2016

Health Benefit Statements Affect Consumer Liking, Emotions, and Purchase Intent: A Case of Gluten-Free, Sugar Reduced Banana Muffins

Amber Renee Jack
Louisiana State University and Agricultural and Mechanical College

HEALTH BENEFIT STATEMENTS AFFECT CONSUMER LIKING, EMOTIONS, AND PURCHASE INTENT: A CASE OF GLUTEN-FREE, SUGAR REDUCED BANANA MUFFINS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Nutrition and Food Sciences

by
Amber Renee Jack
B.S., Louisiana State University, 2014
August 2016

ACKNOWLEDGMENTS

First of all, I would like to take the much-needed time to thank my major Professor Dr. Witoon Prinyawiwatkul for being extremely patient and informative. I have taken a lot of vital knowledge from him. I would also like to thank my committee members Dr. Joan King and Dr. Achyut Adhikari for everything they did to help me with my research. I would like to thank my lab mates for taking the time from their own research to guide me in mine, and I would like to thank all the people in the School of Nutrition and Food Sciences who made this an enjoyable and memorable experience! You are all greatly appreciated.

Most significantly, I would like to thank my parents Germaine and Ricky Jack, my sisters Jasmine and Jade Jack, extended family and my friends for dealing with me through the ups and downs of being in a new and competitive graduate program. But thank you especially to my parents who provided me with not only emotional support, but also financial support and always pushed me to succeed even when I did not believe in myself!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Product information given to consumers can be used to improve food choices; however, consumers may respond differently depending on the given information. Nutritional information can serve as an instrument to positively influence healthier food choices and purchase intent. The market for gluten-free products reached $5.5 billion in 2015; however, there is a need for development of acceptable gluten-free and sugar-free products driven by consumers who are nowadays more health conscious. Muffin, a high calorie baked-good product, is very popular among consumers and known for its pleasant aroma and sweet taste qualities. There are a number of commercial gluten-free muffin products, but only a few gluten-free sugar-free or reduced-sugar muffins. Therefore, the purpose of this research was to evaluate effects of reducing the sugar level and health benefit statements on the physicochemical properties and consumer acceptability, emotion and purchase intent of gluten-free banana muffins using stevia as a sucrose replacement at varying levels (0, 50, and 100%). Reducing sucrose by 50% did not significantly decrease consumer acceptability (color, odor, taste, sweetness, moistness, softness, stickiness and overall liking), positive emotions (calm, good, happy, healthy, pleasant, pleased, satisfied and wellness) and purchase intent before health benefit information was displayed. However, reducing sucrose by 100% had significantly negative effects on consumer acceptability and positive emotions (calm, good, happy, pleasant, pleased and satisfied). Health benefit statements had a positive effect on overall liking, purchase intent, and intensities of the emotions calm, good, happy, healthy and pleased for both 50 and 100% sucrose reductions. Additionally, the emotions happy and wellness became significant predictors of purchase intent after health benefit statements were provided. Overall, sugar reduction affected physicochemical and consumer perception of gluten-free banana muffins. Adding 100% Stevia tended to decrease liking scores, and this negative effect was more pronounced for sweet and taste-related attributes than for texture and color-related attributes. The reduced-sugar formulation containing 50% sucrose presented acceptable sensory and physicochemical qualities.

CHAPTER 1. INTRODUCTION

Taste, cost, convenience and nutrition/health are considered the primary food choices that motivate consumers when purchasing food items (Glanz and others 1998). The healthfulness of food is commonly determined by the nutrition information and claims on the packaging (Pohjanheimo 2010), and is increasingly becoming an important factor influencing consumer choice of food products (Connors and others 2001). These extrinsic factors are known to affect consumer behavior regarding purchase decision, perception of product quality and wellness (Pohjanheimo 2010; Deliza and MacFie 1996). Gluten-free and sugar reduced products represent clear examples of this present phenomenon among consumers.

The gluten-free diet has gained substantial popularity in the general population (Pietzak 2012), with the number of consumers purchasing gluten-free products much higher than the number of patients clinically diagnosed with Celiac Disease (Pellegrini and Agostoni 2015). Furthermore, when consumers were asked why they purchased such items, the number one reason was because they perceived gluten-free foods to be healthier than their gluten containing counterparts (Marcson 2011). However, despite these perceived health benefits for the gluten-free diet, there is no publishable evidence validating a gluten-free diet as beneficial for the general population (Gaesser and Angadi 2012). Johansen and others (2009) studied the effects of fat and sugar content information on liking and purchase intent of yogurt. The study found significant increases in hedonic ratings and positive purchase intent after information about low sugar content was given, but not for fat content, for health conscious consumers (Johansen and other 2009). Poonnakasem and others (2016) recently studied effects of different oils and health benefit statements on liking, emotion and purchase intent of sponge cakes. Following awareness of the health benefits of the different oils, product liking, positive purchase intent and emotions scores all increased, while intensity of negative emotions decreased. These studies illustrate how perception of food based off the provided product information can influence consumer liking, acceptance and purchase intent.

Diabetes, a disease that affects more than 29.1 million Americans is a common health issue in the United States (Centers for Disease Control and Prevention 2014). Diabetes is a manageable disease that can be controlled with proper medication and a healthy diet and lifestyle (Centers for Disease Control and Prevention 2014). In diabetes management, patient education is critical as reducing or eliminating gluten has been shown to greatly reduce symptoms, not only in persons with celiac disease but also in individuals suffering from type 1 diabetes mellitus (Centers for Disease Control and Prevention 2014). The association between celiac disease and type 1 diabetes mellitus suggests that gluten may play a role in the pathogenesis of type 1 diabetes mellitus (Smyth and others 2008). Current estimates place the prevalence of celiac disease in patients with Type 1 diabetes mellitus at approximately 5% although a wide range has been reported (Holmes 2002; Leonard and others 2015).

Celiac disease, an autoimmune disorder generated by the ingestion of gluten in genetically susceptible individuals causes damage in the small intestine (World Health Organization 2015). According to the World Health Organization (2015), the autoimmune disorder affects 1 in 100 people worldwide, with 2.5 million Americans going undiagnosed of this disease. As of now, the only known treatment is total elimination of gluten containing food, which leads to recovery of the intestinal mucosa (Green and Jabri 2003). In general there has been a slight increase in commercialized gluten-free items, although they regularly contain excessive amounts of sugar. Products that are gluten-free are not necessarily sugar reduced, as a result, there is an increasing need for these products as the numbers of food allergies and/or intolerances have increased comparatively. Furthermore, the World Health Organization (WHO) has released new guidelines advising children and adults to reduce their daily intake of free sugars to only 10% of their total energy intake. Yet, the only accepted way to reduce sugar and energy in food is to use zero calorie sweeteners (Poppitt 1995), as they still give foods their desired sweet-like taste. Zero calorie sweeteners, properly referred to as nonnutritive sweeteners, can be beneficial when replacing sucrose in baked goods as they are indigestible in the body and are 200-600 times sweeter than sucrose, requiring lesser amounts in a formulation (Viscoine 2005).

Accordingly, the need for gluten-free and sugar-free items have increased dramatically along with consumer consciousness about health-related issues and food-induced illnesses. As regards the increase in awareness of diet-related chronic diseases, the food industry has taken initiatives to develop reduced-sugar foods with comparable sensory attributes to its high sugar counterparts. As more research has been reported on the association between gluten-free and sugar-reduced diets, its relationship is one that cannot be ignored.

Muffins, a high calorie, popular, baked good item are known for their pleasant aroma, sweet tasting qualities and high consumer acceptance. Sweeteners are important ingredients in muffins, with sucrose being the most common as it is responsible for the sweetness, flavor, texture formation, volume increase, crust color, shelf-life and moisture retention of the muffin (Cross and others 2006). Because of its range of benefits, baked goods that are sucrose reduced commonly result in a reduced batter viscosity, which causes a low volume and poor structural formation (Manisha and others 2012). While sucrose is the most common sweetener in baked goods, it is not fitting for all food applications. Therefore, alternative sweeteners can be of great use as they can be used to provide functionality, reduce caloric intake, control diabetes, minimize occurrence of dental caries and assist in cost reduction (O'Donnell and Kearsley 2012). Investigation of sucrose substitution and reduction is therefore necessary for the creation of gluten-free baked goods with color, texture and flavor characteristics similar to traditional baked goods.

1.1 Objectives

The primary purpose of this research was to evaluate effects of sugar reduction on the quality and consumer perception of gluten-free muffins.

Specifically, the objectives were:

i. To determine effects of stevia at varying levels (0, 50, and 100%) on the physicochemical quality, consumer acceptability, purchase intent and consumer emotions when utilized as a sucrose alternative in gluten-free banana muffins formulations.

ii. To evaluate impact of gluten free and sugar reduced health benefit statements on consumer liking, emotion and purchase intent.

CHAPTER 2. LITERATURE REVIEW

2.1 Sucrose Function in Baking

As consumer interest in health foods has risen, so has the demand for sucrose reduced products that yield the same or similar sensory qualities. For this reason, creating highly acceptable sugar reduced products that are low in calories and have similar taste, flavor perception and mouth feel to its high sugar counterparts, could be beneficial to the food industry.

Muffins, a high calorie small domed cake, are known for its sweet tasting characteristics. These sweet tasting qualities can be attributed to the sucrose in the dough formulation. Sucrose, a key ingredient in muffins, plays a significant role in the bulk, structural and textural properties of overall muffin dough. Its functions extend beyond its use as a sweetener and flavor enhancer as it is imperative for the overall dough quality in baked goods (Tzia and others 2012).

2.1.1 The Maillard reaction and browning

In baked goods, with the addition of liquid, sucrose undergoes conversion to glucose and fructose, converting it into a reducing sugar (Davis 1995). The combination of the two reducing sugars, protein, from a molecule containing amine and the addition of heat allows for the onset of the Maillard reaction (McWilliams 2008). The potential end products of the Millard reaction are melanoidins, which provides not only the brown crust color of the desired baked good but also the wonderful nutty or caramel flavor, depending on the preferred final product (González-Mateo and other 2009). Melanoidins range from colors of intense yellow and brown with orange and reddish shades (González-Mateo and other 2009). Further compounds created by the Maillard reaction include aldehydes, ketones, and pyrazines (Chinachoti 1995). These reactions can be responsible for the overall quality of the final product subsequently determining consumer acceptance and preference (McWilliams 2008). The degree to which each compound is created is affected by external conditions, which differ depending on the formulation and processing of the product (González-Mateo and others 2009). “Favorable conditions for the Maillard reaction include (1) temperatures above 50° C; (2) pH of 4-7, (3) an intermediate moisture content, and high protein and carbohydrate contents.” (Ramírez and others 2000). An adjustment in the type of amount of sugar is known to influence the Malliard reaction rate, affecting some of these conditions. A study conducted by Gallagher and others (2003) investigating baked biscuits supports this concept, finding that browning drastically decreased when sucrose was reduced or removed.

2.1.2 Moisture retention and water activity

Water activity, is a critical factor in determining the overall food product shelf-life and quality. In the food industry sucrose is commonly used as a humectant, providing moisture retention of countless baked goods (Figoni 2004). Humectants are known to bind water and control water activity (a_w), restricting the ability of microorganisms to grow (Cauvin & Young 2006). Overall crumb tenderness and texture in wheat containing baked goods is greatly dependent on the interactions between sucrose and other ingredients, which provide moisture retention of the batter (Figoni 2008). Baked goods made with a higher content of sugar have a longer shelf-life, which consumers tend to prefer when purchasing food products. As a result a modification in sugar type or content in a food formulation should be investigated for its effects on the final product a_w and shelf-life (Figoni 2008).

2.1.3 Texture

Additionally, an important role sucrose has in baking is its ability to retard gluten formation. In baking, sucrose acts as a tenderizer by retarding and restricting gluten formation in flours during mixing, thru limiting the water absorption of the flour components, therefore preventing the toughening of gluten (Kim 1994). The addition of the correct amount of sugar is imperative as it allows for the gluten protein to maintain its elastic nature, which allows for gasses to be held within the batter (Figoni 2008). If too much gluten develops, the dough will become tough and undesirable (Kim 1994). Generally speaking, the more sucrose added, the more tender the baked goods will be. Although, the addition of too much sucrose produces baked goods that do not rise properly, resulting in an inadequate structure after cooling (Figoni 2004).

2.1.4 Physical structure

Another important requirement for an acceptable muffin is the adequate formation of a structural framework of starch granules and protein. Sucrose plays an important role, having the ability to reduce starch gelatinization temperature, delaying egg protein denaturation allowing air bubbles to properly expand, by the carbon dioxide and water vapor (Rosenthal 1995). This improves the microstructure, porosity and allows for volume increase (Rosenthal 1995). Thus, the amount of sugar added to the batter can be manipulated to increase or reduce the height of baked good. Additionally, reducing starch gelatinization creates a finer texture and crumb color. During, the final stages of baking the batter changes from an emulsion, to a porous structure when the proteins coagulate and the wheat starch gelatinizes together. This stage provides the necessary strength to the baked good to resist the stress resulting from cooling (Equipment M.B 1979).

2.2 Physical and Chemical Properties of Sucrose

Sucrose, also known as table sugar or saccharose is a non-reducing disaccharide (Vardakas and others 2012). Disaccharides are molecules containing 2 monosaccharide units. Sucrose is composed of a $\propto$-D-glucopyranosyl unit and a β-D- fructofuransoyl unit liked with a $\propto$- D- glysoscic bond with a chemical formula $C_{12}H_{22}O_{11}$ (Vardakas and others 2012). To be used as energy for humans, sucrose has to be hydrolyzed into D- gluclose and D-fructose by the enzyme sucrase, which is found in the human intestinal tract (Vardakas and others 2012).

Sucrose is a nutritive sweetener as it provides calories when consumed (Brown and Rother 2012). Sucrose a hygroscopic molecule has the ability to hold water and is readily soluble in water (Davis 1995). Solubility of sucrose increases as temperature increases and has a melting and decomposition temperature of 186° C forming caramel (Davis 1995). Sucrose is also effective in lower temperature foods (Vardakas and others 2012). The sufficient production of ice creams and other frozen desserts is dependent on the development of fine crystals to aid in product smoothness (Vardakas and others 2012).

2.3 Sensory Properties of Sucrose

Sucrose is universal in food preparations due to its unique sweetening and functional properties, hence its high preference and liking among humans. It is said that human are born with a natural liking for sweetness (Sullivan and Birch 1990), as humans have readily consumed sweet foods since the beginning of time. Sugars and other sweeteners alike are measured by their sweetness intensity. Sweetness, perceived by taste, is one of the four fundamental sensations (Nabors and Geraldi 1991). In comparison with other sugars, sucrose is rated a 100 on the point scale (Vardakas and others 2012). However, it is difficult to measure sweetness as sweetness perception is affected by factors such as sugar concentration, temperature, pH, the viscosity of the carrier medium, and the specific ability of the each person to taste depending on their detection threshold (Vardakas and others 2012). Additionally the type of evaluation technique and panelist demographics, also both affect the results of a sensory evaluation test of sweetness (Bower and Boyd 2003).

2.4 Nonnutritive Sweeteners - Stevia

Nonnutritive sweeteners are sweeteners that contain few or no calories or nutrients. They are of high use in the food industry as they are many times sweeter than sugar, allowing for a reduced amount when added in foods. Currently, in the United States there are eight nonnutritive sweeteners that are approved for use in the United States as food additives by the Food and Drug Administration , which include saccharin, aspartame, acesulfame potassium, sucralose, neotame, advantame, steviol glycosides, and luo han guo fruit extracts (FDA 2015).

The nonnutritive sweetener steviol glycosides come from stevia. "Stevia," is a name commonly used for the extracts from the leaves of a Stevia plant (Anton and others 2010). Stevia is a genus from the Asteraceae family, containing over 230 different species. It is native to the Amambay region of Northeastern Paraguay and has also been known to grow in the subtropics of Brazil and Argentina, where its dry leaves have been used for many years, as a natural sweeting agent (Soejarto 2002). Out of all the species only two plants, *Stevia rebaudiana and Stevia phlebophyll* have sweet tasting qualities (Kim and Kinghorn 2002). However, over the years, the species, *stevia rebaudiana* has gained substantial interest of food companies as it provides sweetness without the additional calories or nutritional drawbacks. However, the presence of bitter compounds incorporated during the extraction process has caused low consumer acceptance in some food items (Kim and Kinghorn 2002). Nonetheless, there are various benefits of using stevia, particularly for baked items.

2.4.1 Stevia function in baking

The sale of leaves of Stevia is growing in the natural food market as its functional and sensory properties, are superior to those of many other nonnutritive sweeteners (Goyal and others 2010). Its functional properties are so advantageous, it's had wide range use for sugar substitution in products like soups, gravies, dough's and frozen desserts (Lemus-Mondaca and others 2012).

Stevia leaf powder has been shown to have a high water holding capacity due to its high protein content (Lemus-Mondaca and others 2012). An important function in viscous foods like dough's and baked products are proteins ability to increase water-holding capacity and enhancing the swelling ability (Lemus-Mondaca and others 2012). In addition, proteins also are known to aid in the formation and stabilization of emulsions in cakes and batters (Lemus-Mondaca and others 2012).

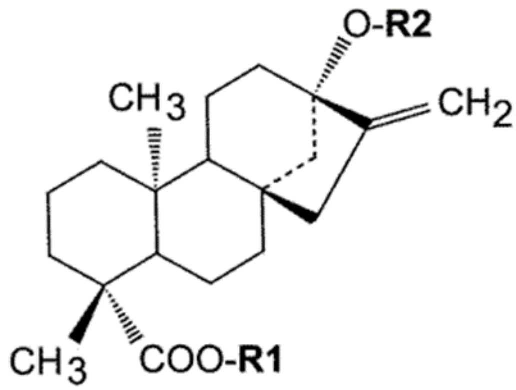
In baked products such as muffins, flavor and mouth feel are of great importance (Lemus-Mondaca and others 2012). Stevia leaf powder has been shown to possess fat absorbing ability, which adds flavor to and increases mouthfeel of products (Lemus-Mondaca and others 2012). However browning and caramelization are not functions of stevia as it is reasonably thermal stable under elevated temperatures (Lemus-Mondaca and others 2012).

2.4.2 Physical and chemical properties of Stevia

The chemical compositions of Stevia rebaudiana's leaves extracts are greatly dependent on the cultivation process of the leaves (Genus 2003). The major use of this plant is from its naturally occurring sweetening steviol glycosides, which can easily be extracted with water purified, concentrated, and dried (Carakostas and others 2008). Steviol glycosides are diterpenes, isolated and identified as stevioside, steviolbioside, rebaudioside A, B, C, D, E, F and dulcoside (Genus 2003). Table 1, shows the various steviol glycosides and their receptive R-Groups. Steviol glycosides constitute roughly 15% of the plants dry leaf (Giraldo and others 2005) and all have the same steviol backbone that differs mainly in the content of carbohydrate residues (R1 and R2), mono-, di-, and trisaccharides containing glucose and/or rhamnose at positions C13 and C19 (Kochikyan and others 2006).

The stevia plant is also known to be a good source of protein, dietary fiber, minerals and essential amino acids (Abou-Arab and others 2010). Stevia has been identified to contain elements such as potassium, calcium, magnesium, sodium, zinc and iron (Kobus and Gramza 2015). Stevia is of such high consumer acceptance as it not only adds sweetness but is low calorie having only 2.7kcal/g (Kobus and Gramza 2015). The reason that is has such a low calorie count is because stevia only decomposes slightly in the gastrointestinal tract (Kobus and Gramza 2015).

Table 1 Steviol Glycosides and their receptive *R*-Groups



Compound Name	R1	R1
Steviol	H	H
Steviolbioside	H	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$*
Stevioside	$\beta - Glc$	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$
Rebaudioside-A	$\beta - Glc$	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$ | $\beta - Glc(3 \rightarrow 1)$
Rebaudioside B	H	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$ | $\beta - Glc(3 \rightarrow 1)$
Rebaudioside C (Dulcoside B)	$\beta - Glc$	$\beta - Glc - \alpha - Rha(2 \rightarrow 1)$ | $\beta - Glc(3 \rightarrow 1)$
Rebaudioside D	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$ | $\beta - Glc(3 \rightarrow 1)$
Rebaudioside E	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$	$\beta - Glc - \beta - Glc(2 \rightarrow 1)$
Rebaudioside F	$\beta - Glc$	$\beta - Glc - \beta - Xyl(2 \rightarrow 1)$ | $\beta - Glc(3 \rightarrow 1)$
Dulcoside A	$\beta - Glc$	$\beta - Glc - \alpha - Rha(2 \rightarrow 1)$

*Structure of the major glycosides of Stevia rebaudiana leaves. Glc, Xyl, and Rha represent, respectively, glucose, xylose, and rhamnose sugar moieties (Genus 2003).

2.4.3 Sensory properties of Stevia

The different steviol glycosides: stevioside 110-270, Rebaudisode A 150-320, Rebaudisode C 40-60 and dulcoside 30, not only differ in molecular structure, but also in their sweetness properties (Genus 2003), with rebaudiose A and stevioside being the most occurring (Genus 2003). Stevioside is found at a higher percentage than Rebaudioside-A, however, Rebaudioside-A is sweeter and less bitter than stevioside having one less glucose moiety, thus has the greatest potential for replacing sucrose in baked goods (Genus 2003).

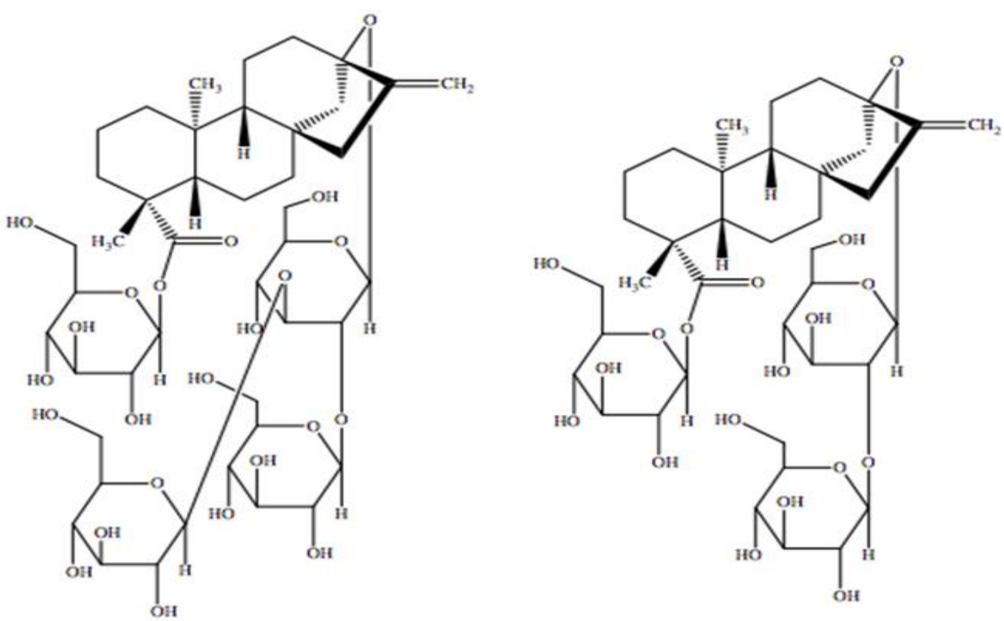


Figure 1 Comparison of the chemical structures of rebaudioside A (left) and stevioside (right) Source: Genus (2003).

However, many alternative sweeteners have been linked to off-flavors in baked goods items, with their presence being easily detected through sensory evaluation techniques. A study conducted by Cardos and Bolini (2008) evaluated the sensory attributes most elicited by stevia using the Quantitative Descriptive Analysis technique. The analysis showed that the attributes of bitterness, residual bitterness and residual sweetness were most elicited by stevia (Cardoso and Bolini 2008). Consequently, off-flavors have been associated with lower consumer purchase intent and acceptability. The off-flavors can be as a result of the extraction process as many processes use ethanol, methanol, or even rubbing alcohol to extract and purify the compounds (Puri and others 2012).

2.4.4 Safety of Stevia

In 2008, purified steviol glycosides received the Generally Recognized As Safe (GRAS) status for general-purpose sweetener in foods (FDA 2015). Before this, stevia extracts were only legally sold in the United States as “dietary supplements,” not to be advertised or sold as a sweetener (Carakoras and others 2008). Presently, stevia is considered a natural sweetener since it is derived from a plant (Jamieson 2008), with many plant glycosides showing uses as an anti-diabetic, anti-obesity, antibacterial and also used in cancer prevention (Bernal and others 2011).

In general, stevia is non-cariogenic and show no allergic reactions or adverse effects when used in food items (Abou-Arab and others 2010), and is a safe non-calorie sweetener for diabetics, as it does not affect blood sugar levels (Lemus-Mondaca and others 2012). Moreover, stevia is not only safe but could have beneficial effects on human health (Abou-Arab and others 2010), as it exhibits medicinal properties being used as an anti-inflammatory, anti-hypertensive, anti-hyperglycaemic, anti-diarrhoeal and also has been used to treat cancer (Lemus-Mondaca and others 2012). For this reason, variations of steviol glycosides are used in an abundance of industrial foods including soft drinks, fruit juices, desserts, frozen items, candy, sauces, sweet corn, breads, biscuits and Table-top sweetener (Lemus-Mondaca and others 2012).

2.5 Health Effects of Gluten

Genetic predisposition, environmental factors and immunologically-based inflammation are known to be the three factors that contribute to the onset of celiac disease (Murray 1999). The gliadin fraction in gluten-containing grains is the instigator leading to an immunogenic response in individuals with Celiac Disease. The immune response to gliadan produces toxins that destroy the villi in the small intestine. Villi are, small finger shaped objects that line the wall of the intestine to help the body absorb nutrients in food such as iron, folate, vitamin B_{12}, calcium, proteins, fats, and fat-soluble vitamins (Mcgill 2005). If damage is not detected early it can led to malnutrition, permanent damage to the small intestine and other serious health conditions (Fasano 2009) and even when no symptoms are present damage can still occur (Mugema 2009).

2.5.1 Celiac disease

Celiac disease is an autoimmune disorder is caused by the ingestion of gluten containing grains (wheat, rye, barely) in genetically susceptible individuals. The occurrence of celiac disease is increasing due to improved medical diagnoses and awareness of the disease, with more than two million Americans going undiagnosed (World Health Organization 2015). Gluten, typically an “essential” constituent in muffins, is known for its elastic properties, structural formation qualities, and for its contribution to the overall appearance and crumb structure of many baked products. For this reason, removal of gluten in baked goods often results in a lower quality, decreased mouth feel and lower overall flavor of the final product (Gallagher and others 2003). However, gluten must be removed from the diets of individuals with celiac disease as it causes intestinal damage (Sciarini and others 2008).

2.5.2 Population that needs to avoid gluten

Not long ago, the geographic distribution of celiac disease was mostly in developed western countries (Catassi and Fasano 2008). However, new epidemiological studies have proven that the disease is more geographically dispersed, with as many as 1 in 100 people worldwide being affected with this disease (World Health Organization 2015). Celiac disease, affects both adults and children, being more predominant in the female population at a ratio of (3:1) (Green and Cellier 2007). Digestive issues are more commonly seen in infants and children, common symptoms include: abdominal bloating, chronic diarrhea, votming, constipation, weight loss, fatigue, failure to thrive, Attention Deficit Hyperactivity Disorder (ADHD), irritability and behavior issues (World Health Organization 2015). However, adults are less prone to having digestive issues, with common symptoms for adults include: anemia, arthritis, bone loss, bone or joint pain, depression or anxiety, seizures, infertility and missed menstrual periods (World Health Organization 2015).

2.5.3 Treatment of Celiac disease

While there are an excess amount of symptoms, diagnosis of celiac disease is commonly misdiagnosed as symptoms closely relate to other common bowl disorders, like irriTable bowl syndrome (Fasano and Catassi 2005). Moreover, currently the only treatment for celiac disease known is a lifetime adherence to a gluten-free diet. Which is easier said than done, as gluten is a common ingredient in baked goods. For this reason, before adhering to gluten-free diet individuals should verify that they do in fact have Celiac Disease. An endoscopic biopsy of the small intestine is commonly used to confirm diagnosis of celiac disease after a patient has been screened for the celiac disease antibody using a tTG-IgA test (Fasano and Catassi 2005).

However, in the last few years, drug therapy research has been studied with expectations of the market to reach $8 billion by 2019 as there has been encouraging development in natural food based drugs like thymus extract, quercetin and enzymes (Fasano and Catassi 2005).

2.6 Gluten-Free Flours

The structure of baked goods is mainly dependent on the flour being used as different flours have different functional properties. Baked goods are typically created with wheat flour that is usually enriched with vitamins, minerals and fiber. Wheat dough helps with its foam structure as wheat dough is a colloidal system with hydrated biopolymers consisting the continuous phase and the dispersed phase consisting of carbon dioxide (Gan and others 1995). Thus, gluten-free baked goods cannot be counted on to provide that same nutrients or structure as gluten-free batters are more gel like as they are colloidal systems with starch particulates making up the continuous phase and water constituting the dispersed phase (Dobraszyk and others 2001).

In addition, the lack of gluten regularly produces batters that are less viscous, resulting in a have an inadequate texture, color and other post baking quality defects. However, recently, there has been a significant increase in the development of gluten-free flours, using various approaches, which include use of starches, dairy products, gums, hydrocolloids and other non-gluten containing proteins to mimic and improve the quality of gluten containing products (Torbica and others 2010). Two popular flours used in gluten-free baking are rice and buckwheat flour.

2.6.1 Rice flour

Rice flour is known to be one of the most popular flour substitutions for gluten-free baked goods, as it is known for its easily digestible carbohydrates, colorless appearance and hypoallergenic properties (Gujral and Rosell 2004). The type of rice flour used is determinate of the end product wanted, as each flour has properties that influence the quality of the end product. Currently there are three different rice products used in gluten-free baking which include: rice paddy, brown rice and white rice. The dissimilarities of flours made with rice are as a result of the differences in milling methods of the starch components of the rice (Bean 1986).

But, rice flour requires an excess amount of liquid compared to wheat flour, as it dries out easily. However, with the addition of large amounts of liquid the dough shows a higher stability (Torbica and others 2010).

2.6.2 Buckwheat flour

Buckwheat is plant cultivated for its seeds that are nutrient dense and gluten-free (Caballero and others 2003). In spite of its misleading name, buckwheat is safe for people suffering from celiac disease, as it contains no gluten (Skerritt 1986).

Buckwheat flour is a highly acceptable flour as it is known for its health benefit qualities like reducing high blood pressure, controlling blood sugar, lowering cholesterol and lowering the risk of cancer (Skerritt 1986). Its health comes from its high lysine, iron, copper and magnesium content (Caballero and others 2003), as well as its high amounts of rutin, polyphenols and antioxidant benefits (Caballero and others 2003).

However, a downfall of these two flours, as well as most gluten-free flours, is their inability to ferment, which helps develop a viscoelastic network (Torbica and others 2012). This network is responsible for retaining CO_2 (Torbica and others 2012). For this reason, structuring agents such as carboxymethylcellulose, hydroxypropylmethylcellulose, pectin, agar, xanthan gum, and different starches are commonly used to improve the viscoelastic network (Torbica and others 2010).

In general, the removal of gluten in baked goods is a knowing problem for cereal technologists and bakers alike, but has initiated intense research and development of acceptable gluten-free products. Currently gluten-free products on the market are of lower quality in terms of texture, nutrients, flavor and mouthfeel than their gluten containing counterparts (Gallagher and others 2003).

2.7 Physical and Chemical Properties of Gluten

Gluten is known for its vital function in baking as its complex chemistry is responsible for water absorption capacity, cohesivity, viscosity, and dough elasticity of baked goods (Wieser 2007). Without gluten baked goods loose most of these vital properties, for this reason the majority of gluten-free baked goods have a relativity short shelf-life and are of poorer quality to their gluten containing counterparts (Torbica and others 2010).

Gluten is the major protein in wheat flour, as it is the determinate in the leavening and processing in different baked goods (Wieser 2007). Rich in protein, gluten is known for its ability to retain gas bubbles in dough allowing for its cohesive and viscoelastic properties. "Gluten can be defined as the rubbery mass that remains when wheat dough is washed to remove starch granules and water-soluble constituents (Wieser 2007)." After washing, the dough contains mostly protein (75-85%) and lipids (5-10%), with the remainder being mostly starch (Wieser 2007). Gluten contains hundreds of protein components, which either are present as monomers or, linked by inter-chain disulphide bonds, as oligo- and polymers (Wrigley and Bietz 1988). Gluten has a unique amino acid composition, which is high in glutamine and proline (Wrigley and Bietz 1988). The two main proteins found in gluten are glutenins and gliadins (Wrigley and Bietz 1988), as they compose of 80% of the wheat flour protein (Uthayakumaran and others 1999). Gliadins contribute to dough viscosity as when they are hydrated they become sticky, while glutenins help with the dough elasticity as it is pretty tough (Uthayakumaran and others 1999).

2.8 Nutritional Issues of Gluten-Free Products

On August 5 2013, the United States Food and Drug Administration issued requirements for the gluten-free labeling of food. These requirements state that if foods are to be displayed as "gluten-free" or use synonyms such as: "no gluten", "free of gluten" or "without gluten", that the product must be naturally gluten-free before processing and not contain a gluten containing grain or an ingredient derived from a gluten containing grain that has not been processed to remove the gluten, with 20 parts per million begin the highest amount of gluten that can be in a food item (Food and Drug Administration 2013).

However, many studies have shown that a gluten-free diet may not guarantee an adequate nutritional intake. The gluten-free diet, is the healthiest when foods are consumed that were gluten-free before processing (Saturni and others 2010). Conversely, most processed gluten-free foods are higher amounts of fat, sugar, and sodium then their gluten containing counter parts. (Saturni and others 2010). It is common that individuals often feel restricted having to adhere to a strict gluten-free diet and tend to compensate for the restrictions by eating foods higher in fats, sugars, and calories (Saturni and others 2010). Inadquete fiber intake has also been shown in persons following a gluten-free diet as many gluten-free foods are made with starches and/or refined flours with low contents of fiber (Saturni and others 2010). However, the use of pseudo-cereals like buckwheat in replacement of wheat have shown to improve intake of protein, iron, calcium and fiber content of individuals with Celiac Disease (Saturni and others 2010).

2.9 Consumer Perception, Purchase Intent and Health Benefit Statements

The gluten-free diet has gained a lot of acceptance and popularity over the years. Before only individuals with celiac disease would consume gluten-free foods, however consumers are purchasing gluten-free products with others goals in mind. These goals include weight loss, a healthier lifestyle and also to manage conditions like irritable bowel syndrome or autism (Pietzak 2012). Moreover, in 2014 the gluten-free diet reached sales of over $973 million and had a compound annual growth rate of over 34% over a 5 year period. In addition, the projected sales of gluten-free foods are expected to exceed $2 billion in 2019 (Packaged Foods 2015). In conclusion, the gluten-free market is not anticipated to slow down anytime soon.

The Nutritional Labeling and Education Act of 1990 was developed to help consumers make more health-educated choices when purchasing food items (Kozup and others 2003), as the information shown on the packaging of food is known to have a significant effect on consumers perception of the food (Schifferstein and others 2013). While health claims have been on the labels of food packages since 1984 they were often criticized on being vague and misleading (Silverglade 1996). The claim displayed on the front of packaging displays information on the relationship between the product and reducing risk of a health related condition, while the Nutrition Facts label displays standard nutrition information on calories, fat, cholesterol, sodium, carbohydrates and protein (FDA 1994). In general, food companies use the packaging information to highlight important information that they are required to share, and some information that could highlight certain benefits associated with the product (Carrillo and others 2012). This information regularly affects how consumers perceive the products expectations.

Nutritional claims statements suggest that the food has a specific benefit due to the product containing or not containing a certain amount of something (ex. ‘gluten-free’, or ‘sugar reduced’) (Dean 2011). Therefore, health claims can offer benefits as they show a clear message to the consumer about the ingredients of the product (Dean 2011). The change in perception could be related to hedonics, sensory attributes, quality, etc. (Miraballes and others 2014). This means that food descriptions can affect both taste and the healthiness of food, even if a products formulation is not necessarily healthy (Chandon and Wansink 2012). However, it is still to be determined whether sensory acceptability alone is a predictor of sale prediction (Koster and others 2003), as overall acceptability has limited predictive value, since emotions influence consumer preferences and choices (Koster and others 2003). In addition it has been shown that emotions produced by products positively impact subsequent purchase intention (Koster and others 2003).

2.10 Conclusions from Literature Review

Investigation of sucrose reduction and substitution is necessary for the creation of gluten-free baked goods that yield similar color, texture and flavor of components of traditional baked goods. For this reason and considering the current trend of consumer behavior toward healthier more natural food products, there is the need to study effects of alternative sweeteners such as Stevia on the physicochemical quality and consumer perception of foods such as gluten-free muffins, as well as impact of health benefit statements attributed to these “healthy” ingredients.

CHAPTER 3. MATERIALS AND METHODS

3.1 Materials and Preparation of Gluten-Free Banana Muffins

All ingredients used in this research were food grade and are listed in Table 2. Stevia was used as a sucrose replacement in gluten-free banana muffin treatments made with different amounts of sugar (0%, 50%, 100%) as detailed in Table 3. For simplification, treatments will be referred to as sugar (100% sucrose), reduced-sugar (50% sucrose) and Stevia (0% sucrose) formulations throughout the text.

Table 2 Ingredients used for gluten-free banana muffins fixed

Ingredient	Amount	Percent of Formulation
Rice flour	320g	16.60
Buckwheat flour	80g	4.15
Corn starch	100g	5.19
Xanthan gum	10g	0.52
Milk	450mL	23.34
Oil	350mL	18.15
Eggs	300g	15.56
Baking soda	10g	0.52
Salt	6g	0.31
Banana	300g	15.56
Cinnamon	2g	0.10

Table 3 Treatment formulations with ingredients (sugar/stevia) varied

Treatment	Sugar (g)	Stevia (g)
100% Sucrose	250	0
Reduced-sucrose	125	16
100% Stevia/Sucrose-free	0	32

The 3 formulations of gluten-free banana muffins were prepared according to the recipe described by Iovana and others (2015) with modification. For each treatment, the dry ingredients were first combined excluding the baking soda to delay the onset of the reaction. Measured amounts of rice flour, buckwheat flour (Arrowhead Mills, NY, USA), corn starch (Argo Inc., TN, USA), xanthan gum (Bob's Red Mill® Natural Foods, OR, USA), sugar and/or stevia, salt and cinnamon (Great Value®, Wal-Mart, AR, USA) were mixed together. Next, the wet ingredients including milk, oil, eggs, peeled banana and vanilla (Great Value®, Wal-Mart, AR, USA) were added. Eggs and peeled bananas were beaten separately for 30 seconds using a KitchenAid® stand mixer (KitchenAid®, MI, USA). Finally, baking soda (Arm and Hammer, NJ, USA) was added. After all the ingredients were combined, they were kneaded using the Globe Mixer (Globe, SP5-MIXER5QT, OH, USA) on level 2 for 15 minutes. Following kneading, a portion of the batter (55g) was placed into a paper baking cup (5.5 cm diameter and 3cm height), and placed in an electric oven (Jenn-air, Pro-style, MI, USA).

Muffins were baked using the convection setting for 20 minutes at 180°C. The finished muffins were left to cool at room temperature for 1 hour, and put into paper bags (Great Value®, Wal-Mart, AR, USA) for storage, prior to the consumer study the following day. All muffins were therefore prepared 1 day before the consumer test. The same process was used to make the muffins analyzed for physicochemical properties.

3.2 Measurement of Physicochemical Properties

All physicochemical measurements were performed in duplicate replications. Moisture content of unground muffin samples was evaluated using the AOAC air oven method 945.14 (AOAC 1990). Samples were weighed (15g) and dried in a convection oven (VWR Scientific

Product, OR, USA) for 24 hours at 60 °C. The moisture content (MC) was expressed on a dry basis as the water mass in grams per 100 grams of dry matter, and calculated as: MC = {[initial weight ─ oven dry weight]/oven dry weight} *x* 100%.

Water activity (a_w) of gluten-free banana muffin crumbs was determined using a a_w meter (Hygrolab, Rotronic, NY, USA). The muffins were cut with a knife and placed into 14 mm disposable PS-14 a_w cups up to 75% of the total cup volume. The samples were measured using the standard function of the device, which automatically measures the a_w value of the food item.

Crumb color of the muffins was measured using a portable Konica Minolta colorimeter (Model BC-10, Minolta Camera Co. Ltd., Osaka, Japan). Before the samples were analyzed, the equipment was calibrated with a white standard and blank calibration. Measurements were made at the top of each sample and at its center after it was cut in half. Color values were stated as $L*$ (lightness), $a*$ (+ for redness and - for greenness) and $b*$ (+ for yellowness and - for blueness), H° (hue, H° = 0 for red, H° = 90 for yellow) and C* (chroma).

The texture profile analysis (TPA) method was performed using a compression test according to the AACC standard 74-09 method (AACC International 2000), and reported as hardness (N), cohesiveness and springiness (%). TA-XT Plus texture analyzer (Texture Technologies, MA, USA) was equipped with a cylinder probe with a diameter of 2 inches, and the test speed was 2 mm/s and the strain was 40%. Two replicates (six whole muffins/replicate) for each treatment (twelve muffins total/treatment) were analyzed, with probe insertion through the top of the muffin.

3.3 Consumer Studies of Gluten-Free Muffins

The research protocol for consumer testing was approved by the Louisiana State University Agricultural Center Institutional Review Board. The criteria for recruitment of study subjects were: (1) at least 18 years of age, (2) willingness to consume muffins, (3) availability of 10 minutes for completion of the test. Participants (*n*=128) were randomly recruited from a pool of faculty, staff and students at Louisiana State University, Baton Rouge, LA, USA.

Panelists were presented with 55g-samples of 3 muffin formulations (100% sucrose; reduced-sucrose, and 100% stevia), each labeled with a 3-digit code (Figure 2). Sample presentation followed a randomized complete block design in a counter-balanced order to minimize psychological biases (Cochran and Cox 1957). The amount of each muffin served was about 55g to reflect the normal serving size of muffins. Non-salted plain crackers and water at room temperature were also provided for palate cleansing in between samples. Panelists were seated in fluorescent-lit partitioned sensory booths (Figure 2) and provided informed consent based on the purpose of the research, procedures, and the ingredients, which could cause an allergic reaction. Consumers then completed a demographic questionnaire specifying their age, gender, and indicating their use of gluten-free or sugar-reduced products (yes/no). Consumer acceptance, emotional responses, and purchase intent of the samples were then assessed.

Regarding consumer acceptance testing, each panelist evaluated the 3 samples for 8 sensory attributes (color, odor, taste, sweetness, moistness, softness, stickiness and overall liking) on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely (Peryam and Pilgrim 1957). Additionally, the Just-About-Right (JAR) scale (1 = too weak, 2 = just about right, 3 = too strong) was used to evaluate perceived sweetness intensity, moistness, softness, and stickiness of the samples.

Figure 2 Sample presentation of treatments (left) and panelists in partitioned sensory booths evaluating the products (right)

Consumer emotional responses to the samples were evaluated using 8 positive [calm, good, happy, healthy, pleased, pleasant, satisfied, wellness (healthy lifestyle)] and 3 negative [guilty, unsafe (regarding nutritional facts), worried] emotion terms. Emotion terms were arranged in alphabetical order and their intensities rated on a 5-point scale (1 = not at all, 2 = slightly, 3 = moderately, 4 = very, and 5 = extremely). Selection of emotion terms was based on preliminary studies (n = 114; 76% females, ≥ 18 years) conducted to determine which of 50 positive and negative emotion terms were most experienced by consumers (≥ 20% frequency) when consuming muffins (Figure 3). Emotions with a frequency ≥ 20% (King and Meiselman 2010; Wardy and others 2015) were selected for the consumer study.

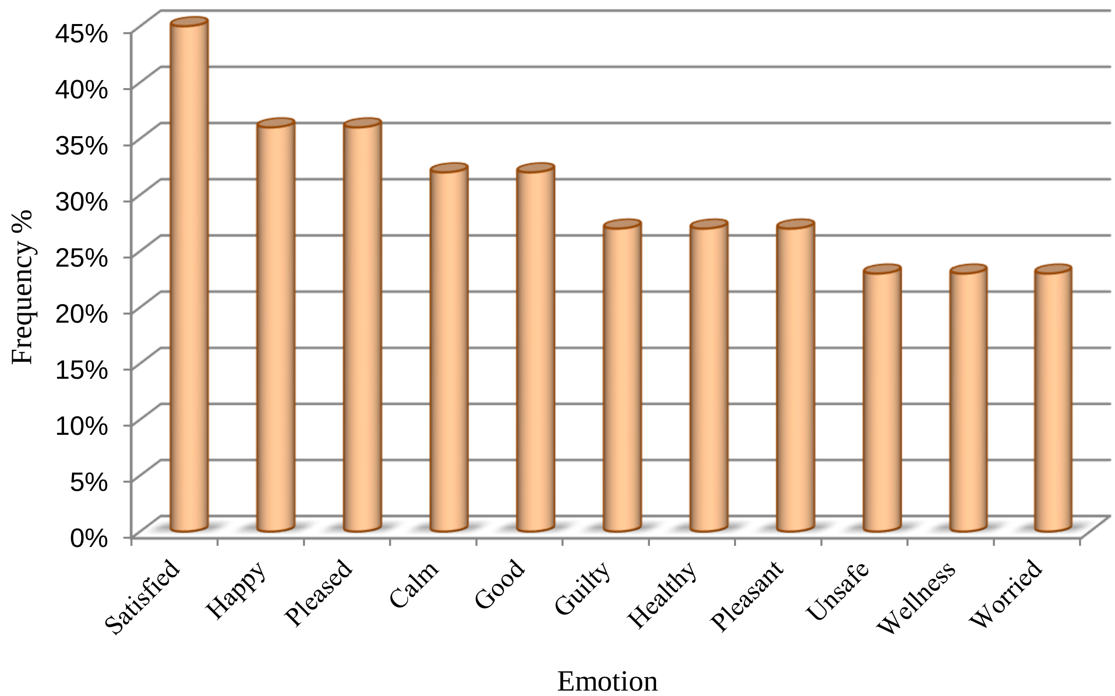


Figure 3 Emotion terms elicited by muffins from consumer responses (N = 114). Terms with >20% frequency count are shown.

Finally, purchase intent of the samples was evaluated using a binomial (yes/no) scale. Following evaluation of initial acceptance, emotional responses and purchase intent, consumers were informed about the sugar reduction level and gluten content corresponding to each sample. For example, "This product is gluten-free (wheat-free) and had a 50% sugar reduction." Overall liking, emotional response and purchase intent of the samples were then re-evaluated. The Compusense® five (version 5.6, Compusense Inc., Guelph, Canada) computerized data collection system was used for questionnaire development and data collection.

3.4 Statistical Analysis

Frequency counts of demographic data, questions about consumption of gluten-free or sugar-reduced products and purchase intent before and after information about the sugar level and gluten content of the samples had been given, were performed. To analyze physicochemical, sensory and emotion data, the statistical analysis software (SAS, 2003, version 9.3) was used. Data was analyzed using a predetermined confidence level of 95% ($\alpha = 0.05$). A one-way analysis of variance (ANOVA) was performed to determine if significant differences existed between the 3 muffin treatments in terms of physicochemical properties, sensory acceptability and emotional responses. Tukey's posthoc test was used to locate differences among the sample means. A dependent *t*-test was used to determine significant differences in consumer responses before and after health benefit statements. The McNemar's test was used to determine significant differences in the purchase intent of the each treatment before and after health benefit statements were provided. A penalty analysis was performed on the JAR data to assess the mean drop in overall liking for each attribute. Multivariate analysis of variance (MANOVA) and descriptive discriminant analysis (DDA), were conducted to identify overall significant differences among the 3 treatments, and the most discriminating attributes, considering all attributes simultaneously. Lastly, logistic regression analysis was used to determine sensory and emotion variables influencing purchase intent.

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Effects of Sugar Reduction on Sensory Liking

The mean consumer acceptability scores and their respective standard deviations for color, odor, taste, sweetness, moistness, softness, stickiness and overall liking of gluten-free muffin formulations are presented in Table 4. Perception of color, odor, taste, sweetness, moistness, softness, stickiness, and overall liking were only asked before the panelists received information about sugar reduction level or gluten content.

Table 4 Mean sensory acceptability scores[A] of gluten-free banana muffins made at different sugar reduction levels

Attribute	Sugar*	Reduced-Sugar	Stevia
Color	6.59 ± 1.45a	6.45 ± 1.33ab	6.11 ± 1.65b
Odor	6.42 ± 1.57a	6.27 ± 1.44ab	5.88 ± 1.66b
Taste	6.31 ± 1.64a	6.12 ± 1.60a	5.13 ± 1.99b
Sweetness	6.23 ± 1.74a	6.04 ± 1.62a	4.79 ± 2.01b
Moistness	6.61 ± 1.62a	6.47 ± 1.57a	5.54 ± 1.94b
Softness	6.74 ± 1.57a	6.40± 1.55a	5.52 ± 1.83b
Stickiness	6.28 ± 1.64a	6.27 ± 1.38a	5.63 ± 1.74b

[A]Mean ± standard deviations based on a 9-point hedonic scale. Mean values in the same row followed by different letters are significantly different ($P < 0.05$).
Based on 128 consumer responses.
*Sugar = 0% reduced treatment formulation; Reduced-Sugar = 50% reduced treatment formulation; Stevia = 100% reduced treatment formulation.

Generally, consumer acceptability of Stevia was lower ($P < 0.05$) than that of sugar and reduced-sugar muffins for all sensory attributes besides color and odor, which were similar between Stevia and reduced-sugar (Table 4). Interestingly, consumer liking for sugar and reduced-sugar treatments were not significantly different ($P > 0.05$) between samples for all sensory attributes with liking scores of 6.23–6.74 and 6.04–6.47 respectively (Table 4), indicating that, consumers found the sensory properties of sugar muffins and the reduced-sugar muffins to be equally acceptable.

In terms of sweetness, liking for Stevia (4.79) was rated 1.30x lower ($P > 0.05$) than sugar (6.23) (Table 4). Consumers therefore noticed the biggest difference in sweetness between sugar and stevia treatments. A similar trend was observed for the moistness, softness and stickiness of the muffins, with the sugar and reduced-sugar muffins being “slightly liked” compared to “neither like nor dislike” for Stevia samples.

Analysis of Just-About-Right (JAR) intensity ratings revealed that, the distribution consumer responses in the JAR group ranged from 32.81–67.18% (sweetness), 57.03–82.81% (softness), 64.84–83.59% (stickiness), and 58.59–78.12% (moistness). At least 70% responses in the JAR group for sugar and reduced-sugar formulations were observed for softness, stickiness and moistness indicating optimal levels for these, but not for sweetness (Figure 4; Appendix 4). Based on the penalty analysis (Figure 4) using JAR scale ratings and mean acceptability scores, a large number of consumers (up to 65%) perceived that the muffin treatments were not sweet enough, resulting in a mean drop of 2.03–2.82 on a 9-point overall liking scale for sugar, reduced-sugar and Stevia formulations. For moistness, up to 29% of consumers perceived the muffins as not being moist enough, resulting in a mean drop in liking of 2.74–3.16. Similarly, up to 38% of consumers perceived a lack of softness in the muffins, resulting in a mean drop of 2.35–2.72. However, impact of stickiness of muffin samples on overall liking was not as concerning, with penalties $< |0.6|$, especially for the reduced-sugar formulation (Appendix 4). In brief, overall liking scores of the muffins were negatively affected by the lack of moistness and/or softness of both the reduced-sugar and Stevia formulations, and also by the sweetness intensity of all 3 formulations.

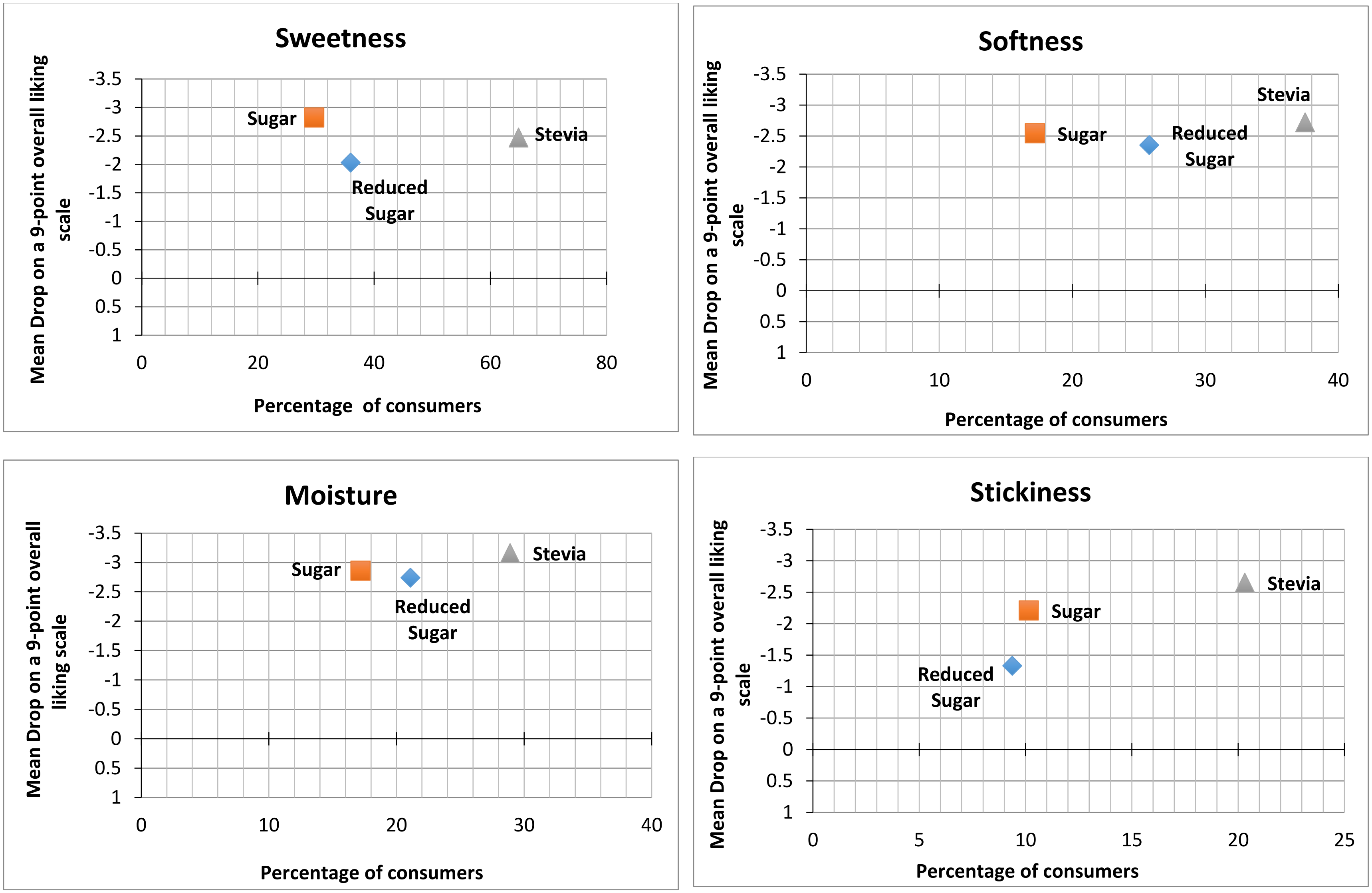


Figure 4 Penalty plots showing mean drops in overall liking as affected by "not enough" JAR attributes (sweetness, moistness, softness and stickiness) of gluten-free banana muffins. *Sugar = 0% reduced treatment; Reduced-Sugar = 50% reduced treatment; Stevia = 100% reduced treatment.

4.2 Overall Product Differences and Discriminating Sensory Attributes

For the purpose of determining if an overall difference existed among all 3 muffin formulations considering all sensory attributes simultaneously, a MANOVA was conducted which produced a significant result ($P < 0.001$). According to Koeferli and others (1998), MANOVA yields further information from sensory data as it can be used to reveal patterns, correlate parameters and classify data.

Posthoc descriptive discriminant analysis (DDA) following a significant MANOVA determined which attributes were responsible for the overall difference among the three treatments. According to the first dimension of the pooled-within canonical structure (Can 1) which explained 96% of the variance, sweetness, overall liking, softness, taste and moistness were critical discriminating attributes with canonical correlations (r) ≥ 0.5 (Table 5). Among these discriminating attributes, sweetness perception and overall liking of the muffin treatments were evidently very important to the differences among treatments perceived by the consumers ($r \geq 0.8$).

Table 5 Canonical structure *r*'s describing group differences among gluten-free banana muffins made at different sugar reduction levels

Attribute	Can 1[a]	Can 2[a]
Color	0.3351	-0.2151
Odor	0.3627	-0.1934
Taste	0.7290*	0.0451
Sweetness	0.8774*	0.1983
Moistness	0.6838	0.1515
Softness	0.7666*	-0.3872
Stickiness	0.4687	0.3276
Overall Liking	0.8246*	0.0845
Cumulative variance explained (%)	95.7	100

[a]Based on the pooled within group variances. Can 1 and 2 refer to the 1st and 2nd canonical discriminant functions respectively. *Critical discriminating attributes ($r \geq \pm 0.5$).

4.3 Effects of Sugar Reduction and Health Benefit Statements on Consumer Emotional Responses

Table 6 shows the effects of sugar reduction level and gluten-free health benefit statements on consumer emotional responses. Before health benefit statements were provided, no significant differences ($P > 0.05$) in emotion intensities were found between all 3 muffin samples for all negative emotions (*guilty, unsafe*, and *worried*),and also for the positive emotions *healthy and* wellness. However, the intensities of the positive emotions *calm, good, happy, pleasant, pleased and satisfied* were significantly lower ($P < 0.05$) for muffins made with Stevia than for the other formulations (Table 6). This may be due to the significantly lower sweetness, taste and odor ratings observed for Stevia compared to the other formulations. Hence, sensory properties may have had a direct impact on the product emotions expressed by consumers.

Following awareness of the sugar reduction level and gluten content of the products, differences in evoked emotions emerged. Particularly for the positive emotions *good, happy, healthy, pleasant and pleased*, consumers reported similar intensities for both sugar and Stevia which were lower ($P < 0.05$) than for the reduced-sugar formulation (Table 6). Consumers felt *guiltier* and less *wellness* due to sugar, while Stevia made them feel less satisfied. The only emotions that were not significantly affected by health benefit statements were *calm*, *unsafe* and *worried* between all muffin treatments (Table 6).

Comparing emotional terms before and after revealed a positive significant effect ($P <$ 0.05) of health benefit statements on the intensities of the positive emotions *calm, good, happy, healthy and pleased* for both reduced-sugar and Stevia, *pleased* for sugar only, and *worried* for Stevia only formulations. Overall, health benefit statements had more impact on positive emotions elicited by reduced-sugar and Stevia, compared to sugar.

Table 6 Mean consumer emotion scores[A] of gluten free banana muffins made at different sugar reduction levels**.

Emotion		Sugar*	Reduced-Sugar	Stevia
Calm	Before[B]	2.48 ± 0.98a	2.48 ± 0.88a*	2.27 ± 0.93b*
	After[B]	2.54 ± 0.97a	2.68 ± 0.90a*	2.52 ± 2.16a*
Good	Before	2.72 ± 0.96a	2.72 ± 0.86a*	2.22 ± 0.97b*
	After	2.70 ± 0.94ab	2.94 ± 0.88a*	2.52 ± 1.05b*
Guilty	Before	1.69 ± 0.98a	1.55 ± 0.89a	1.58 ± 0.95a
	After	1.69 ± 0.89a	1.44 ± 0.76b	1.40 ± 0.90b
Happy	Before	2.63 ± 0.96a	2.66 ± 0.94a*	2.23 ± 1.05b*
	After	2.57 ± 0.97ab	2.81 ± 1.02a*	2.45 ± 1.05b*
Healthy	Before	2.33 ± 1.04a	2.38 ± 1.00a*	2.27 ± 1.07a*
	After	2.37 ± 1.10b	2.91 ± 1.01a*	3.06 ± 1.20a*
Pleasant	Before	2.70 ± 0.94a	2.68 ± 0.97a	2.27 ± 1.00b*
	After	2.67 ± 0.96ab	2.80 ± 0.97a	2.48 ± 1.08b*
Pleased	Before	2.82 ± 0.95a*	2.72 ± 1.01a*	2.16 ± 0.99b*
	After	2.65 ± 0.97ba*	2.88 ± 0.94a*	2.39 ± 1.13b*
Satisfied	Before	2.80 ± 0.97a	2.66 ± 0.97a	2.23 ± 1.00b
	After	2.76 ± 1.02a	2.88 ± 0.99a	2.38 ± 1.09b
Unsafe	Before	1.53 ± 0.85a	1.41 ± 0.83a	1.51 ± 0.90a
	After	1.45 ± 0.74a	1.35 ± 0.76a	1.40 ± 0.90a
Wellness	Before	2.41 ± 0.98a	2.33 ± 0.96a	2.34 ± 1.04a
	After	2.34 ± 1.04b	2.92 ± 1.12a	3.02 ± 1.26a
Worried	Before	1.30 ± 0.64a	1.30 ± 0.70a	1.39 ± 0.78a*
	After	1.34 ± 0.71a	1.24 ± 0.62a	1.26 ± 0.70a*

[A]Mean ± standard deviation from 128 consumer responses based on a 5-point scale. Mean values in the same row followed by different letters are significantly different ($P < 0.05$).
[B]Emotion scores were obtained both before and after consumers had been given information about sugar reduction level and gluten content. *Indicates significant differences based on the dependent sample *t*-test ($P < 0.05$) to evaluate effect of health benefit statements.
**Sugar = 0% reduced treatment formulation; Reduced-Sugar = 50% reduced treatment formulation; Stevia = 100% reduced treatment formulation.

4.4 Effects of Sugar Reduction and Health Benefit Statements on Overall Liking and Purchase Intent.

The sugar reduction level and gluten-free statement given to the panelists significantly affected overall liking of the muffins. As shown in Figure 5 after health benefit statements were introduced, overall liking for sugar muffins decreased (6.38 to 6.20), while that of reduced-sugar (6.16 to 6.33) and Stevia (5.03 to 5.13) increased (Figure 5). Consequently, reduced-sugar became the most accepted treatment followed by sugar. However, noted increments for any of the treatments were not significantly different. Stevia had the lowest product acceptability both before and after health benefit statements (Figure 5).

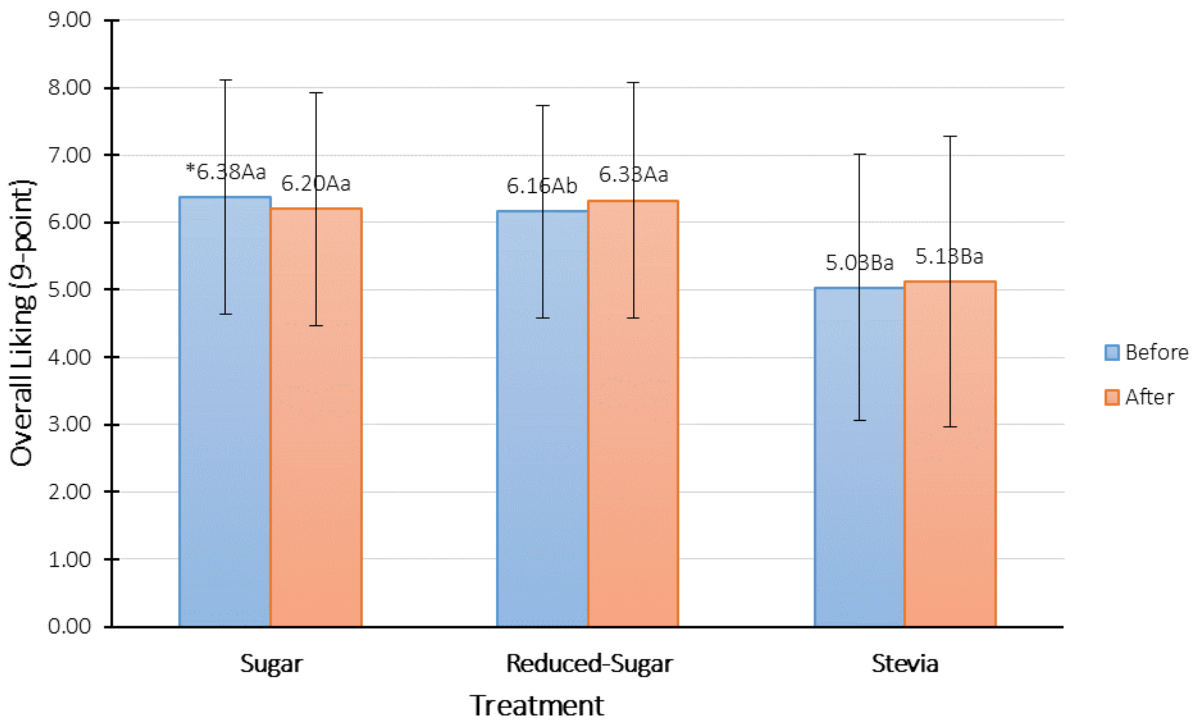


Figure 5 Overall liking (Mean ± SD bars) of gluten-free, sugar reduced banana muffins before and after providing health benefit statements to consumers (*N*=128).
*Mean values followed by different uppercase (ANOVA) and lowercase (*t*-test) letters are significantly different ($P < 0.05$).
Sugar = 0% reduced treatment formulation; Reduced-Sugar = 50% reduced treatment formulation; Stevia = 100% reduced treatment formulation.

The purchase intent for reduced-sugar and Stevia significantly increased (based on the McNemar's test; $P < 0.05$) from 44.5% to 53.1%, and 22.7% to 32.8%, respectively, after the panelists were informed of the sugar reduction level and gluten-free content (Figure 6). The biggest change in purchase intent was seen with Stevia where the purchase intent increased from

23 to 33%. Although the purchase intent of the Stevia formulation increased significantly, Stevia was still the least likely treatment to be purchased. The second biggest change was seen for reduced-sugar with an 8.6% reduction; even though it still maintained the highest positive purchase intent of 53% while that of the sugar formulation decreased by 2.3% from 48.4 to 46.1 (Figure 6).

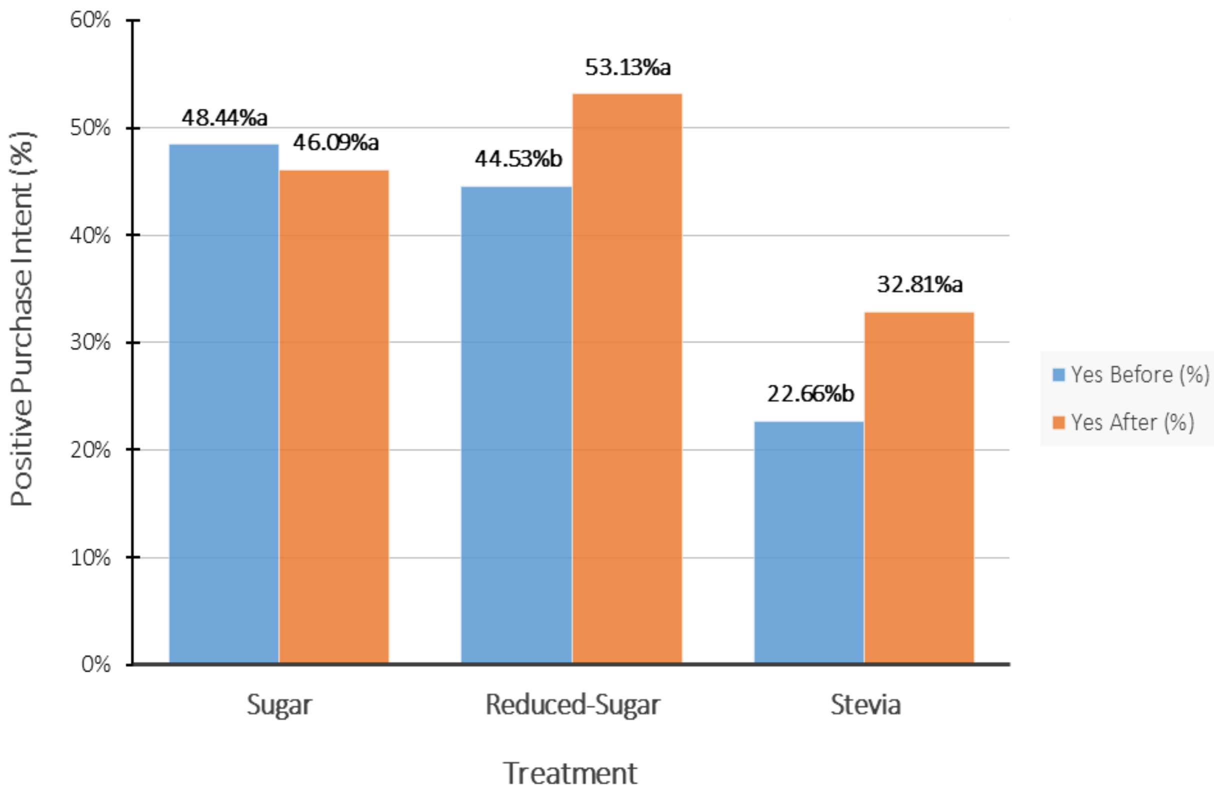


Figure 6 Purchase intent of gluten-free, sugar reduced banana muffins before and after providing health benefit statements to consumers (N=128).
*Different lowercase letters are significantly different ($P < 0.05$; McNemar's test) before and after providing health benefit statements.
Sugar = 0% reduced treatment formulation; Reduced-Sugar = 50% reduced treatment formulation; Stevia = 100% reduced treatment formulation.

4.5 Predicting Purchase Intent Using Logistic Regression Analysis (LRA)

In this study, the probability of the muffin products to be purchased was modeled using LRA. Only the attributes that were evaluated before and after the health benefit statements were included in the LRA model (Table 7).

Before the health statements were provided, color, sweetness, overall liking, and *satisfied* were significant in the LRA models (Table 7). Color and sweetness were not evaluated after, and overall liking was the only variable that remained a significant predictor once the health benefit statements were presented, while *satisfied* became an insignificant predictor. Furthermore, the emotions *happy,* and *wellness* became significant predictors, with odds ratio values of 1.867 and 1.457, respectively, after the benefit statements. This means that for every one-point increase in the intensity of *happy* and *wellness* emotions on a 5-point scale, the odds of the products being purchased would be 1.87 and 1.46 times higher than not being purchased, respectively, after informing consumers of the health benefits (Table 7). As a result, these emotions must be targeted in product design to increase positive purchase intent of reduced-sugar gluten-free muffins.

All the demographic variables were not significant predictors of purchase intent before health benefit statements were provided (Table 7); however, the variable *normally purchase gluten free products* became a significant predictor when health benefits were stated with an odds ratio of 0.321. Hence for a change in the consumer response from a no to a yes for *normally purchase gluten free products*, the odds of the muffins being purchased would be 3.12 times or 67.9% lower than not being purchased. Optimization studies based on preferences of different consumer segments need to be addressed in future research.

Table 7 Combined odds ratio estimates[A] for predicting purchase intent of gluten free banana muffins before and after providing health benefit statements

	Variables	Purchase Intent Before		Purchase Intent After	
		Pr > χ2	Odds ratio	Pr > χ2	Odds ratio
Demographics	Gender (Male: 45.31%)	0.749	1.121	0. 512	1.212
	Normally Purchase Sugar Free Products (35.94%)	0.804	1.095	0.839	0.940
	Normally Purchase Gluten Free Products (10.16%)	.436	1.569	0.030*	0.321*
Sensory attributes	Color	0.005*	0.625*	-**	-
	Odor	0.975	0.995	-	-
	Taste	0.507	1.175	-	-
	Sweetness	0.015*	1.458*	-	-
	Moistness	0.480	0.895	-	-
	Softness	0.623	1.087	-	-
	Stickiness	0.518	0.905	-	-
	Overall liking	<.0001*	3.323*	<.0001*	1.895*
Emotions	Calm	0.321	0.756	0.445	0.824
	Good	0.632	1.177	0.750	0.914
	Guilty	0.997	0.999	0.684	1.107
	Happy	0.393	1.284	0.037*	1.867*
	Healthy	0.273	1.299	0.795	0.948
	Pleasant	0.387	0.754	0.707	1.123
	Pleased	0.257	1.484	0.312	1.379
	Satisfied	0.027*	2.023*	0.375	1.273
	Unsafe	0.088	0.635	0.820	1.064
	Wellness	0.681	0.908	0.048*	1.457*
	Worried	0.490	0.774	0.640	0.850

[A]Based on logistic regression analysis, using a full model of gender, normal purchasing statements, liking, and 11 emotions. Analysis of maximum likelihood estimates was used to obtain parameters estimates. *Significance of parameter estimates was based on the Wald χ^2 value at $P < 0.05$. **Not measured

4.6 Effects of Sugar Reduction on Physicochemical Properties

Table 8 shows physicochemical quality indices for the 3 muffin formulations. Formulations with a lower sugar content produced muffins with a lower specific volume than for those with 100% sugar. According to Tzia and others (2012), sucrose plays a significant role in the bulk, structural and textural properties of overall muffin dough and critical to the overall dough quality in baked goods. In this study, the specific volume of sugar and stevia muffins were similar ($P > 0.05$) but higher than that of the reduced-sugar formulation.

Table 8 Physicochemical properties of gluten-free muffins made at different sugar reduction levels[A]

	Sugar*	Reduced-Sugar	Stevia
Specific volume (cm^3/g)	3.09 ± 0.14a	2.70 ± 0.17b	2.95 ± 0.09a
Moisture (%)	35.00 ± 3.15b	38.30 ± 1.03a	41.10 ± 1.68a
Water Activity	0.93 ± 0.00b	0.94 ± 0.00b	0.96 ± 0.00a
Crumb Color Top			
L*	47.30 ± 1.49b	53.40 ± 2.56a	48.8 ± 2.81b
a*	10.60 ± 2.41a	7.28 ± 2.04a	8.25 ± 3.16a
b*	14.90 ± 1.43a	16.10 ± 3.53a	14.60 ± 3.58a
Crumb Color Inside			
L*	55.70 ± 0.99a	55.50 ± 2.06a	54.30 ± 3.73a
a*	5.57 ± 1.73a	5.45 ± 1.25a	3.92 ± 1.00a
b*	12.30 ± 0.60a	11.90 ± 2.05ab	9.87 ± 1.55b
Texture Profiles			
Hardness (N)	19.70 ±1.06a	22.60 ± 0.12a	22.50 ± 2.97a
Cohesiveness	0.69 ± 0.02a	0.67 ± 0.01b	0.66 ± 0.01b
Springiness (%)	88.80 ± 0.77a	89.20 ± 1.13a	88.70 ± 0.90a

[A]Mean ± standard deviation values from 2 independent replications. Mean values in the same row followed by different letters are significantly different ($P < 0.05$).
*Sugar = 0% reduced treatment formulation; Reduced-Sugar = 50% reduced treatment formulation; Stevia = 100% reduced treatment formulation.

Water activity (a_w) is a measure of the partial vapor pressure of water in a product divided by the partial vapor pressure of pure water at the same temperature, and is an important index of the chemical and microbial stability of the product during storage (Labuza and others 1985). As shown in Table 8, a_w of gluten-free banana muffins ranged from 0.936 (sugar) to 0.956 (Stevia), and a 100% reduction in sugar content result in a significantly higher a_w value ($P < 0.05$). A beneficial role of sugar in batters is that, they not only provide sweetness but also, lower the a_w of the batter (Hahn 2001). An advantage of lowering the a_w is that, it provides microbial stability for long periods of time, with the preferable a_w being between 0.82 and 0.88 (Hahn 2001). If the water activity is above those numbers, the dough may not stable in terms of microbial stability unless the batter is frozen (Hahn 2001), or humectants could be added to the formulations to reduce the a_w.

Crumb color (top) for sugar and Stevia muffins was darker ($P < 0.05$) than for reduced-sugar muffins based on L* values (Table 8). Color of the inside crumb was however similar across treatments, except for less yellowness (b*) of Stevia compared to sugar muffins. These observations could be attributed to the lower sugar content resulting in the reduced yellowness of the inside of the muffin. The relevance of product appearance on consumer liking may vary, and not be a critical driver of liking (Moskowitz and Krieger 1995; Li and others 2015). In the present study, color liking scores for Stevia were similar to reduced-sugar, but significantly lower for sugar muffins ($P < 0.05$), even though they were all acceptable (all scores > 6.1; Table 4). This may likely be due to the reduced yellowness of the Stevia formulation compared to the sugar formulation.

Texture hardness, cohesiveness and springiness were determined for the treatments (Table 8). Hardness is the force necessary to obtain a given deformity while cohesiveness is the strength of the internal bonds making up the body of the product. Springiness refers to the distance recovered by the sample during the time between the end of the first bite and the start of the second bite. The hardness values from the TPA test were higher for reduced-sugar (22.56 N) and Stevia (22.48 N) formulations compared with sugar muffins (19.71 N). However, sugar muffins were more cohesive than reduced-sugar and Stevia muffins, while springiness was comparable across all 3 formulations (Table 8). In this study, 100% sugar reduction in gluten-free muffins affected liking scores of moistness, softness, and stickiness, but did not make these attributes unacceptable (all scores > 5.5; Table 4). Despite some statistically significant differences, physical texture measurement values were generally similar, and this could explain the observed acceptability of reduced-sugar gluten-free muffins.

Overall, it was observed that sugar reduction affected physicochemical and sensory properties of gluten-free banana muffins. 100% Stevia tended to decrease liking scores, and this negative effect was more pronounced for sweet and taste-related attributes than for texture and color-related attributes (Tables 4 and 8).

CHAPTER 5. SUMMARY AND CONCLUSIONS

This study investigated effects of reducing the sugar level and health benefit statements on the physicochemical properties and consumer perception of gluten-free banana muffins. Three different gluten-free muffin formulations made with different amounts of sugar (0%, 50%, 100%), with Stevia used as a sucrose replacement, were examined. Consumer acceptability of sensory attributes (color, odor, taste, sweetness, moistness, softness and stickiness), ratings of attribute intensities, emotional responses, and health benefit statements were evaluated along with physicochemical quality indices including specific volume, water activity, color and texture attributes.

Consumer acceptability of muffin formulations with 100% and 50% sucrose were not significantly different for all sensory attributes: however, consumer acceptability of 100% sugar replacement with Stevia was lower than that of sugar and reduced-sugar muffins for all sensory attributes besides color and odor. Sweetness, overall liking, softness, taste and moistness were critical sensory discriminating attributes among muffin treatments. Overall liking scores of the muffins were negatively affected by the lack of moistness and/or softness of both the reduced-sugar and Stevia formulations, and also by the sweetness intensity of all formulations. Sweetness, overall liking, softness, taste and moistness were critical sensory discriminating attributes among muffin treatments. Health benefit statements had a positive effect on overall liking, purchase intent, and intensities of the emotions calm, good, happy, healthy and pleased for both reduced-sugar and Stevia treatments, but a rather negative impact on the sugar formulation. Additionally, the emotions happy and wellness became significant predictors of purchase intent after health benefit statements had been provided, reflecting consumer consciousness towards healthier food products.

Overall, sugar reduction affected physicochemical and consumer perception of gluten-free banana muffins. 100% Stevia tended to decrease liking scores, and this negative effect was more pronounced for sweet and taste-related attributes than for texture and color-related attributes. The reduced-sugar formulation containing 50% sucrose presented an acceptable alternative for consumers seeking healthier options based on their sensory and physicochemical quality. Future studies aimed at optimizing the formulation and cost of reduced-sugar gluten-free muffins are therefore needed.

REFERENCES

Abou-Arab, A.E., Abou-Arab, A.A. & Abu-Salem, M.F. (2010). Physico-chemical assessment of natural sweeteners steviosides produced from Stevia rebaudiana Bertoni plant. *African Journal of Food Science*, 4 (5), 269–281.

Anton, S.D., Martin, C.K., Han, H., Coulon, S., Cefalu, W.T., Geiselman, P. & Williamson, D. A. (2010). Effects of stevia, aspartame, and sucrose on food intake, satiety, and postprandial glucose and insulin levels. *Appetite*, 55 (1), 37–43.

Association of Official Analytical Chemists (AOAC). (1990). Official Methods of Analysis, Method 945.14: air oven method (103–104 °C) (15th edn). Arlington, VA.

Bean, M.M. (1986). Rice flour: its functional variations. *Cereal Foods World*.

Bernal, J., Mendiola, J.A., Ibáñez, E. & Cifuentes, A. (2011). Advanced analysis of nutraceuticals. *Journal of Pharmaceutical and Biomedical Analysis*, 55 (4), 758–774.

Brown, R.J. & Rother, K.I. (2012). Nonnutritive sweeteners and their role in the gastrointestinal tract. *The Journal of Clinical Endocrinology & Metabolism*, 97 (8), 2597–2605.

Bower, J.A. & Boyd, R. (2003). Effect of health concern and consumption patterns on measures of sweetness by hedonic and just-about-right scales. *Journal Of Sensory Studies*,18 (3), 235–248.

Caballero, B., Trugo, L. & Finglas, P. (2003). *Encyclopedia of food sciences and nutrition: Volumes 1–10* (2nd edn). Elsevier Science BV.

Carakostas, M.C., Curry, L.L., Boileau, A.C. & Brusick, D.J. (2008). Overview: the history, technical function and safety of rebaudioside A, a naturally occurring steviol glycoside, for use in food and beverages. *Food and Chemical Toxicology*, 46 (7), S1–S10.

Bolini, A. & Maria, H. (2008). Descriptive profile of peach nectar sweetened with sucrose and different sweeteners. *Journal of Sensory Studies*, 23 (6), 804–816.

Carrillo, E., Varela, P. & Fiszman, S. (2012). Effects of food package information and sensory characteristics on the perception of healthiness and the acceptability of enriched biscuits. *Food Research International*, 48 (1), 209–216.

Catassi, C. & Fasano, A. (2008). Celiac disease. *Current Opinion in Gastroenterology*, 24 (6), 687–691.

Fasano, A. & Catassi, C. (2005). Celiac disease in children. *Best Practice & Research Clinical Gastroenterology*, 19 (3), 467–478.

Cauvin, S. & Young, L. (2006). Productos de panadería: Ciencia, Tecnologia y Prática Editorial Acribia, SA. *Zaragoza–España*.

CDC. (2014). *Centers for Disease Control and Prevention*. National diabetes statistics report: estimates of diabetes and its burden in the United States. *Atlanta, GA: US Department of Health and Human Services*.

Claire, J. (2014). The Chemistry of Baking. Senior Theses. Paper 23. http://scholarcommons. sc.edu.libezp.lib.lsu.edu/senior_theses/23.

Chinachoti, P. (1995). Carbohydrates: functionality in foods. *The American Journal of Clinical Nutrition*, 61 (4), 922S–929S.

Chun, S. Y. & Yoo, B. (2004). Rheological behavior of cooked rice flour dispersions in steady and dynamic shear. *Journal of Food Engineering*, 65 (3), 363–370.

Cochran, W.G. & Cox, G.M. (1957). Experimental designs (2nd edn). John Wiley & Sons, Inc., New York.

Connors, M., Bisogni, C.A., Sobal, J. & Devine, C.M. (2001). Managing values in personal food systems. *Appetite*, 36 (3), 189–200.

Cross, N.A., Corke, H., De Leyn, I. & Nip, W.K. (2006). Bakery products: science and technology: 551.

Davis, E.A. (1995). Functionality of sugars: physicochemical interactions in foods. *The American Journal of Clinical Nutrition*, 62 (1), 170S–177S.

Dean, M., Lähteenmäki, L. & Shepherd, R. (2011). Nutrition communication: consumer perceptions and predicting intentions. *Proceedings of the Nutrition Society*, 70 (01), 19–25.

Deliza, R. & MacFie, H.J. (1996). The generation of sensory expectation by external cues and its effect on sensory perception and hedonic ratings: a review. *Journal of Sensory Studies* 11 (2), 103–128.

Dobraszczyk, B.J., Campbell, G.M. & Gan, Z. (2001) Bread: a unique food. In: *Cereals and Cereal Products: Technology and Chemistry*, (edited by D.A.V. Dendy & B.J. Dobraszczyk). Pp. 182–232. Aspen, Maryland, USA.

Equipment, M.B. (1979). Model studies of cake baking. I. Continuous observations of starch gelatinization and protein coagulation during baking. *Cereal Chemistry*, 56 (4), 305–309.

Fasano, A. (2009). Surprises from celiac disease. *Scientific American*, 301 (2), 54–61.

FDA. (1994). *Food and Drug Administration*. A Food Labeling Guide, Center for Food Safety and Applied Nutrition, http://www.cfsan.fda.gov/~dms/flg–toc.html.

FDA. (2015). *Food and Drug Administration*. Additional Information about High–Intensity Sweeteners Permitted for use in Food in the United States, Food Additives & Ingredients, http://www.fda.gov/Food/IngredientsPackagingLabeling/FoodAdditivesIngredients/ucm397725.htm.

Figoni, P. (2004). How Baking Works. John Wiley & Sons, Inc., Hoboken, New Jersey, USA. Pp 80, 137–141,183–193, 233, 240–242, 257–264, 31– 32, 37.

Figoni, P. (2008). *How baking works: exploring the fundamentals of baking science*. John Wiley & Sons, Inc., New Jersey, USA.

FDA. (2013). *Food and Drug Administration*. Code of Federal Regulations, Title 21. *21 CFR 312.32 (c)(1)(i)(C)–IND Safety Reporting*.

Gaesser, G.A. & Angadi, S.S. (2012). Gluten–free diet: Imprudent dietary advice for the general population? *Journal of the Academy of Nutrition and Dietetics* 112 (9), 1330–1333.

Gallagher, E., O'Brien, C.M., Scannell, A.G.M. & Arendt, E.K. (2003). Evaluation of sugar replacers in short dough biscuit production. *Journal of Food Engineering*, 56 (2), 261–263.

Gan, Z., Ellis, P.R. & Schofield, J.D. (1995). Mini review gas cell stabilization and gas retention in wheat bread dough. *Journal of Cereal Science*, 21, 215–230.

Geuns, J.M. (2003). Stevioside. *Phytochemistry*, 64 (5), 913–921.

Giraldo, C., Marín, L. & Habeych, D. (2005). Obtención de edulcorantes de Stevia rebaudiana Bertoni. *Revista CENIC Ciencias Biológicas*, 36, 3–10.

Green, P.H. & Jabri, B. (2003). Coeliac disease. *The Lancet*, 362 (9381), 383–391.

Green, P. H. & Cellier, C. (2007). Coeliac disease. *New England Journal of Medicine*, 357 (17), 1731–1743.

Glanz, K., Basil, M., Maibach, E., Goldberg, J. & Snyder, D.A.N. (1998). Why Americans eat what they do: taste, nutrition, cost, convenience, and weight control concerns as influences on food consumption. *Journal of the American Dietetic Association*, 98 (10), 1118–1126.

Goyal, S.K. & Goyal, R.K. (2010). Stevia (*Stevia rebaudiana*) a bio–sweetener: a review. *International Journal of Food Sciences and Nutrition*, 61 (1), 1–10.

González-Mateo, S., González-SanJosé, M. L. & Muñiz, P. (2009). Presence of Maillard products in Spanish muffins and evaluation of colour and antioxidant potential. *Food and Chemical Toxicology*, 47 (11), 2798–2805.

Gujral, H.S. & Rosell, C.M. (2004). Improvement of the breadmaking quality of rice flour by glucose oxidase. *Food Research International*, 37 (1), 75–81.

Hahn, P.W. (2001). *U.S. Patent No. 6, 217,929*. Washington, DC: U.S. Patent and Trademark Office.

Iovan, M., Stoin, D., Traşcă, T. & Rădoi, B. (2015). Studies regarding the obtaining and sensory analysis of gluten–free muffins with buckwheat flour addition. *Journal of Agroalimentary Processes and Technologies*, 21 (3), 222–226.

Jamieson, P. (2008). The sugarfree toolbox e bulk ingredients and intense sweeteners. *The Manufacturing Confectioner*, 88 (11), 33–46.

Johansen, S. B., Næs, T., Øyaas, J. & Hersleth, M. (2010). Acceptance of calorie–reduced yoghurt: Effects of sensory characteristics and product information. *Food Quality and Preference*, 21 (1), 13–21.

King, S.C., Meiselman, H.L. & Carr, B.T. (2010). Measuring emotions associated with foods in consumer testing. *Food Quality and Preference*, 21 (8), 1114–1116.

Kochikyan, V.T., Markosyan, A.A., Abelyan, L.A., Balayan, A.M. & Abelyan, V.A. (2006). Combined enzymatic modification of stevioside and rebaudioside A. *Applied Biochemistry and Microbiology*, 42 (1), 31–37.

Kozup, J.C., Creyer, E.H. & Burton, S. (2003). Making healthful food choices: the influence of health claims and nutrition information on consumers' evaluations of packaged food products and restaurant menu items. *Journal of Marketing*, 67 (2), 19–34.

Kobus-Moryson, M. & Gramza-Michałowska, A. (2015). Directions on the use of Stevia Leaves (*Stevia Rebauidana*) as an additive in food products. *Acta Scientiarum Polonorum Technologia Alimentaria*, 14 (1), 5–13.

Koeferli, C.S., Schwegler, P.P. & Hong-Chen, D. (1998). Application of classical and novel sensory techniques in product optimization. *LWT–Food Science and Technology*, 31 (5), 407–417.

Köster, E.P., Couronne, T., Léon, F., Lévy, C. & Marcelino, A.S. (2003). Repeatability in hedonic sensory measurement: a conceptual exploration. *Food Quality and Preference*, 14 (2), 165–176.

Kim, C.S. (1994). The Role of Ingredients and Thermal Setting in High–Ratio Layer Cakes Systems. *Journal of the Korean Society of Food Science and Nutrition*, 23, 520–529.

Kim, N.C. & Kinghorn, A.D. (2002). Highly sweet compounds of plant origin. *Archives of Pharmacal Research* 25 (6), 725–746.

Holmes, G.K.T. (2002). Screening for coeliac disease in type 1 diabetes. *Archives of Disease in Childhood*, 87 (6), 495–498.

Labuza, T.P., Kaanane, A. & Chen, J.Y. (1985). Effect of temperature on the moisture sorption isotherms and water activity shift of two dehydrated foods. *Journal of Food Science*, 50 (2), 385–392.

Lemus-Mondaca, R., Vega-Gálvez, A., Zura-Bravo, L. & Ah-Hen, K. (2012). Stevia rebaudiana Bertoni, source of a high–potency natural sweetener: A comprehensive review on the biochemical, nutritional and functional aspects. *Food Chemistry*, 132 (3) 1121–1132.

Leonard, M.M., Cureton, P.A. & Fasano, A. (2015). Managing coeliac disease in patients with diabetes. *Diabetes, Obesity and Metabolism*, 17 (1), 3–8.

Li, X.E., Jervis S.M. & Drake, M.A. (2015). Examining extrinsic factors that influence product acceptance: a review. *Journal of Food Science,* 80, R901–909.

Mcgill, M. (2005). What causes celiac disease? *Nursing 2015*, 35 (7), 29.

McWilliams, M. (2008). Foods: experimental perspectives. (6th edn). Prentice Hall, Upper Saddle River, New Jersey and Columbus, Ohio,

Manisha, G., Soumya, C. & Indrani, D. (2012). Studies on interaction between stevioside, liquid sorbitol, hydrocolloids and emulsifiers for replacement of sugar in cakes. *Food Hydrocolloids* 29 (2), 363–373.

Marcason, W. (2011). Is there evidence to support the claim that a gluten–free diet should be used for weight loss? *Journal of the American Dietetic Association,* 111(11), 1786.

Miraballes, M., Fiszman, S., Gámbaro, A. & Varela, P. (2014). Consumer perceptions of satiating and meal replacement bars, built up from cues in packaging information, health claims and nutritional claims. *Food Research International*, 64, 456–464.

Mizukoshi, M., Maeda, H. & Amano, H. (1980). Model studies of cake baking. II. Expansion and heat set of cake batter during baking. *Cereal Chemistry, (USA).*

Moskowitz, H.R. & Krieger, B. (1995). The contribution of sensory liking to overall liking: an analysis of six food categories. *Food Quality and Preference*, 6, 83–90.

Murray, J.A. (1999). The widening spectrum of celiac disease. *The American Journal of Clinical Nutrition*, 69 (3), 354–365.

Mugema, L. (2009). Creating celiac disease awareness in Africa. Retrieved on May 4 2016 from http://www.celiac.com/articles/21841/1.

Nabors, L. & Geraldi, R.C. (1991). Alternative Sweeteners. Marccel Dekker. *Inc. New York*.

Ng, S.W., Slining, M.M. & Popkin, B.M. (2012). Use of caloric and noncaloric sweeteners in US consumer packaged foods 2005–2009. *Journal of the Academy of Nutrition and Dietetics* 112 (11), 1828–1834.

O'Donnell, K. & Kearsley, M. (eds). (2012). *Sweeteners and sugar alternatives in food technology*. John Wiley & Sons.

Peryam D.R. & Pilgrim, F.J. (1957). Hedonic scale method of measuring food preferences. *Food Technology*, 11, 9–14.

Pohjanheimo, T. (2010). Sensory and Non–sensory Factors Behind the Liking and Choice of Healthy Food Products. Functional Foods Forum; Department of Biochemistry and Food Chemistry, University of Turku.

Poppitt, S.D. (1995). Energy density of diets and obesity. *International Journal of Obesity*, 19, S20–S26.

Pellegrini, N. & Agostoni, C. (2015). Nutritional aspects of gluten-free products. *Journal of the Science of Food and Agriculture*, 95 (12), 2380–2385.

Pietzak, M. (2012). Celiac Disease, Wheat Allergy, and Gluten Sensitivity When Gluten–free Is Not a Fad. *Journal of Parenteral and Enteral Nutrition*, 36 (1 suppl), 68S–75S.

Poonnakasem, N., Pujols, K.D., Chaiwanichsiri, S., Laohasongkram, K. & Prinyawiwatkul, W. (2016). Different oils and health benefit statements affect physicochemical properties, consumer liking, emotion, and purchase intent: a case of sponge cake. *Journal of Food Science,* 81, S165–S173.

Puri, M., Sharma, D., Barrow, C.J. & Tiwary, A.K. (2012). Optimisation of novel method for the extraction of steviosides from Stevia rebaudiana leaves. *Food Chemistry*, 132 (3), 1113–1120.

Ramírez, I., Dorta, F., Espinoza, V., Jiménez, E., Mercado, A. & Peña-Cortés, H. (2006). Effects of foliar and root applications of methanol on the growth of Arabidopsis, tobacco, and tomato plants. *Journal of Plant Growth Regulation*, 25 (1), 30–44.

Rosenthal, A.J. (1995). Application of aged egg in enabling increased substitution of sucrose by litesse (polydextrose) in high-ratio cakes. *Journal of the Science of Food and Agriculture*, 68 (1), 127–131.

Saturni, L., Ferretti, G. & Bacchetti, T. (2010). The gluten-free diet: safety and nutritional quality. *Nutrients*, 2 (1), 16–34.

Schifferstein, H.N., Fenko, A., Desmet, P.M., Labbe, D. & Martin, N. (2013). Influence of package design on the dynamics of multisensory and emotional food experience. *Food Quality and Preference*, 27 (1), 18–25.

Skerritt, J.H. (1986). Molecular comparison of alcohol-soluble wheat and buckwheat proteins. *Cereal Chemistry*, 63 (4), 365–369.

Smyth, D.J., Plagnol, V., Walker, N.M., Cooper, J.D., Downes, K., Yang, J.H., Howson, J.M., Stevens, H., McManus, R., Wijmenga, C. & Heap, G.A. (2008). Shared and distinct genetic variants in type 1 diabetes and celiac disease. *New England Journal of Medicine*, 359 (26), 2767–2777.

Silverglade, B.A. (1996). The Nutrition Labeling and Education Act: progress to date and challenges for the future. *Journal of Public Policy & Marketing*, 15 (1), 148–150.

Soejarto, D.D. (2002). Botany of Stevia and Stevia rebaudiana. *A. Douglas Kinghorn* 18.

Sullivan, S.A. & Birch, L.L. (1990). Pass the sugar, pass the salt: Experience dictates preference. *Developmental Psychology*, 26 (4), 546.

Tzia, C., Giannou, V., Lebesi, D. & Cranioti, C. (2012). *Chemistry and Functional Properties of Carbohydrates and Sugars (monosaccharides, disaccharides, and polysaccharides).* Pp. 11–45. CRC Press, Taylor & Francis Group.

Torbica, A., Hadnađev, M. & Dapčević, T. (2010). Rheological, textural and sensory properties of gluten–free bread formulations based on rice and buckwheat flour. *Food Hydrocolloids*, 24 (6), 626–632.

Uthayakumaran, S., Gras, P.W., Stoddard, F.L. & Bekes, F. (1999). Effect of varying protein content and glutenin-to-gliadin ratio on the functional properties of wheat dough. *Cereal Chemistry*, 76 (3), 389–394.

Vardakas, T., Labropoulos, A. & Anestis, S. (eds). (2012). *Sweeteners: Nutritional Aspects, Applications, and Production Technology*. CRC Press.

Viscoine, L. (2005). Alternative sweeteners: how they reduce glycemic load and provide nutritional balance. *Soft Drinks International*, 37–40.

Wardy, W., Sae–Eaw, A., Sriwattana, S., No, H.K. & Prinyawiwatkul W. (2015). Assessing consumer emotional responses in the presence and absence of critical quality attributes: a case study with chicken eggs. *Journal of Food Science*, 80 (7): S1574–1582.

Wieser, H. (2007). Chemistry of gluten proteins. *Food Microbiology*, 24 (2), 115–119.

Wrigley, C.W., Bietz, J.A. & Pomeranz, Y. (1988). Proteins and amino acids. *Wheat: Chemistry and Technology. Volume I.*, (3rd edn), 159–275.

WHO. (2015). *World Health Organization*. What is Celiac Disease? – Celiac Disease Foundation. (n.d.). Retrieved May 09 2016, from https://celiac.org/celiac–disease/what–is–celiac–disease/WHO calls on countries to reduce sugars intake among adults and children.

APPENDIX 1. IRB APPROVAL

LSU AgCenter Institutional Review Board (IRB)
Dr. Michael J. Keenan, Chair
School of Human Ecology
209 Knapp Hall
225-578-1708
mkeenan@agctr.lsu.edu

Application for Exemption from Institutional Oversight

All research projects using living humans as subjects, or samples or data obtained from humans must be approved or exempted in advance by the LSU AgCenter IRB. This form helps the principal investigator determine if a project may be exempted, and is used to request an exemption.

- Applicant, please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the LSU AgCenter IRB. Once the application is completed, please submit the original and one copy to the chair, Dr. Michael J. Keenan, in 209 Knapp Hall.

- A Complete Application Includes All of the Following:
  (A) The original and a copy of this completed form and a copy of parts B through E.
  (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  (C) Copies of all instruments and all recruitment material to be used.
    - If this proposal is part of a grant proposal, include a copy of the proposal.
  (D) The consent form you will use in the study (see part 3 for more information)
  (E) Beginning January 1, 2009: Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing and handling data, unless already on file with the LSU AgCenter IRB.
  Training link: (http://grants.nih.gov/grants/policy/hs/training.htm)

1) Principal Investigator: Witoon Prinyawiwatkul **Rank:** Professor **Student?** No
School of Nutrition and Food Sciences Ph: 8-5188
E-mail: wprinyawiwatkul@agcenter.lsu.edu and wprinya@lsu.edu

2) Co-Investigator(s): please include department, rank, phone and e-mail for each NONE
- If student as principal or co-investigator(s), please identify and name supervising professor in this space

3) Project Title: Consumer Acceptance and Perception of New and Healthier Food Products
4) Grant Proposal?(yes or no) NO **If Yes, Proposal Number and funding Agency**
Also, if Yes, either: **this application completely matches the scope of work in the grant Y/N**
OR
more IRB applications will be filed later Y/N
5) Subject pool (e.g. Nutrition Students) LSU Faculty, Staff, Students and off-campus consumers
- Circle any **"vulnerable populations" to be used:** (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted. **NONE**

6) PI signature [signature] ****Date** 3-12-2015 (no per signatures)
****I certify that my responses are accurate and complete.** If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

Committee Action: Exempted Not Exempted ✓ **IRB#** HE15-9
Reviewer Michael Keenan **Signature** Michael Keenan **Date** 3-16-2015

APPENDIX 2. RESEARCH CONSENT FORM

I, ______________________, agree to participate in the research entitled "Sensory Characteristics of Gluten-Free Banana Muffins" which is being conducted by Witoon Prinyawiwatkul of the School of Nutrition and Food Science at Louisiana State University Agricultural Center, (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. Two hundred consumers will participate in this research. For this particular research, about 5-10 minute 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 investigator any food allergies I may have.

2. The reason for the research is to gather information on factors influencing consumer perception and acceptability of gluten-free foods containing sugar and alternative sweeteners. The benefit that I may expect from it is a satisfaction that I have contributed to solution and evaluation of problems related to such examination.

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 may be an allergic reaction to rice flour, buckwheat flour, corn starch, xanthan gum, milk, oil, eggs, baking soda, salt, banana, cinnamon, vanilla, sugar, stevia, and unsalted crackers. However, because it is known to me beforehand that all those foods and ingredients are to be tested, 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 investigator 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. Michael Keenan of LSU AgCenter at 578-1708. I agree with the terms above.

Signature of Investigator: __________________ Signature of Participant: __________________

Date: ____________________________________ Witness: _________________________________

APPENDIX 3. CONSUMER RESEARCH QUESTIONNAIRE

SCREENER:

(1) Consume muffins or similar products,
(2) Not allergic to muffin ingredients
(3) Over 18 years old

PART 1: DEMOGRAPHICS

Gender: ( ) Female ( ) Male

Age (years): ( ) 18-30 ( ) 31-40 ( ) 41-50 ( ) 51-60 ( ) >60

Race: ( ) African American ( ) Caucasian American ( ) Asian ( ) Hispanic ( ) Other

Do you normally purchase or consume Gluten Free Products?

Yes ( ) No ( )

Do you normally purchase or consume Sugar Reduced/Free Products?

Yes ( ) No ( )

PART 2: SAMPLE TESTING

Instructions:

- Please have unsalted crackers and water to cleanse your palate between each sample.
- Please taste at least half of Sample XXX.

1. How would you rate the following attributes of this product?

    a. Color

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]

b. Odor

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]

c. Taste

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 SWEETNESS 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]

Please rate how you perceive the SWEETNESS intensity of this product.
[ ] Not sweet enough [ ] Just about right [ ] Too sweet much

3. 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]

Please rate how you perceive the MOISTNESS of this product.
[ ] Not moist enough [ ] Just about right [ ] Too moist

4. How would you rate the SOFTNESS 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]

Please rate how you perceive the SOFTNESS of this product?
[ ] Not soft enough [ ] Just about right [ ] Too soft

5. How would you rate the STICKINESS 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]

Please rate how you perceive the STICKINESS of this product?
[ ] Not sticky enough [ ] Just about right [ ] Too sticky

6. How would you 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]

7. How does this product make you FEEL?

Feeling	Not at all [1]	Slightly [2]	Moderately [3]	Very much [4]	Extremely [5]
Calm	❑	❑	❑	❑	❑
Good	❑	❑	❑	❑	❑
Guilty	❑	❑	❑	❑	❑
Happy	❑	❑	❑	❑	❑
Healthy	❑	❑	❑	❑	❑
Pleasant	❑	❑	❑	❑	❑
Pleased	❑	❑	❑	❑	❑
Satisfied	❑	❑	❑	❑	❑
Unsafe (regarding nutrition facts)	❑	❑	❑	❑	❑
Wellness (healthy lifestyle)	❑	❑	❑	❑	❑
Worried	❑	❑	❑	❑	❑

8. Would you PURCHASE this product? ( ) YES ( ) NO

PART 3: HEALTH BENEFIT STATEMENTS

Sample XXX= This product is gluten free (wheat free) and made with regular sugar.

Sample XXX= This product is gluten free (wheat free) and has a 50% sugar reduction.

Sample XXX= This product is gluten free (wheat free) and sugar free.

Then REPEAT Overall Liking, Emotions, and Purchase Intent for each sample AFTER the health benefit statement.

APPENDIX 4. RELEVANT EXTRA MATERIAL

Table 9 Just-About-Right (JAR) distribution[A] of sensory intensities

Attribute	Treatment*	Not Enough (%)	JAR (%)	Too Much (%)
Sweetness	Sugar	29.70	67.18	3.12
	Reduced-Sugar	35.93	57.82	6.25
	Stevia	64.85	32.81	2.34
Softness	Sugar	17.19	82.81	0.00
	Reduced-Sugar	25.78	72.66	1.56
	Stevia	37.50	57.03	5.47
Stickiness	Sugar	10.16	83.59	6.25
	Reduced-Sugar	9.38	81.25	9.37
	Stevia	20.31	64.84	14.85
Moistness	Sugar	17.19	78.12	4.69
	Reduced-Sugar	21.09	73.44	5.47
	Stevia	28.91	58.59	12.50

[A]Based on the responses' total.
*Sugar = 0% reduced treatment formulation; Reduced-Sugar = 50% reduced treatment formulation; Stevia = 100% reduced treatment formulation.

Table 10 Mean drop[A] and total penalty[B] in overall liking due to "not enough" JAR sensory intensities

Attribute	Treatment*	Not Enough JAR (%)	Mean Drop	Total Penalty
Sweetness	Sugar	29.70	-2.82	-0.84
	Reduced-Sugar	35.93	-2.03	-0.73
	Stevia	64.85	-2.47	-1.60
Softness	Sugar	17.19	-2.54	-0.44
	Reduced-Sugar	25.78	-2.35	-0.61
	Stevia	37.50	-2.72	-1.02
Stickiness	Sugar	10.16	-2.21	-0.22
	Reduced-Sugar	9.38	-1.33	-0.12
	Stevia	20.31	-2.65	-0.54
Moistness	Sugar	17.19	-2.86	-0.49
	Reduced-Sugar	21.09	-2.74	-0.58
	Stevia	28.91	-3.16	-0.91

[A]Mean drop = [mean overall liking of the "not enough" JAR group – mean overall liking of JAR group]. [B]Total penalty = [mean drop × % "not enough" JAR response]
*Sugar = 0% reduced treatment formulation; Reduced-Sugar = 50% reduced treatment formulation; Stevia = 100% reduced treatment formulation.

VITA

Amber Renee Jack, a native of Houston, Texas, received her Bachelors in Sports Management from Louisiana State University (LSU). She was accepted into the School of Nutrition and Food Sciences at LSU to pursue her interests in new food product development and sensory analysis. She anticipates graduating with her Master's Degree in Food Science in August 2016, after which she plans to be an entrepreneur in the food industry.