the product, the McNemar test was performed. In this case, the null hypothesis (H_0: $\pi_{1+} = \pi_{+1}$) states that the probability of the purchase intent is the same before and after the consumers tasted the product, i.e., no significant difference in the probability of purchase intent before and after consumers tasted the butter cake product. Thus, it is being tested whether the probability of consumers who answered yes after (π_{+1}) and the probability of those who answered yes before (π_{1+}) is significantly different.

Table 22: Changes in Probability of Purchase Intent using McNemar Test

Formulation	χ^2	**p-value**	**95% Confidence Interval**	
1	15.696	<0.0001	0.118	0.309
2	24.500	<0.0001	0.209	0.421
3	7.200	0.0073	0.040	0.229
4	13.500	0.0002	0.104	0.305
5	12.250	0.0005	0.076	0.239
6	15.696	<0.0001	0.118	0.309
7	3.267	0.0707	-0.005	0.161
8	4.000	0.0455	0.004	0.178
9	5.000	0.0253	0.017	0.208
10	9.800	0.0017	0.065	0.253

According to the results of the McNemar test, the probability of purchase intent of the butter cake product after consumers are informed of potential health benefits is significant at $\alpha = 0.05$ for all formulations except the one that contained 50% wheat and 50% PGR flours (Table 22). We can predict with 95% confidence that the probability of purchase intent will be increased by at least 21% and at most 42% for the formulation containing 50% wheat and 50% rice flours. Also, for the formulation containing 100% rice flour, we can predict with 95% confidence that the probability of purchase intent after being informed about potential health benefits will increase by at least 4% and at most 23%.

3.3.9 Proportional Odds Models

The full model using the proportional odds model takes all predictors into account, including visual puffiness, appearance/color, odor, taste, texture, moistness, and sandiness of the butter cake product. This model has $\chi^2 = 12.11$ with 7 degrees of freedom, with a p-value of 0.0971. This model is fitting moderately well. However, the backward stepwise selection procedure was used in conjunction with this procedure. This resulted in the selection of a model that only contains the predictors: odor, taste, texture, and moistness. This model has $\chi^2 = 4.21$ with 3 degrees of freedom, with a p-value of 0.2392. This relatively high p-value indicates that the model is fitting well. The hypothesis being tested is that the reduced model fits as well as the full model. Some non significant predictors were removed from the model using this procedure (odor, taste, texture, and moistness were significant) leaving a final reduced model containing only these predictors, from which the odds ratios were calculated.

$\text{Log}\,[P(Y <= j)/P(Y > j)] = \beta_0\, j + \beta_1\, \text{odor} + \beta_2\, \text{taste} + \beta_3\, \text{texture} + \beta_4\, \text{moistness}$

$\text{Log}\,[P(\text{Like})/P(\text{Neither + Dislike})] = -12.7 + 0.25\text{odor} + 1.10\text{taste} + 0.64\text{texture} + 0.36\ \text{moistness}$

$\text{Log}\,[P(\text{Neither + Like})/P(\text{Dislike})] = -11.2 + 0.25\text{odor} + 1.10\text{taste} + 0.64\text{texture} + 0.36\ \text{moistness}$

Table 23: Proportional Odds Model Odds Ratio Estimates

Attribute	Pr > χ^2	Odds Ratio Estimate
Odor	0.0008	1.289
Taste	< 0.0001	3.002
Texture	< 0.0001	1.892
Moistness	< 0.0001	1.435

The odds ratio estimates for the reduced model in Table 23. The odds of liking the product relative to either neither or disliking the product increases 1.29 times as x increases to x + 1 for odor for all other factors being held constant. The odds of liking the product relative to either neither or disliking the product increases 3.00 times as x increases to x + 1 for taste, when all other factors remain the same. The odds of liking the product relative to either neither or disliking the product increases 1.89 times as x increases to x + 1 in terms of texture, all other factors held constant. The odds of liking the product relative to either neither or disliking the product increases 1.43 times as x increases to x + 1 for moistness with all other factors being equal. From these results, one can conclude that all of these predictors (odor, taste, texture, and moistness) are important predictors in terms of overall liking. This relates directly to results from logistic regression analysis which concluded that taste, texture, and moistness were important factors in terms of consumer acceptance and purchase intent.

3.3.10 Product Optimization

Product optimization was performed using the three-component mixture design experiment in conjunction with the logistic regression. The predictive models were obtained using a restricted regression analysis (without intercept) and used to plot the mixture response surface (MRS). Each of the sensory attributes in question were represented using a MRS

(Figure 7). The optimal formulation was determined by superimposing all of the attributes with a mean acceptance score greater than 6.0.

It is evident from Figure 8 that the superimposition of all attributes with consumer acceptance levels greater than 6.0 created an extremely small area from which to derive the optimum formulations. Therefore, logistic regression analysis was used in order to determine the most critical attributes in terms of both consumer acceptance and purchase intent in order to eliminate attributes that were not of critical importance. The probability greater than Chi-square (χ^2) was looked at in order to determine these critical attributes. If Prob > χ^2 for a particular attributes was less than 0.1 ($\alpha = 1\%$), then that attribute was considered significant in terms of either consumer acceptance, purchase intent, or both.

The Prob > χ^2 for each attribute is shown in Table 18. In terms of consumer acceptance, only overall liking, taste, and texture (Prob > χ^2 = <0.0001, 0.0019, and 0.0870, respectively) are significant. These same attributes (Prob > χ^2 = <0.0001, 0.0170, and <0.0001, respectively) are also significant in terms of consumer purchase intent.

Therefore, the MRS of overall liking, taste, and texture were the only attributes used in determining the optimal formulation. The superimposition of the MRS plots (Figure 9) of overall liking, taste and texture indicates that any formulations with 50-95% wheat, 0-50% rice and 0-40% pre-gelatinized rice flours would yield an acceptable product that would potentially be accepted and purchased by the consumers.

3.4 Conclusions

The main purpose of this study was to determine the optimal formulation of a butter cake product containing mainly rice flour. However, the use of 100% rice flour in a cake formulation is difficult because it changes the structural and textural formation of the cake, and, in turn, it changes consumers' attitudes and perceptions about product acceptance and purchase intent. In conclusion, it was determined through the superimposition of the MRS plots of overall liking, taste and texture indicates that any formulations with 50-95% wheat, 0-50% rice and 0-40% pre-gelatinized rice flours would yield an acceptable product. The use of rice flour prepared from broken rice kernels would increase the utilization of the broken rice and also add value back to it.

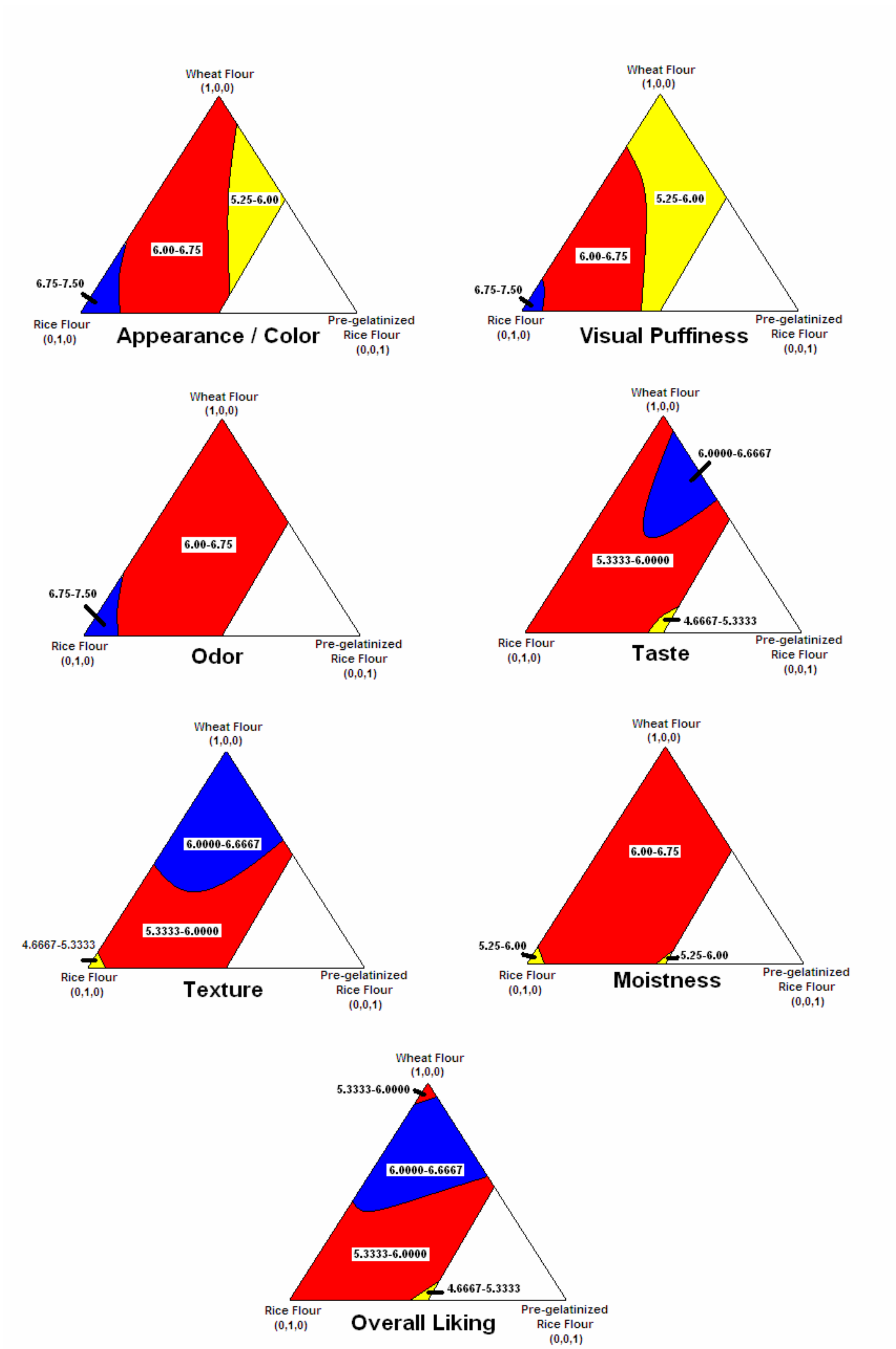


Figure 7: Response Mixture Surface (RMS) for each of the Sensory Attributes Evaluated by Consumers.

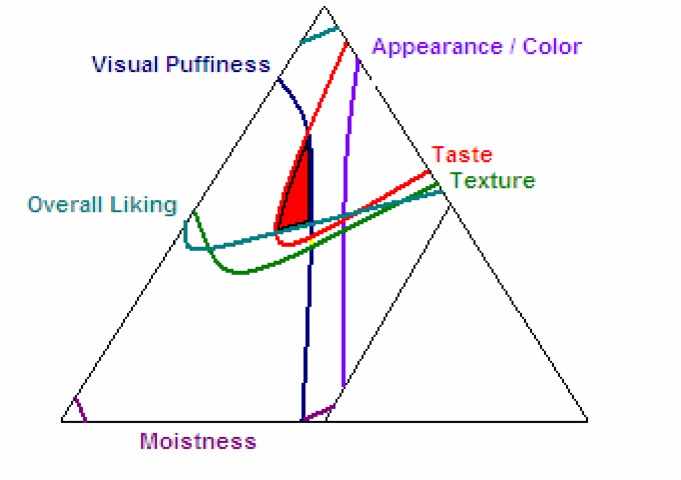


Figure 8: Superimposition of each Product Attribute Showing Optimal Formulation

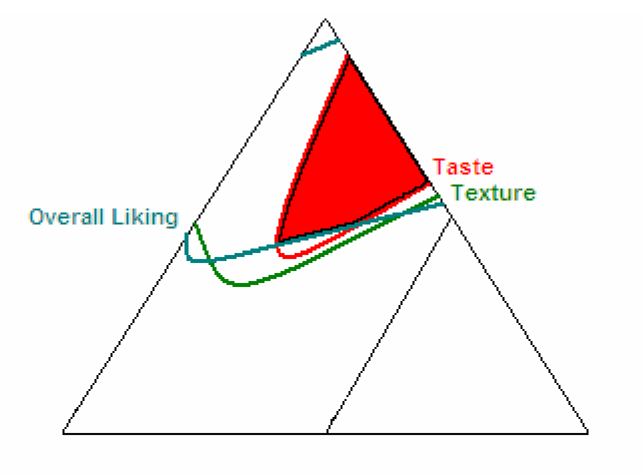


Figure 9: Superimposition of Critical Product Attributes to Determine Optimal Formulation

CHAPTER 4. SENSORY DISCRIMINATION TEST FOR THE PRODUCTS MADE FROM WHEAT AND RICE FLOURS

4.1 Introduction

One of the major differences between the butter cakes made from rice flour and those from wheat flour is the sandiness present in the cakes. Other differences exist in visual, aroma, and taste categories as well. For this reason, it is extremely important to determine if potential consumers are able to differentiate among various butter cake formulations. If consumers are unable to correctly differentiate among the samples containing 100% wheat flour, 100% rice flour, and 50/50 wheat to rice flour, then it is possible to market the 100% rice flour cake. This is of special significance to those individuals who are severely intolerant to gluten, the protein found in wheat flour.

The objectives of this study were (1) to determine whether consumers are able to differentiate the butter cake formulations from the control (100% wheat) and (2) to compare results with the previous studies to determine if a significant difference exists in terms of overall liking of three butter cake formulations.

4.1.1 Discriminative Sensory Testing

When samples are easily distinguishable by consumers, scaling measure are useful for determining differences among products. However, when samples are more closely related, difference tests are more appropriate for determining differences (Cliff *et al.*, 2000). The major question of interest when performing discriminative sensory tests is whether or not a sensory difference exists between samples. Many different tests exist to determine if panelists can detect overall differences in specific attributes of two or more samples. Some of these tests include, but are not limited to, A-Not-A tests, difference from control tests, and traditional and/or bipolar R-index tests.

Discriminative sensory testing is extremely useful when determining changes in product attributes. This technique can be used to determine whether products change with respect to differing processing techniques, packaging, and storage conditions. It can also be used to determine the presence or absence of an overall difference or difference in specific attributes of products. Two other uses of discriminative sensory testing are to monitor a potential panelist's ability to differentiate between samples and to screen potential panelists for descriptive analysis procedures.

Three distinct steps occur when a panelist performs a sensory test. Firstly, when the stimulus is perceived, its sensory attributes will be stored into memory. Secondly, the subject uses cognitive strategies in order to perform the task required, such as discriminating between samples. Finally, a response is generated by the panelist based on the combination of the cognitive process used and the information available (Rousseau, 2001).

4.1.2 Signal Detection Theory

Signal detection is a measurement technique that allows for the separation of a judge's true sensitivity from response bias. When signal detection theory was first developed, it was used primarily to offer a measure of the sensory input signal required in order to detect differences between samples (Cliff *et al.*, 1997). While signal detection was originally applied to issues in auditory and visual stimuli, it can be applied to issues in taste, smell, or other sense modalities (Lawless and Heymann, 1998). Signal detection involves 2 or more levels of stimulus. The noise (N) is the background stimulus, while the signal (S) is a weak but higher level of stimulus near the threshold. It is important to note that in sensory experiments involving food products, the signal can be new products while the noise can be the control product. Over many different presentations of the stimuli, correct decisions (also known as "hits") are made when a signal is presented and perceived (Figure 10). Conversely, sometimes the judge responds incorrectly by responding positively for noise stimuli, thus resulting in a false alarm (Lawless and Heymann, 1998).

The theory of signal detection makes several assumptions. First, it is assumed that the sensations from both the signal and noise are normally distributed with equal variances. Also, the judge will place a stable criteria for judgment of the stimulus once he is familiar with the stimuli (Lawless and Heymann, 1998). One also assumes that variability exists in both the signal and the noise due to variation in the background levels in sensory nerves and other factors. When larger overlap occurs between the signal and the noise distributions, it becomes harder for the judge to discriminate between the two stimuli (Lawless and Heymann, 1998).

In signal detection theory, d' is the sensory difference between signal and noise stimuli (Figure 11). This represents the separation of the means of the two distributions in units of standard deviation. The d' value is calculated from the difference of the Z-score from the proportion of hits minus the Z-score from the proportion of false alarms (Lawless and Heymann, 1998). The value for d' remains approximately constant as each subjects' criteria for decision changes. It is important to note that if the hit rate equals the false alarm rate, then no discrimination exists between the two levels of stimuli, thus the panelist is unable to discriminate between the intensities of the stimuli. An advantage of using this value is that it is possible to estimate the sensory differences in specific attributes independently of where the observer sets the criterion for response (Lawless and Heymann, 1998). Unfortunately, this method is a time consuming process (Cliff *et al.*, 1997). Likewise, one of the major limitations of the d' value is

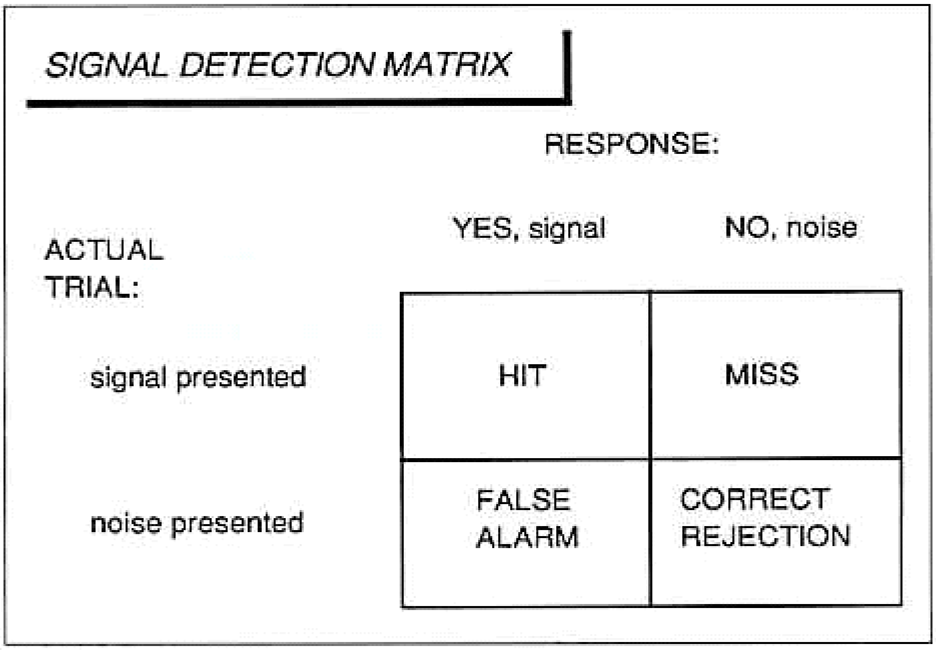


Figure 10: Signal Detection Matrix (Lawless and Heymann, 1998)

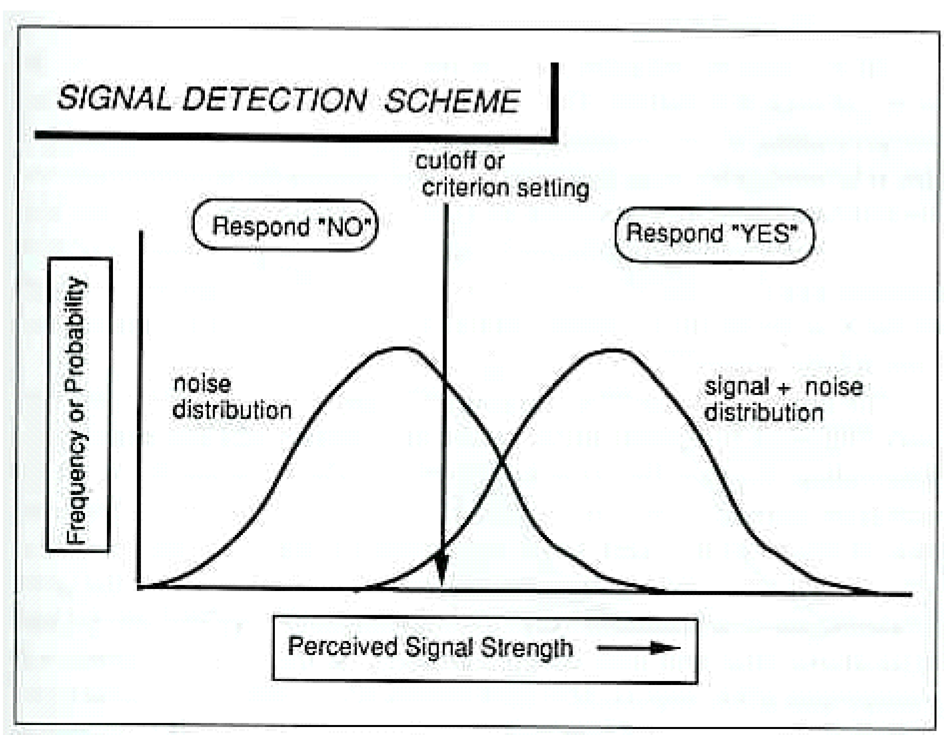


Figure 11: Signal Detection Scheme (Lawless and Heymann, 1998)

that it requires a normal distribution in order to be calculated (Lawless and Heymann, 1998). For these reasons, procedures were developed based on signal detection theory that allowed calculations of differences between samples.

4.1.3 ROC Curve-Differing Sensitivities

One measure of discrimination which does not depend entirely on signal and noise is the calculation of the area under the Receiver Operating Characteristic (ROC) Curve (Figure 12). This type of curve can be formed when using data from a same-different test, where it is plotted using the proportion of 'Hits' and 'False Alarms' (Rosseau, 2001). Hits are the proportion of answers that correctly differentiate the samples, while false alarms are the proportion of answers that are different when the samples were the same. The ROC curve is useful in that it allows for the definition of a judge's ability to detect stimuli across different levels of criterion (Lawless and Heymann, 1998). This level of discrimination is proportional to the area under the ROC which is related to the d' value. If d' is equal to zero, then the hit and false alarm rates are equal. This means that the participant is unable to discriminate correctly between the two stimuli. In fact, curves that bend more toward the upper left represent a higher level of discrimination between the stimuli.

4.1.4 R-Index Approach

One of the most used techniques for determining the degree of difference between samples is the 9-point hedonic scale; however, the R-index approach can be used as a simple alternative for measuring consumers' perceptions about particular product attributes (Pipatsattayanuwong et al, 2001). The theories of signal detection of stimuli are applied to foods when using the R-index. The R-index is a value of the probability that a given panelist will be able to correctly distinguish among two samples. This value is, therefore, an extremely useful

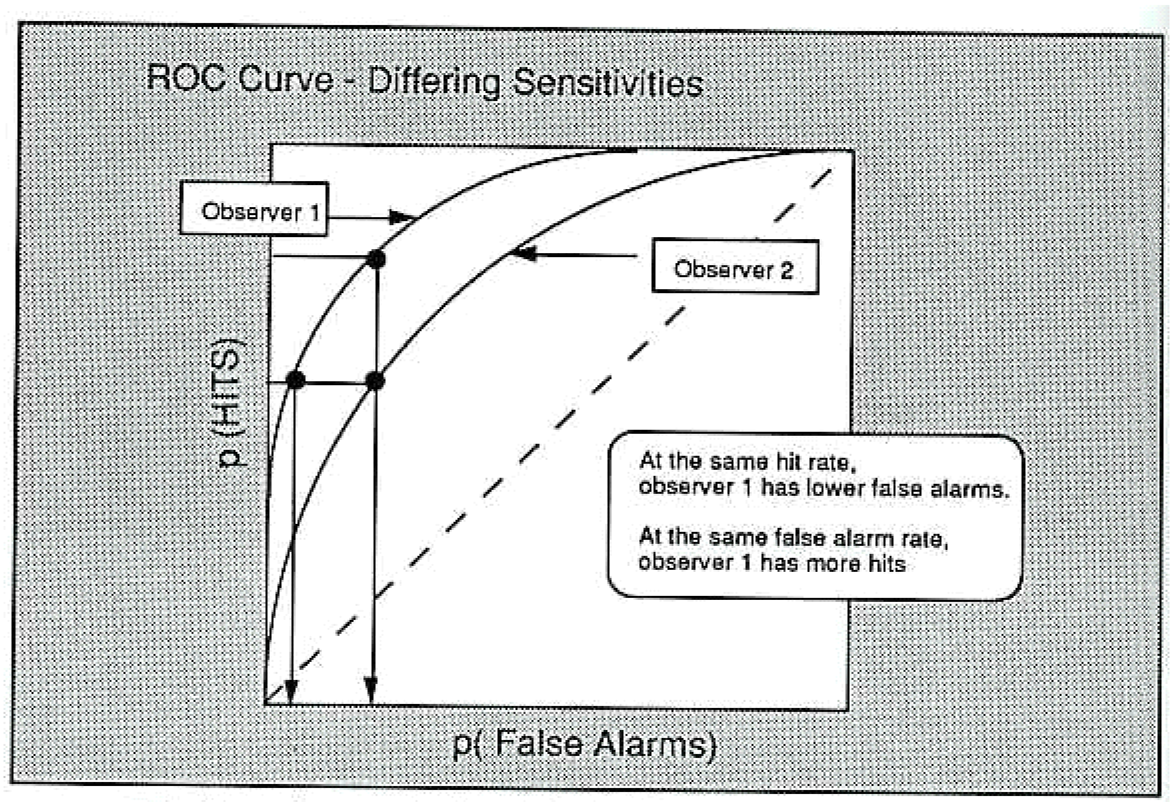


Figure 12: ROC Curve-Differing Sensitivities

measure of the difference between food samples. In fact, the higher the degree of difference between the control and the other samples, the greater the probability of a judge being able to correctly distinguish between samples. One reason that the R-Index is extremely useful when testing food products is that it is difficult to perform the large number of trials necessary in order to obtain a precise estimate of d' using signal detection theory (Lawless and Heymann, 1998).

The R-index is a measure of discrimination that does not depend on the exact forms of distributions for signal and noise; it converts rating scales to an index, which is related to the percentage of area under the ROC curve (Lawless and Heymann, 1998). Also, according to Cliff *et al*., (2000), this test is independent of response bias or criterion level for individual judges. The magnitude of the signal required before the judge can discriminate between the signal and the background noise is called the response bias. This is a cognitive area of discrimination and differentiation and has no relation to the sensory system and its sensitivity (O'Mahony, 1992).

An R-Index value of 100% means that the judge can discriminate correctly between the samples. An R-Index value of 50% means that the judge is using a chance discrimination process. Intermediate values between these two indicate a probability of discrimination between chance and correct choice (Cliff *et al.*, 2000).

The use of the traditional R-Index approach has several advantages. First, it enables one to perform a more powerful parametric analysis. This is especially useful when greater than two samples are tested. Secondly, if a judge is sensitive and accurate, then only few judges are needed with a large number of replications. Also, the judge does not have to make a numerical estimate of the degree of difference between the food samples; they are simply required to state whether they feel if the sample is the same or different. However, some disadvantages of this technique are that it is time consuming, requires more samples, and does not provide a direction of the difference with regard to the attribute in question. Also, the traditional R-Index provides only the probability of the judge being able to distinguish between the samples; however, it does not give the direction or magnitude of the difference.

A bipolar R-Index measure exists when samples may have a higher or lower intensity in terms of the specified attribute. R_{more} is calculated from the values which judges specify either more sure (S+), more not sure (S+?), same not sure (N?), and same sure (N). R_{less} is calculated from the values which judges specify either less sure (S-), less not sure (S-?), same not sure (N?), and same sure (N). In this method, N? and N are used for both R-Index calculations. In this case, the data are used twice, leading to an overestimation of the sample size.

Even though both the unipolar and bipolar methods provide consistent results, the bipolar R-index values reveal bidirectional differences among the samples; for this reason they provide more information about consumers' perceptions of the product.

4.2 Materials and Methods

4.2.1 Butter Cake Preparation

Rice flour was obtained from Rivland Foods, Houston, TX. All-purpose wheat flour (Gold Medal Flour, General Mills Sales, Inc., Minneapolis, Minnesota) was purchased from the local grocery store. All other ingredients were obtained locally. The total flour content in each of the cakes was 24.8%. Each formulation contained the same amounts of butter (17.4%), sugar (7.44%), corn syrup (23.0%), eggs (14.5%), milk (11.9%), baking powder (0.682%), cream of tartar (0.155%), and vanilla (0.207%). See Table 24 for details about percentages of ingredients in the formulations.

The first step in the baking process included melting the butter and combining it with the sugar and corn syrup. Next, the flour and baking powder were sifted together and then added to the mixture. The mixer (KitchenAid 6 quart Stand Mixer, KitchenAid, U.S.A) was turned on the stir setting just to combine the ingredients. Next, the yolks and whites of the eggs were separated. The egg yolks were added one at a time to the mixture, followed by the vanilla and milk. It was mixed for 3 minutes on level 6 with the flat beater. This mixture was set aside for later use. The next step in the process involved beating the egg whites with cream of tartar into stiff peaks. This was done using the wire whip attachment and mixing for 4 minutes on level 10. The egg white mixture was subsequently folded into the mixture gently so as not to break up the air bubbles in the meringue. Next, the batter was poured into two 5 x 9 inch pans (greased with cooking oil spray) and baked at 350°F for 40-50 minutes until golden brown.

Table 24 shows each of the individual formulations for the butter cake product as well as the percentages of each type of flour contained. The rest of the ingredients remained the same for each different formulation. Formulation 1 100% rice flour, formulation 2 contained a 50:50 ratio of wheat to rice flour, and formulation 3 contained 100% wheat flour.

Table 24: Differing Formulations of Butter Cakes[a]

Formulation	% Wheat Flour	% Rice Flour	% Pre-gelatinized Flour
1	0	100	0
2	50	50	0
3	100	0	0

[a] The flour component system (100% in the mixture design) was 24.8% of the total composition. 23.0% corn syrup, 17.4% butter, 14.5% eggs, 11.9% milk, 7.44% sugar, 0.682% baking powder, 0.207% vanilla, and 0.155% cream of tartar comprised the remaining part of the formulation.

4.2.2 Consumer Test

100 untrained consumers participated in this study. Consumers were randomly selected from the Baton Rouge, LA, area. Criteria for recruitment included the following: (1) they had to be at least 18 years of age, (2) they were not allergic to wheat, rice, butter, sugar, corn syrup, eggs, milk, vanilla, and cream of tartar, and (3) they were available for the required 30-35 minutes to complete the survey.

Consumers were asked to fill out three separate sections of the survey. The first section involved a visual inspection of the butter cake. They were asked if the three coded samples in terms of overall appearance (249, 368, and 157) were either the same or different from the labeled control (100% wheat flour) and if they were sure or unsure of their decision. They were also asked to rate the denseness, moistness, and sandiness of the butter cake when compared to the control. Consumers specified if they thought these attributes were more than (sure, unsure), the same (sure, unsure) or less than (sure unsure) the labeled control sample. Consumers were asked to evaluate the odor or aroma of the three coded samples as compared to the control. They specified if each sample was the same or different and whether they were sure or unsure of their decision.

Finally, consumers evaluated the samples by tasting them and comparing them with the labeled control sample. They were asked to evaluate the samples in terms of sweetness, softness, moistness, mouthfeel (oil/fat coating on the surface of the tongue), sandiness, and stickiness (adherence to palate or tongue). The consumers determined if the samples were more than (sure, unsure), the same (sure, unsure) or less than (sure, unsure) the labeled control in terms of the above attributes.

4.2.3 Statistical and Data Analysis

The R-Index approach was used in order to determine if consumers would be able to distinguish differences in attributes of the butter cakes when compared to the control. This test requires that judges answer the question. It is a forced-choice test. Using this technique, judges must be able to distinguish which of the samples are signal sure (S), signal not sure (S?), noise not sure (N?), and noise sure (N).

The traditional R-Index approach only requires that the judge rate whether the sample is the same (sure, unsure) or different (sure, unsure) from the labeled control (Table 25). This value is calculated as follows and can be expressed as a percentage.

Table 25: Traditional R-Index Approach

	Judge's Response				**Total**
Sample Served	**S**	**S?**	**N?**	**N**	
S	*a*	*b*	*c*	*d*	$n_s = a+b+c+d$
N	*e*	*g*	*h*	*h*	$n_N = e+f+g+h$

R-Index = {[a(f+g+h) + b(g+h) + ch] + [½ (ae+bf+cg+dh)]} / [(a+b+c+d) + (e+f+g+h)]

The bipolar R-Index approach requires that the panelist rates the attributes as more (sure, unsure), same (sure, unsure) or less (sure, unsure) than the labeled control (Table 26). This value provides both the magnitude and the direction of the difference that was perceived by the participant.

Table 26: Bipolar R-Index Approach

	More than Control Sure (S+)	**More than Control Unsure (S+?)**	**Same as Control Unsure (N?)**	**Same as Control Sure (N)**
Signal	a_1	b_1	c_1	d_1
Noise	e_1	f_1	g_1	h_1
	Less than Control Sure (S-)	**Less than Control Unsure (S-?)**	**Same as Control Unsure (N?)**	**Same as Control Sure (N)**
Signal	a_2	b_2	c_2	d_2
Noise	e_2	f_2	g_2	h_2

The bipolar R-Index value is calculated as follows:

$$\text{R-More} = \frac{\{[a_1(f_1+g_1+h_1) + b_1(g_1+h_1) + c_1h_1] + [\tfrac{1}{2}(a_1e_1+b_1f_1+c_1g_1+d_1h_1)]\}}{[(a_1+b_1+c_1+d_1) + (e_1+f_1+g_1+h_1)]}$$

$$\text{R-Less} = \frac{\{[a_2(f_2+g_2+h_2) + b_2(g_2h_2 + c_2h_2 + [\tfrac{1}{2}(a_2e_2+b_2f_2+c_2g_2+d_2h_2)]\}}{[(a_2+b_2+c_2+d_2) + (e_2+f_2+g_2+h_2)]}$$

Because we want to determine if the attribute in question is either more or less in intensity, a frequency table was prepared with the number of discriminators compared to the proportion of more or less values recorded. Of the two measures, either more or less, one direction was chosen based on which had the higher number of cumulative responses. Therefore, it was possible to determine whether a significant difference existed between the samples using a one-tailed test at $\alpha = 0.05$.

4.3 Results and Discussion

The results for the traditional R-Index are presented in Table 27. The attributes that were tested using this method were visual puffiness and odor/aroma of the cake samples. For these two attributes, panelists were asked only to determine if the coded samples were the same or different from the labeled control and if they were sure or unsure. The hypothesis that was being tested was that no significant difference exists between the cakes made from 50/50 wheat/rice flours and 100% rice flour from the control of 100% wheat flour. This would mean that the judges were not able to correctly discriminate between the samples.

However, as is shown in Table 27, all of the calculated R-Index values were greater than critical value at a significance level of 0.05 using a two-tailed test (Bi *et al*., 1995). Therefore, we can conclude that consumers are able to correctly discriminate between cakes made from rice flour from those made from wheat flour in terms of visual puffiness and odor or aroma. This information is verified by a previous study (Table 28) which shows that consumers perceived the 100% wheat formulation to be significantly different from the 50/50 wheat/ rice blend and the 100% rice flour formulation in terms of visual puffiness using a 9-point hedonic scale. However, in terms of odor/aroma, a significant difference did not exist between the three butter cake formulations when participants rated the samples using a 9-point hedonic scale. This means they can differentiate the odor among the 3 samples, but they preferred the odor from the 3 samples equally. From the previous studies, it has been determined that neither visual puffiness nor odor were viewed as critical factors for product acceptance and purchase decision of the butter cake products (Table 28).

This information shows that consumers can correctly distinguish between the samples containing rice flour from the control containing only wheat flour in terms of both visual puffiness and odor. However, because it has been previously established that neither of these factors play a critical role in consumers' decision to purchase the product, they are not as important as other factors.

As stated previously, the bipolar R-Index not only gives the magnitude of the difference perceived by consumers, but it also gives the direction of the difference (either more or less) with

Table 27: Traditional R-Index for Attributes of Butter Cakes

Attribute	Sample	Different Sure S	Different Unsure S?	Same Unsure N?	Same Sure N	n	R-Index	R-critical
Visual Puffiness	249	47	18	23	12	100	84.10	59.66
	368	58	19	13	9	99	87.71	59.66
	157	6	5	21	67	99		
Odor	249	25	19	24	31	99	63.31	59.66
	368	53	19	20	9	101	80.40	59.66
	157	10	12	27	49	98		

Table 28: Mean Consumer Acceptance Scores for Sensory Attributes and Overall Liking of Differing Butter Cake Formulations*

Formulation Number**	Mean Consumer Acceptance Score						
	Visual Puffiness	Appearance/ Color	Odor/ Aroma	Taste	Texture	Moist	Overall Liking
100% Wheat	5.67 cde (1.78)	6.27 bcd (1.73)	6.47 ab (1.52)	5.81 ab (1.77)	6.27 ab (1.62)	6.78 a (1.67)	5.90 ab (1.71)
50% Wheat 50% Rice	6.91 a (1.28)	7.09 a (1.10)	6.90 a (1.37)	5.83 ab (1.76)	6.04 abc (1.78)	6.57 ab (1.59)	6.13 a (1.45)
100% Rice	6.80 a (1.48)	7.26 a (1.30)	6.88 a (1.36)	5.59 ab (2.01)	5.20 cd (2.08)	5.78 b (1.89)	5.57 ab (1.89)

*Numbers in parenthesis represent standard deviation of 90 consumer responses.
**Formulation numbers are shown in Table 1 and Figure 1.
a, b, c, d, e Means within the same column followed by different letters are significantly different ($p<0.05$)

respect to a specified attribute. The bipolar R-Indices$_{less}$ were calculated for the following attributes: visual denseness, visual moistness, visual sandiness, sweetness, softness, moistness, mouthfeel, sandiness, and stickiness. From the data collected, it was possible to determine which direction of the R-Index value to calculate. Table 29 shows this procedure. The R-Indices$_{less}$ were calculated for visual denseness, visual moistness, moistness after tasting, mouthfeel, and stickiness for both the 50/50 blend and the 100% rice flour cakes. Likewise, for the sample containing 100% rice flour, the R-Indices for less sweetness and softness were calculated. For both samples containing rice flour, the R-Indices$_{more}$ for visual sandiness and sandiness were calculated. Also, the R-Index for more softness was calculated for the sample containing a 50/50 ratio of wheat to rice flour.

According to Table 30, all of the calculated R-indices were significantly different from the critical value, thus indicating that consumers were able to correctly determine a difference in the samples from the control sample in terms of visual sandiness, softness (only for the 50/50 blend), and sandiness by tasting. This indicates that consumers correctly perceived more stimuli in these attributes than the control, or noise. This is a correct conclusion because the rice flour is more sandy than wheat flour, and consumers were indeed able to differentiate between the two.

In general, consumers perceived attributes for the cakes containing rice flour having a less intense stimulus than the control (Table 31). Also, consumers were able to correctly differentiate between the 50/50 blend of wheat and rice flours in terms of sweetness (Table 31); however, they were not able to determine whether it had more or less of the attribute than the control. In fact, all of the attributes were considered to be less except for visual sandiness, softness (sample 247), and sandiness after tasting. Judges determined that visual denseness, visual moistness, sweetness (sample 368), softness (sample 368), moistness, mouthfeel, and stickiness were all less than the control made from 100% wheat flour. However, it is important to note that in the previous studies (Table 28), in terms of taste the three formulations were not significantly different when rated using a 9-point hedonic scale. Also, in terms of texture, only the 100% wheat and 100% rice flours were significantly different. Likewise, with respect to moistness, the 50/50 blend of wheat and rice flours was not significantly different from either the 100% wheat or 100% rice formulations; however, the 100% wheat and 100% rice formulations were significantly different. Therefore, it is possible conclude that although consumers did perceive less of each of the aforementioned attributes when compared with the control, the fact that significant differences were not found indicate that consumers could potentially be willing to trade having less of a specific attribute in order to gain certain health benefits, especially if they are not able to consume any products containing wheat and its derivatives.

Table 29: Direction of Intensity of Stimulus for Each Attribute of Butter Cake Samples

Attribute	Sample	S+	S+?	N?	N	S-	S-?	Total N	Discriminators S+, S+?, S-, S-?	More	Less	Bipolar R-Index
Visual Dense	249	7	8	12	6	43	22	98	80	15	65	Less
	368	7	5	11	5	52	17	97	81	12	69	Less
Visual Moistness	249	7	12	23	12	28	18	100	65	19	46	Less
	368	7	8	18	8	39	21	101	75	15	60	Less
Visual Sandiness	249	11	24	26	9	17	10	97	62	35	27	More
	368	31	19	17	6	19	6	98	75	50	25	More
Taste Sweet	249	20	11	21	16	21	10	99	62	31	31	More/Less
	368	12	9	17	6	46	8	98	75	21	54	Less
Taste Softness	249	28	7	25	15	16	9	100	60	35	25	More
	368	22	13	12	7	35	11	100	81	35	46	Less
Taste Moistness	249	10	11	16	15	34	14	100	69	21	48	Less
	368	14	1	12	4	53	16	100	84	15	69	Less
Taste Mouth	249	10	8	23	11	39	8	99	65	18	47	Less
	368	13	6	17	4	45	16	101	80	19	61	Less
Taste Sandiness	249	35	21	16	13	12	2	99	70	56	14	More
	368	61	21	8	2	5	2	99	89	82	7	More
Taste Stickiness	249	9	7	18	12	38	16	100	70	16	54	Less
	368	6	10	11	4	57	11	99	84	16	68	Less

Table 30: R-Index for Attributes with "More" than Control

Attribute	Sample	S+	S+?	N?	N	n	R-Index	R-critical (1-tailed)
Visual Sandiness	249	11	24	26	9	70	75.20	59.71
	368	31	19	17	6	73	83.46	59.39
Taste Softness	249	28	7	25	15	75	72.64	59.39
Taste Sandiness	249	35	21	16	13	85	83.73	58.83
	368	61	21	8	2	92	95.42	58.59

Table 31: R-Index for Attributes with "Less" than Control

Attribute	Sample	S-	S-?	N?	N	n	R-Index	R-critical (1-tailed)
Visual Denseness	249	43	22	12	6	83	82.91	59.1
	368	52	17	11	5	85	84.76	59.1
Visual Moistness	249	28	18	23	12	81	78.51	59.1
	368	39	21	18	8	86	84.50	59.1
Taste Sweetness	368	46	8	17	6	77	83.96	59.1
Taste Softness	368	35	11	12	7	65	83.61	60.07
Taste Moistness	249	34	14	16	15	79	78.45	59.1
	368	53	16	12	4	85	89.29	59.1
Taste Mouthfeel	249	39	8	23	11	81	81.89	59.1
	368	45	16	17	4	82	88.66	59.1
Taste Stickiness	249	38	16	18	12	84	80.58	59.1
	368	57	11	11	4	83	89.43	59.1

Table 32: R-Index for Attributes with "More/Less" than Control

Attribute	Sample	S	S?	N?	N	n	R-Index	R-critical (2-tailed)
Taste Sweetness	249	41	21	21	16	99	72.58	59.66

4.4 Conclusions

Consumers were able to correctly discriminate between the different formulations of butter cake (100% rice flour, 50/50 wheat/rice flours) when compared to the labeled control formulation containing 100% wheat. However, because in the previous studies, no significant difference was found between the three formulations in many of the attributes in question, it is possible to conclude that consumers would be willing to forsake certain attributes in order to gain a potential health benefit from consuming this product, especially if they are not able to consume wheat products.

Therefore this study has shown that consumers are willing to purchase a butter cake product containing rice flour while forgoing certain sensory attributes. This could potentially lead to an increased use of rice flour in bakery products not containing wheat. Not only is this beneficial to those individuals who are not able to consume wheat and wheat by-products, but also for the rice industry. If this product were developed on a large scale commercial basis, it could increase the demand for rice flour from broken kernels, thus increasing the demand for lesser-valued broken rice which could be used in this value-added product.

CHAPTER 5. CONCLUSIONS AND SUMMARY OF RESULTS

Significant differences in visual puffiness, appearance and odor acceptability were not observed between NWRBC and WHBC. WHBC had an overall liking rating (7.1) greater than that of WRBC (4.1) and NWRBC (5.0). When the hypothetical question was asked "Would you purchase this product if you were allergic to wheat?" the positive purchase intent increased from 35 to 65% and 21 to 77%, respectively, for NWRBC and WRBC. Taste, texture, moistness and overall liking were attributes differentiating among wheat and non-wheat butter cakes. Logistic regression analyses indicated that overall liking, appearance, and moistness were critical to overall acceptance, while taste and texture were critical to purchase decision.

According to the mixture design, 10 butter cake formulations were developed from rice (0-100%), wheat (0-100%), and pre-gelatinized rice (PGR, 0-50%) flours. According to the balanced incomplete block design, each consumer (n=300) evaluated 3 of 10 samples for acceptability of visual puffiness, appearance, odor, taste, texture, moistness, and overall liking using a 9-point hedonic scale. This design allowed each product to be tested 90 times. Overall acceptance and purchase intent were determined (yes/no). Predictive models for acceptability were obtained using a mixed model without an intercept (alpha=0.05). Superimposition of the optimal areas having a score greater than 6.0 from each attribute was done to obtain an optimal formulation range. Consumers preferred products with the wheat:rice:PGR flour ratio of 50:50:0, 75:0:25 and 50:25:25. Logistic regression analyses identified overall liking, taste and texture as attributes critical to overall acceptance and purchase decision. These attributes served as the limiting factors to obtain the optimal formation range. Superimposition of the optimal response surface areas of overall liking, taste and texture revealed that any formulations containing 50-95% wheat, 0-50% rice and 0-40% pre-gelatinized rice flours would yield a product with acceptability scores of 6.0. Using predictive discriminant analyses, product acceptance can be predicted with 83% and 80% accuracy, respectively, based on overall liking and taste alone. Purchase decision can be predicted with 84% and 81% accuracy, respectively, based on overall liking and texture alone. Logistic regression analyses also identified (prob.>χ^2 less than 0.10) overall liking, texture and taste as attributes critical to both product acceptance and purchase decision. The odds ratio estimate for texture and taste is 3.24 and 3.45, respectively, meaning that as the acceptability score of texture and taste increases 1.0 unit (on a 9-point hedonic scale), the chance that the product will be purchased increases by 3.24 and 3.45 times.

Consumers were able to correctly discriminate between the different formulations of butter cake (100% rice flour, 50/50 wheat/rice flours) when compared to the labeled control formulation containing 100% wheat. However, because in the previous studies, no significant difference was found between the three formulations in many of the attributes in question, it is possible to conclude that consumers would be willing to forsake certain attributes in order to gain a potential health benefit from consuming this product, especially if they are not able to consume wheat products.

Texture and taste were identified as important attributes required for further formulation improvement of a rice butter cake product. A butter cake product containing rice flour could feasibly be prepared. Positive purchase intent increased after the fact about Celiac Spruce Disease had been given. Further formulation refinement should be focused on taste and texture to gain more consumer acceptability. Potential exists for developing a butter cake predominantly made from broken-rice flour, which will, in turn, increase revenues for the farmers and processors. Consumers are willing to purchase a butter cake product containing rice flour while forgoing certain sensory attributes. This could potentially lead to an increased use of rice flour in bakery products not containing wheat. Not only is this beneficial to those individuals who are not able to consume wheat and wheat by-products, but also for the rice industry. If this product were developed on a large scale commercial basis, it could increase the demand for rice flour from broken kernels, thus increasing the demand for lesser-valued broken rice which could be used in this value-added product.

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APPENDIX A: STUDY 1

a. Research Consent Form

I, ____________________, agree to participate in the research entitled "Optimization and Characterization of Sensory Qualities of a Prototype Butter Cake Product," which is being conducted by Witoon Prinyawiwatkul of the Department of Food Science at Louisiana State University, phone number (225)578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. One hundred consumers will participate in this research. For this particular research, about 20-25 min participation will be required for each consumer.

The following points have been explained to me:

1. In any case, it is my responsibility to report prior participation to the investigators any allergies I may have.
2. The reason for the research is to gather information on consumer sensory acceptability of a butter cake recipe from wheat and rice flour. The benefit that I may expect from it is a satisfaction that I have contributed to solution and evaluation of problems relating to such examinations.
3. The procedures are as follows: Three coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
4. Participation entails minimal risk: The only risk which can be envisioned is that of an allergic reaction to wheat, rice, butter, sugar, corn syrup, eggs, milk, vanilla, and cream of tartar. However, because it is known to me beforehand that the food to be tested are common food ingredients, the situation can normally be avoided.
5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigators listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. David Morrison, Assistant Vice Chancellor of LSU AgCenter at 578-8236. I agree with the terms above.

______________________________	______________________________
Signature of Investigator	Signature of Participant
Date: _________________________	Witness: _______________________

b. Sample Survey Form

SAMPLE #_____

1. How would you rate the **VISUAL PUFFINESS** of this product?

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

2. How would you rate the **APPEARANCE/COLOR** of this product?

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

3. How would you rate the **ODOR/AROMA** of this product?

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

4. How would you rate the **TASTE** of this product?

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

5. How would you rate the **OVERALL TEXTURE/MOUTHFEEL** of this product?

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

6. How would you rate the **MOISTNESS** of this product?

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

7. Is the texture of this product "**SANDY**"? ☐ **YES** **IF YES** ☐ **ACCEPTABLE**
☐ **NO** ☐ **NOT ACCEPTABLE**

8. Please rate your **OVERALL LIKING** of this product?

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

9. Is this product **ACCEPTABLE**?

YES ☐ NO ☐

10. Would you **BUY** this product if it were commercially available?

YES ☐ NO ☐

11. If you were allergic to wheat (Celiac Spruce), would you **BUY** this product if it were made from rice flour?

YES ☐ NO ☐

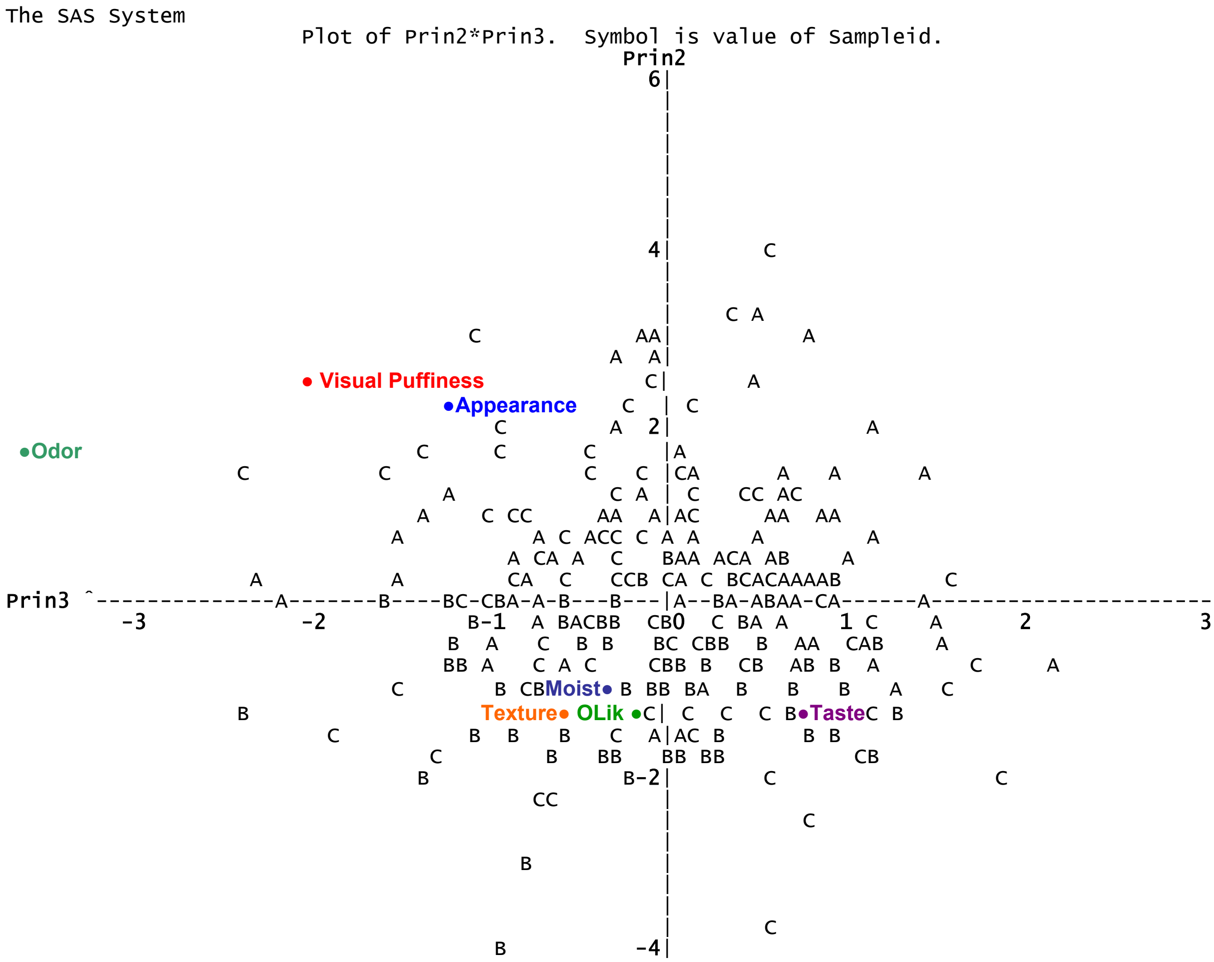
c. Rice Cake SAS Code

```
dm 'log;clear;output;clear';
data one;
input Panel Sampleid $ Gender Vpuff Appear Odor Taste
Texture Moist Sandy     SandyAcc Oliking Accept Buy   BuyCS;
datalines;
proc sort; by Sampleid;
proc means mean std n maxdec=2;by Sampleid;
var Vpuff Appear Odor Taste Texture Moist Oliking;
proc freq; by Sampleid;
tables Sandy SandyAcc Accept Buy BuyCS;
tables Sandy*SandyAcc;
proc anova;
class Sampleid;
model Vpuff Appear Odor Taste Texture Moist Oliking = Sampleid;
means Sampleid/tukey lines;
Proc candisc out=outcan mah;
class Sampleid;
var Vpuff Appear Odor Taste Texture Moist Oliking;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Vpuff Appear Odor Taste Texture Moist Oliking;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Vpuff;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Appear;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Odor;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Taste;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Texture;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Moist;
proc discrim crossvalidate pool=yes posterr;
class Accept;
var Oliking;
proc discrim crossvalidate pool=yes posterr;
class Buy;
var Vpuff Appear Odor Taste Texture Moist Oliking;
proc discrim crossvalidate pool=yes posterr;
class Buy;
var Vpuff;
proc discrim crossvalidate pool=yes posterr;
class Buy;
var Appear;
proc discrim crossvalidate pool=yes posterr;
class Buy;
```

```
var Odor;
proc discrim crossvalidate pool=yes posterr;
class Buy;
var Taste;
proc discrim crossvalidate pool=yes posterr;
class Buy;
var Texture;
proc discrim crossvalidate pool=yes posterr;
class buy;
var Moist;
proc discrim crossvalidate pool=yes posterr;
class Buy;
var Oliking;
Proc logistic data = one;
model Accept = Vpuff Appear Odor Taste Texture Moist Oliking;
Proc logistic data = one;
model Accept = Vpuff;
Proc logistic data = one;
model Accept = Appear;
Proc logistic data = one;
model Accept = Odor;
Proc logistic data = one;
model Accept = Taste;
Proc logistic data = one;
model Accept = Texture;
Proc logistic data = one;
model Accept = Moist;
Proc logistic data = one;
model Accept = Oliking;
Proc logistic data = one;
model Buy = Vpuff Appear Odor Taste Texture Moist Oliking;
Proc logistic data = one;
model Buy = Vpuff;
Proc logistic data = one;
model Buy = Appear;
Proc logistic data = one;
model Buy = Odor;
Proc logistic data = one;
model Buy = Taste;
Proc logistic data = one;
model Buy = Texture;
Proc logistic data = one;
model Buy = Moist;
Proc logistic data = one;
model Buy = Oliking;
run;
```

d. Rice Cake PCA SAS Code

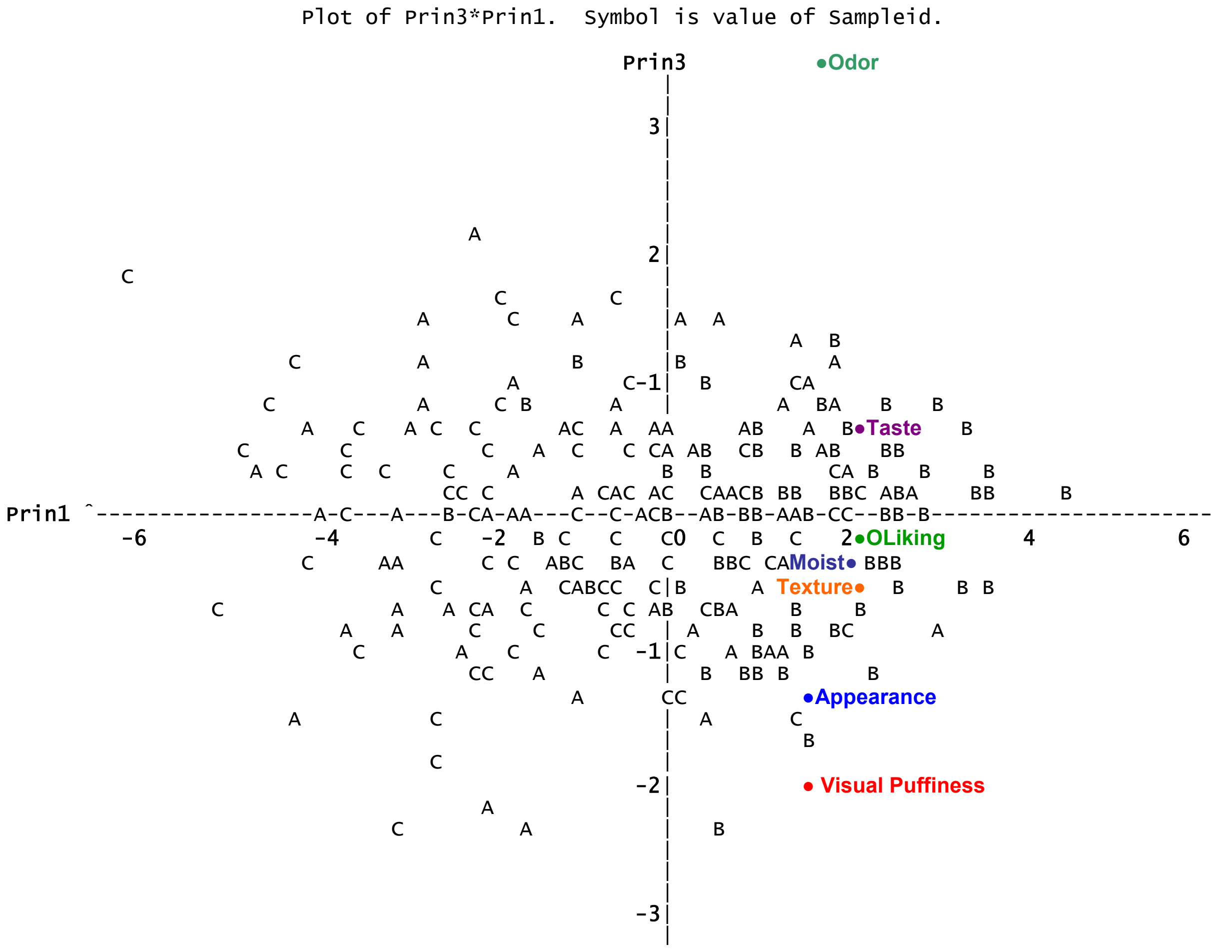
```
dm 'log;clear;output;clear';
data one;
input Panel Sampleid $ Gender Vpuff Appear Odor Taste
Texture Moist Sandy     SandyAcc Oliking Accept Buy   BuyCS;
datalines;
proc princomp out = prin;
var Vpuff Appear Odor Taste Texture Moist Oliking;
proc plot;
plot prin2*prin1 = Sampleid;
plot prin2*prin3 = Sampleid;
plot prin3*prin1 = Sampleid;
run;
```



NOTE: 2 obs had missing values. 71 obs hidden.

Figure 13: PCA bi-plot (product attribute) involving Principal Component 2 and Principal Component 3

The SAS System



NOTE: 2 obs had missing values. 69 obs hidden.

Figure 14: PCA bi-plot (product attribute) involving Principal Component 3 and Principal Component 1

APPENDIX B: STUDY 2

a. Research Consent Form

I, ____________________, agree to participate in the research entitled "Optimization and Characterization of Sensory Qualities of a Prototype Butter Cake Product," which is being conducted by Witoon Prinyawiwatkul of the Department of Food Science at Louisiana State University, phone number (225)578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. One hundred consumers will participate in this research. For this particular research, about 20-25 min participation will be required for each consumer.

The following points have been explained to me:

2. In any case, it is my responsibility to report prior participation to the investigators any allergies I may have.
3. The reason for the research is to gather information on consumer sensory acceptability of a butter cake recipe from wheat and rice flour. The benefit that I may expect from it is a satisfaction that I have contributed to solution and evaluation of problems relating to such examinations.
4. The procedures are as follows: Three coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
5. Participation entails minimal risk: The only risk which can be envisioned is that of an allergic reaction to wheat, rice, butter, sugar, corn syrup, eggs, milk, vanilla, and cream of tartar. However, because it is known to me beforehand that the food to be tested are common food ingredients, the situation can normally be avoided.
6. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
7. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigators listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. David Morrison, Assistant Vice Chancellor of LSU AgCenter at 578-8236. I agree with the terms above.

______________________________	______________________________
Signature of Investigator	Signature of Participant
Date: _________________________	Witness: _______________________

b. Demographic Study

All information will not be identified with your name.

1. What is your age group? (Please check one)

18-24 years____ 25-34 years____ 35-44 years______
45-54 years____ 55-64 years____ Over 64 years____

2. What is your gender? Male_________ Female________

3. Which do you consider yourself to be? (Please check one)

African-American______ Hispanic/Spanish______ Other (Please specify)
Asian______ White (Caucasian)_____ _________________

4. Level of education? (Please check one)

Less than high school____ Some college________ Graduate (M.S., M.A., Ph.D., Ed.)____
High school____ Completed College____

5. Which of these categories best describes your gross 2000 household income? (Please check one)

Under $9,999________ $10,000 – 19,999________ $20,000 – 29,999________
$30,000 – 39,999________ $40,000 – 49,999________ $50,000 – 59,999________
$60,000 – 69,999________ $70,000 – 79,999________ $80,000 – 89,999________
$90,000 – 99,999________ Over $100,000__________

PRODUCT INFORMATION:

1. Do you consume rice or rice-based products? Yes____ No_____

2. Have you purchased and/or consumed butter cake products? Yes____ No_____

3. What is the most important quality attribute that you want in a butter cake product? (Please check one)

Taste_______________ Texture (Puffiness)______ Texture (Sandiness)_____
Appearance/Color_____ Texture (Mouthfeel)_____ Other (Please specify)
Odor/Aroma_________ Texture (Moistness)_____ _____________________

4. Would you buy a non-wheat butter cake product made from rice flour?
Yes_____ No_____

5. If you were allergic to wheat (Celiac Spruce Disease), would you purchase a butter cake product made from rice flour? Yes_____ No_____

6. What would be your most favorite flavor for a butter cake product? (Please check one)

Plain______ Chocolate_____ Other (Please specify)
Berry_____ Coffee________ _________________

c. Sample Survey Form

SAMPLE #_____

1. How would you rate the **VISUAL PUFFINESS** of this product?

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

2. How would you rate the **APPEARANCE/COLOR** of this product?

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

3. How would you rate the **ODOR/AROMA** of this product?

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

4. How would you rate the **TASTE** of this product?

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

5. How would you rate the **OVERALL TEXTURE/MOUTHFEEL** of this product?

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

6. How would you rate the **MOISTNESS** of this product?

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

7. Is the texture of this product "**SANDY**"? ☐ **YES** **IF YES** ☐ **ACCEPTABLE**
☐ **NO** ☐ **NOT ACCEPTABLE**

8. Please rate your **OVERALL LIKING** of this product?

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

9. Is this product **ACCEPTABLE**?

YES ☐ NO ☐

10. Would you **BUY** this product if it were commercially available?

YES ☐ NO ☐

11. If you were allergic to wheat (Celiac Spruce), would you **BUY** this product if it were made from rice flour?

YES ☐ NO ☐

d. SAS Code

```
dm 'log;clear;output;clear';
data one;
input panel age   gender ethnic ed income eatrice     eatbcake quality buynw
      buycs1
flavor      sampleid vpuff    appear odor taste texture moist sandy sandaccp
      oliking
accept      buynw buycs2;
datalines;
proc sort; by sampleid;
proc means mean std n maxdec=2;by sampleid;
var vpuff appear odor taste texture moist oliking;
proc freq; by sampleid;
tables sandy sandaccp accept buynw buycs2;
proc freq; by sampleid;
tables sandy*sandaccp;
proc anova;
class sampleid;
model vpuff appear odor taste texture moist oliking = sampleid;
means sampleid/tukey lines;
Proc candisc out=outcan mah;
class sampleid;
var vpuff appear odor taste texture moist oliking;
proc discrim crossvalidate pool=yes posterr;
class accept;
var vpuff appear odor taste texture moist oliking;
proc discrim crossvalidate pool=yes posterr;
class accept;
var vpuff;
proc discrim crossvalidate pool=yes posterr;
class accept;
var appear;
proc discrim crossvalidate pool=yes posterr;
class accept;
var odor;
proc discrim crossvalidate pool=yes posterr;
class accept;
var taste;
proc discrim crossvalidate pool=yes posterr;
class accept;
var texture;
proc discrim crossvalidate pool=yes posterr;
class accept;
var moist;
proc discrim crossvalidate pool=yes posterr;
class accept;
var oliking;
proc discrim crossvalidate pool=yes posterr;
class buynw;
var vpuff appear odor taste texture moist oliking;
proc discrim crossvalidate pool=yes posterr;
class buynw;
var vpuff;
proc discrim crossvalidate pool=yes posterr;
```

```
class buynw;
var appear;
proc discrim crossvalidate pool=yes posterr;
class buynw;
var odor;
proc discrim crossvalidate pool=yes posterr;
class buynw;
var taste;
proc discrim crossvalidate pool=yes posterr;
class buynw;
var texture;
proc discrim crossvalidate pool=yes posterr;
class buynw;
var moist;
proc discrim crossvalidate pool=yes posterr;
class buynw;
var oliking;
Proc logistic data = one;
model accept = vpuff appear odor taste texture moist oliking;
Proc logistic data = one;
model accept = vpuff;
Proc logistic data = one;
model accept = appear;
Proc logistic data = one;
model accept = odor;
Proc logistic data = one;
model accept = taste;
Proc logistic data = one;
model accept = texture;
Proc logistic data = one;
model accept = moist;
Proc logistic data = one;
model accept = oliking;
Proc logistic data = one;
model accept = vpuff appear odor taste texture moist oliking;
Proc logistic data = one;
model buynw = vpuff;
Proc logistic data = one;
model buynw = appear;
Proc logistic data = one;
model buynw = odor;
Proc logistic data = one;
model buynw = taste;
Proc logistic data = one;
model buynw = texture;
Proc logistic data = one;
model buynw = moist;
Proc logistic data = one;
model buynw = oliking;
run;
```

e. Demographic Frequency SAS Code

```
dm 'log;clear;output;clear';
data one;
input panel age gender ethnic ed income eatrice eatbcake quality buynw buycs1
flavor;
datalines;
proc freq;
tables age gender ethnic ed income eatrice eatbcake quality buynw buycs1
flavor;
run;
```

f. Multilogit Models SAS Code

```
dm 'log;clear;output;clear';
data one;
input panel age   gender ethnic ed income eatrice     eatbcake quality buynw
      buycs1
flavor      sampleid vpuff    appear odor taste texture moist sandy sandaccp
      oliking
accept      buynw buycs2;

if oliking <= 4 then L = 3;
if oliking = 5 then L = 2;
if oliking >= 6 then L = 1;
if sandy = 1 then S = 1;
if sandy = 2 then S = 0;
datalines;
proc sort; by sampleid;
proc print;
proc logistic;
      model L = vpuff   appear odor taste texture moist S / backward lackfit;
      run;
proc logistic;
      model L = vpuff appear odor taste texture moist S;
      run;
```

APPENDIX C: STUDY 3

a. Research Consent Form

I, ____________________, agree to participate in the research entitled "Optimization and Characterization of Sensory Qualities of a Prototype Butter Cake Product," which is being conducted by Witoon Prinyawiwatkul of the Department of Food Science at Louisiana State University, phone number (225)578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. One hundred consumers will participate in this research. For this particular research, about 30-35 min participation will be required for each consumer.

The following points have been explained to me:

1. In any case, it is my responsibility to report prior participation to the investigators any allergies I may have.
2. The reason for the research is to gather information on consumer sensory acceptability of a butter cake recipe from wheat and rice flour. The benefit that I may expect from it is a satisfaction that I have contributed to solution and evaluation of problems relating to such examinations.
3. The procedures are as follows: One control and three coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
4. Participation entails minimal risk: The only risk which can be envisioned is that of an allergic reaction to wheat, rice, butter, sugar, corn syrup, eggs, milk, vanilla, and cream of tartar. However, because it is known to me beforehand that the food to be tested are common food ingredients, the situation can normally be avoided.
5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigators listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. David Morrison, Assistant Vice Chancellor of LSU AgCenter at 578-8236. I agree with the terms above.

______________________________	______________________________
Signature of Investigator	Signature of Participant
Date: _________________________	Witness: _______________________

b. R-Index Form

GENDER: Male _____ Female _____

Part I: VISUAL. Please evaluate each sample by LOOKING and comparing it with the labeled CONTROL sample.

OVERALL APPEARANCE				
Sample ID	Same I am sure	Same I am not sure	Different I am not sure	Different I am sure
249				
368				
157				

DENSENESS						
Sample ID	More I am sure	More I am not sure	Same I am not sure	Same I am sure	Less I am sure	Less I am not sure
249						
368						
157						

MOISTNESS						
Sample ID	More I am sure	More I am not sure	Same I am not sure	Same I am sure	Less I am sure	Less I am not sure
249						
368						
157						

SANDINESS						
Sample ID	More I am sure	More I am not sure	Same I am not sure	Same I am sure	Less I am sure	Less I am not sure
249						
368						
157						

Part II: ODOR. Please evaluate each sample by SMELLING and comparing it with the labeled CONTROL sample.

AROMA / ODOR				
Sample ID	Same I am sure	Same I am not sure	Different I am not sure	Different I am sure
249				
368				
157				

Part III. **TASTE**: Please evaluate each sample by **TASTING and CHEWING** and comparing it with the labeled CONTROL sample.

SWEETNESS						
Sample ID	More I am sure	More I am not sure	Same I am not sure	Same I am sure	Less I am sure	Less I am not sure
249						
368						
157						

SOFTNESS						
Sample ID	More I am sure	More I am not sure	Same I am not sure	Same I am sure	Less I am sure	Less I am not sure
249						
368						
157						

MOISTNESS						
Sample ID	More I am sure	More I am not sure	Same I am not sure	Same I am sure	Less I am sure	Less I am not sure
249						
368						
157						

MOUTHFEEL (Fat/Oil Coating on Surface of Your Tongue)						
Sample ID	More I am sure	More I am not sure	Same I am not sure	Same I am sure	Less I am sure	Less I am not sure
249						
368						
157						

SANDINESS						
Sample ID	**More I am sure**	**More I am not sure**	**Same I am not sure**	**Same I am sure**	**Less I am sure**	**Less I am not sure**
249						
368						
157						

STICKINESS (Adherence to Your Palate or Tongue)						
Sample ID	**More I am sure**	**More I am not sure**	**Same I am not sure**	**Same I am sure**	**Less I am sure**	**Less I am not sure**
249						
368						
157						

VITA

Ashley Elizabeth Bond was born on October, 19, 1980, in Opelousas, Louisiana. She lived in Vidrine, Louisiana, until she graduated from high school. In May 2002 she graduated from Louisiana State University and Agricultural and Mechanical College with a Bachelor of Science degree in food science. After receiving her bachelor's degree, she began pursuing a graduate degree at Louisiana State University and Agricultural and Mechanical College in the Department of Food Science in fall of 2002. She is a candidate for the degree of Master of Science in food science in August 2004. After graduation, she will begin working at Pennington Biomedical Research Center.