DEVELOPMENT OF HIGH-FIBER BELGIAN WAFFLES AND EVALUATION OF PRODUCT ACCEPTANCE, PRODUCT-ELICITED EMOTION, AND PURCHASE Intent BY MILLENNIAL CONSUMERS

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DEVELOPMENT OF HIGH-FIBER BELGIAN WAFFLES AND EVALUATION OF PRODUCT ACCEPTANCE, PRODUCT-ELICITED EMOTION, AND PURCHASE INTENT BY MILLENNIAL CONSUMERS

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

Andrea Lucia Velasquez
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ABSTRACT

Dietary fiber may help reduce LDL cholesterol levels and prevent cardiovascular diseases. The US-FDA recommends 14g of fiber/1000kcal consumed, but Americans consume <14g of dietary fiber/day. A product containing ≥5 grams of fiber/serving can be claimed as a high-fiber product. Adding dietary fiber to food affects their physicochemical properties and sensory quality, possibly leading to less product acceptability. This study was performed to assess selected physicochemical properties and consumer perception of “high-fiber” Belgian waffles. Waffles were formulated to have fiber contents of <0.5g (control), 5g, 10g, or 15g/serving. Color (L*a*b*) and texture profile (TPA) were measured. Millennial consumers (N=120) rated liking of appearance, aroma, texture, flavor, and overall liking (OL) [a 9-points hedonic scale]; brown-color, softness, and stickiness [a 3-points just-about-right (JAR) scale]; purchase intent (PI) [yes/no]. They selected product-elicited-emotions [check-all-that-apply]. OL and PI were evaluated both before and after providing a “high-fiber-health-claim” (HFHC). Data were analyzed (α=0.05) with ANOVA, McNemar, Cochran’s Q with multiple pairwise-comparison-critical difference, and penalty analysis. As fiber addition generally made the product lighter-yellow (higher L* and b*), 54% of consumers rated brown-color to be [Not Enough] on a JAR scale for the 15g-fiber/serving product. At 15g fiber/serving, waffles became significantly less cohesive and chewy (from TPA) and chewier (from JAR); however, the texture liking score did not significantly decrease compared to the 1g-fiber/serving product (5.8 vs. 6.0). After providing HFHC, all “high-fiber” samples outperformed the control, with OL scores of 6.4-6.7 vs. 5.7, and positive PI of 61-69% vs. 45%. All products generated more positive (44.1-36.2%) than negative emotions. Consumers may be more willing to consume and
buy high-fiber products that are commonly consumed, like waffles. This study demonstrated that although added-fiber physically affected color and texture of waffles, the high-fiber products were acceptable to consumers. Providing HFHC clearly increased PI and should be included on a product label to promote PI.
CHAPTER 1. INTRODUCTION

Food choices are usually influenced by consumers’ perceptions, previous experiences, health concerns, emotions, and more specifically, their sensory properties of foods such as taste, smell, and appearance. In fact, due to a fast-paced lifestyle, Americans have decreased their willingness to cook from scratch and increased their consumption of processed and ready-to-eat food. In addition, as the rates of obesity and cardiovascular diseases are increasing, the intake of whole grains, fruits and vegetables are decreasing (Liu, 2002). This has affected consumers’ concerns and food choices, especially those of Millennial consumers. Nowadays, this population is willing to purchase products that are clean label, innovative, and healthy. Millennial consumers are interested in ready-to-eat food products with those characteristics because of the fast lifestyle they have nowadays. So, food industries are attempting to create innovative food products, increase quality, and satisfy consumers preferences. However, ready-to-eat meals and snacks are usually high-calories and low-fiber, which may be deleterious to Americans’ health when the intake is excessive. However, a study by Sloan (2020) reported that 63% of the population is concerned about the addition of fiber in new food. Fiber is defined as a compound that is not enzymatically degraded to absorbable subunits in the stomach and small intestine (Howarth et al., 2001). Dietary fiber can be extracted from natural sources and processed to be added to food products. Some food industries use certain type of fibers as components to improve texture or other chemical properties. However, the intake of dietary fiber has decreased in the last few years, while obesity and cardiovascular diseases rates have increased (Maskarinec et al., 2012).
Research suggests that the typical Americans’ intake of dietary fiber/day is <14g for every 1000 kcal (Lie et al., 2018). Dietary fiber, independently of its source, can help reduce cardiovascular diseases and Low-Density Lipoprotein (LDL) cholesterol (Erkkilä, 2006). Nutritional guidelines promote increase the intake of whole grains, fruits, and vegetables in order to fill the dietary fiber gap in Americans’ diets. Therefore, the U.S. Food and Drug Administration (FDA) recommends that Americans consume 14g of fiber/1000kcal per day (King et al., 2012). However, Americans do not meet the adequate daily recommendation (Hoy et al., 2014). The fact that consumers are becoming more health conscious, especially Millennial consumers, may positively influence food companies to use dietary fiber as a health promoting ingredient for new product development. Under FDA regulation, a food product can be claimed as a high fiber source when it has >5g/serving size, from natural source or synthetic isolated dietary fiber. The addition of dietary fiber to food products can help increase the intake of dietary fiber in the population of interest. Millennials may have an impact on R&D innovation if the product acceptance is significant and if the food companies want to satisfy consumers health concern and preferences. For instance, bakery products such as waffles and pancakes that are commonly consumed by Millennials and the Generation Z can be innovated by addition of dietary fiber to benefit consumers’ health and help them get their daily adequate recommended level of fiber. The addition of dietary fiber to food products can affect their physicochemical properties and sensory quality such as color, texture, and flavor, and possibly lead to processing challenges and consumers’ rejection. The health-conscious consumers might purchase the products just because they are
beneficial to them. Scientific researchers reported that providing a health claim or health advertisement may increase the purchase intent and overall liking of a product (Poonnakasem et al., 2016).

1.1. References


CHAPTER 2. LITERATURE REVIEW

2.1. Problem statement

The U.S. Department of Agriculture (USDA) Dietary Guidelines for Americans published in 2005, stated that our intake of fiber is so low that it became a nutrient whose consumption is enough to be a concern and the efforts are necessary to promote increased dietary intake. The USDA acknowledges that a diet rich in dietary fiber promotes healthy laxation, reduces the risk of type 2 diabetes and decreases the risk of coronary heart disease (Hazen, 2006). On the other hand, the prevalence of obesity and cardiovascular diseases (CVD) is increasing (Bastien et al., 2014). Obesity is associated with chronic diseases such as diabetes type 2, strokes, and cardiovascular diseases (Lavie et al., 2009). However, the intake of dietary fiber is below the recommended amount (Petersson, 2017). According to the Centers for Disease Control and Prevention (CDC), strokes and cardiovascular diseases are the first and third cause of death in the United States (CDC, 2017). In fact, updated statistics affirmed that cardiovascular disease is the first cause of death both in United States and worldwide (Kochanek, et al., 2019). Therefore, an adequate intake of dietary fiber may create protective effects against obesity, type 2 diabetes, cardiovascular disease, and metabolic syndrome (Lie et al., 2018).

It is possible that the growing rate of cardiovascular disease may be strongly related to human behavior, food choices, income, and nutrition (Winkleby, et al., 2011). Despite encouragement from the government, consumers do not purchase enough foods high in dietary fiber (Senia & Dharmasena, 2016). Indeed, a balance between intake and expenditure is likely to prevent overweight, obesity and
cardiovascular diseases (Hill et al., 2012). This is one of the reasons why consumers are paying more attention to functional foods that can adjust the body function, improved their lifestyle, and prevent diseases of civilization. In the United States of America, the rates of obesity and cardiovascular diseases are increasing and creating concern in health organizations such as the World Health Organization (WHO) and the US-FDA. According to Odgen et al. (2008), the National Health and Nutrition Examination Survey (NHANES), reported an increase in obesity between the late 1980s and 2010 in the United States. In fact, in 2011, a policy statement from the American Heart Association (AHA) stated that cardiovascular disease was the leading causes of death in the United States and that it was responsible for 17% of national health expenditures; therefore, the risk of cardiovascular diseases has increased (Heidenreich et al., 2011).

Globally, people often consume more than their recommended daily calories and suggested amount of sugar but they do not meet the recommended intake levels of dietary fiber (Tale & Lyle, 2017). According to the WHO, one of the nutrients of public concern is dietary fiber, because the intake has been decreasing, while cardiovascular diseases have been increasing. Also, Americans consumed less food with a high content of dietary fiber, such as fruits and vegetables, than the daily recommended amount (Guenther et al., 2006) of fiber suggested by the FDA (14 grams/1000 kcal). Moreover, the population suffering from obesity involves children, young adults, adults, and elderly, regardless of races and genders. Researchers have focused on identifying key factors contributing to the increased obesity with the
objective of developing strategies to prevent further weight gain and probably induce weight loss.

Also, in obesity research there is an area that focuses on how diet affects intake regulations and energy balance, in which fiber comes into action (Burton-Freeman, 2000). Dietary fiber can be found in fruits, vegetables, beans, and whole grain products. Therefore, when the consumption of these products is decreasing, the consumption of dietary fiber will also decrease. Bazzano et al. (2002) showed that “consuming fruits and vegetables ≥3 times/day compared with <1 time/day was associated with a 27% lower stroke incidence, a 42% lower stroke mortality, a 24% lower ischemic heart disease mortality, and a 27% lower cardiovascular disease mortality.” So, a higher consumption of food products that contain fiber may have protective effects on cardiovascular diseases. In order to help people to improve their diets and meet the daily recommended amount of nutrients, food and beverage industries should improve the nutritional value of their products (Tale & Lyle, 2017). Scientists indicate that the consumption of dietary fiber is inversely related to weight gain (Tucker et al., 2009). Therefore, consuming the daily recommended amount of dietary fiber, and practicing healthy habits such as daily workout, may help prevent cardiovascular diseases.

2.2. Dietary fiber

2.2.1. Definition

Initially, dietary fibers were defined as dietary compounds that are not enzymatically degraded to absorbable subunits in the stomach and small intestine
(Howarth et al., 2001). In 2012, a study defined dietary fibers as skeletal remains of plant cells in the diet which are resistant to hydrolysis by human enzymes (Belski, 2012). Also, Garcia-Amezquita et al. (2018), defined dietary fiber as “any carbohydrate polymers with ten or more monomeric units, which are not hydrolyzed by the endogenous enzymes in the small intestine of humans and belong to the following categories: edible carbohydrate polymers naturally occurring in food when consumed, carbohydrate polymers obtained from food raw material by physical, enzymatic or chemical treatment that have shown to have a physiological effect of benefit to health as demonstrated by scientific evidence and, synthetic carbohydrate polymers that have shown to have a physiological effect of benefit to health as demonstrated by scientific evidence.”

According to obesity researchers, dietary fiber includes several nonstarch polysaccharide substances including cellulose, hemicellulose, β-glucans, pectin, mucilage, and gums. These fiber components contribute to food physical properties such as bulkiness, and viscosity that determined the physiological behavior (Burton-Freeman, 2000; Dhingra et al., 2012). Lastly, the FDA defines dietary fiber as occurring fibers that are "intrinsic and intact" in plants and added isolated or synthetic non-digestible soluble and insoluble carbohydrates that FDA has determined to have beneficial physiological effects to human health (FDA, 2016).

### 2.2.2. Type and Sources of dietary fiber

Usually, carbohydrates break into simple sugar molecules. However, fiber does not break into simple molecules, so it passes through the upper gastrointestinal
track undigested. These carbohydrate polymers are classified as soluble or insoluble dietary fiber. The solubility depends on if the fiber dissolves in water or forms a gel. Soluble fiber can be found in oatmeal, nuts, beans, apples and berries; soluble fiber’s main health benefits are to lower cholesterol levels in the blood, and reduce appetite after eating (Spiller, 2001). On the other hand, insoluble fiber does not dissolve in water, and it can be found in common food such as legumes, beans, whole grain products, fruits such as apples, and beans; its main health benefit is to move food through the digestive system, preventing constipation. So, either soluble fiber or insoluble fiber can be found in the same foods. For instance, an apple contains both types of fiber, which makes it higher in nutritional value. Both types of fibers provide health benefits to humans, so consumption of food sources containing dietary fiber can reduce the risk of non-chronic diseases related to high blood sugar levels and high cholesterol levels (Garcia-Amezquita et al., 2018). However, several studies reported that soluble fiber such as guar gum and psyllium improves insulin sensitivity, in comparison to insoluble fiber such as cellulose (Isken et al., 2008; Papathanasopoulos & Camilleri, 2009). Soluble fiber is separated by digestive enzymes in the gastrointestinal tract, increasing the viscosity of food in the stomach and intestine and slowing down the mixing of it. Then it does not allow the attachment of pancreatic amylases and lipases to substrates, and the absorption of nutrients by the intestinal wall (Kučerová et al., 2013). Overall, in a Harvard study of over 40,000 male health professionals, researchers found that a high total dietary fiber intake was linked to a 40 percent lower risk of coronary heart disease (Brown et al., 1999).
Fiber is found naturally in sources such as whole grains, vegetables, fruits, and beans. Foods high in dietary fiber content have low energy because fiber cannot be digested (Howarth et al., 2001). Also, in order to prevent obesity and regulate weight status, the 2010 Dietary Guidelines for Americans proposed that better health could be achieved if half the food we place on our plates are fruits and vegetables. These foods contain high fiber and low energy content, which supports the kilocalorie intake balance required to prevent obesity and cardiovascular diseases. High fiber intake is associated with a lower rate of cardiovascular disease and obesity (Slavin & Lloyd, 2012).

Snack products containing dietary fiber can comply with the regulations by the FDA and snack food with high fiber content has attracted attention of consumers due to various health benefits. A recent study stated that the USDA National Nutrient Database claimed popcorn to be one of the snacks with a high amount of dietary fiber (5.2% fiber) as well as a corn-based extruded snack (4.0% fiber). Han et al. (2018) used six dietary fibers that were mixed with corn meal and subsequently co-extruded for snack production, with the same ratio of fiber to corn meal. They reported that the highest fiber level of the extrudate was observed when xanthan gum, gum acacia or inulin was added to the blend, but the fiber mixture altered its physicochemical properties such as hardness and bulkiness. Therefore, as shown by other researchers, if a fiber provides a physiological effect to benefit humans’ health, it can be defined as dietary fiber even if it is natural, extracted, or synthetic.
2.2.3. Intake of Dietary Fiber

According to several studies, there is an association between greater consumption of cereal fiber and whole grain products containing dietary fiber and cardiovascular disease risk reduction. Therefore, the USDA Dietary Guidelines for Americans promote the consumption of high sources of dietary fiber, such as fruits, vegetables and whole grain products, as well as products with fiber added. But, adolescents and young adults in the United States do not consume recommended amounts of whole grains (Larson et al., 2009), fruits and vegetables; therefore they do not meet the recommended amount of dietary fiber. Also, due to the fiber's physiological benefits to human health, known organizations such as the FDA determined a daily adequate amount of dietary fiber that humans should consume in order to prevent overweight, obesity and/or cardiovascular diseases.

Intake of fiber has decreased in the modern age and varies throughout the world. Back in the Paleolithic times, a man ate 77-120 grams of fiber per day, according to Howarth et al. (2001). This is the amount five to eight times greater than the current intake in the United States. This author compared the intake of Americans to other countries in Africa, finding that in the United States, 59% of adults were overweight or obese and the estimated daily intake of dietary fiber was 15 g/day. While the African countries' intake such as Uganda, was 60-80 g/day and <15% of adults were overweight or obese.
2.2.4. Regulations

The regulation on the intake of dietary fiber has changed over the past few years. The FDA recommends an amount of 25 to 28 grams of dietary fiber on a diet based on 2,000 calories (kcal). Previously, an amount of 14 grams of dietary fiber on a 1,000 kcal was suggested and because human’s daily energy intake is typically around 2,000 kcal, the recommended daily intake of dietary fiber was also increased. As mentioned before, the higher the energy intake, the higher the dietary fiber intake.

Therefore, when food industries want to claim a food product as a source of fiber on the nutritional label, they have to follow the following regulations:

1. For a product to be claimed as a good source of fiber, it must have 2.5 grams of dietary fiber per serving (FDA, 2016).

2. For a product to be claimed as a high source of fiber, it must have 5 or more grams of dietary fiber per serving (FDA, 2016).

The CODEX Alimentarius states that the previous two health claims are authorized based on an authoritative statement by federal scientific bodies related to the benefits of dietary fiber in foods such as whole grain foods with moderate fat content and risk of heart disease and whole grain foods and risk of heart disease and certain cancers (Jones, 2014).

2.2.5. Resistant maltodextrin as dietary fiber

Resistant maltodextrin meets the definition of dietary fiber according to both the American Association of Cereal Chemists and the Food and Nutrition Board of the National Academy of Sciences (NAS). This product is a soluble corn fiber and has
been specially designed for applications in which rapid dispersion and quick dissolution in water are key for final product success. However, depending on the amount of resistant maltodextrin used, differences in physical results may be observed. Maltodextrins show increasing industrial applications depending on the magnitude of the starch hydrolysis (Takeiti et al. 2010). Therefore, their industrial applications may depend on their composition and structure, but fortunately, processed maltodextrins are soluble in water, which make their applications in the industries easier than natural starches. According to Takeiti et al. (2010), maltodextrins are hydrolyzed starch built up by units of α-D-glucose bound together. They consist of a mixture of saccharides, mainly D-glucose, maltose, oligosaccharides and polysaccharides, such as maltotriose and mixtures of maltotetraose. Therefore, maltodextrins can be used as ingredients for the purpose of texture modification, fat replacement, cryoprotectant, bulkiness, increased viscosity, increased volume, and shelf-life extension. According to Pathare et al. (2013), maltodextrins are produced from starch by partial hydrolysis and usually appear as a white hygroscopic spray-dried powder. However, the dextrose equivalent (DE) level in maltodextrins plays a very important role in its functionality as an ingredient, as well as the source of the fiber. A DE level means the number of reducing end aldehyde groups relative to pure glucose at the same concentration. Maltodextrins are classified as low DE corn syrup (DE < 20), common corn syrup (DE 20 to 60), and high DE corn syrup (DE > 60). Each type of maltodextrin provides different functionalities, sweetness, and solubility. The higher the DE value, the
shorter the glucose chains, and the maltodextrins are sweeter and more soluble the maltodextrins are.

2.2.6. Health benefits of dietary fiber

Dietary fiber can help prevent, control, and manage weight problems and CVD. According to Ludwig et al. (1999) fiber consumption projected insulin levels, weight gain, and other CVD risk factors more accurately than total or saturated fat consumption. High-fiber diets may protect against obesity and CVD by lowering insulin levels. It has been proven that a high fiber diet provides control of insulin and glucose levels in blood, and consuming dietary fiber sources such as fruits and vegetables provide satiety (Slavin & Lloyd, 2012). In fact, Tucker et al. (2009) stated that increasing energy intake by eating more complex carbohydrates increased the intake of dietary fiber and decreased the risk in weight and fat gain in women. As a result, the more food energy a person consumes, the higher the intake of dietary fiber.

Moreover, epidemiological data suggests that dietary fiber intake reduces the risk for cardiovascular disease by decreasing blood pressure and cholesterol levels (Grooms et al., 2013). According to Lairon et al. (2005), during the last decade, epidemiological studies related to dietary fiber and cardiovascular disease reported that the intake of dietary fiber in different populations (Hispanics, Americans, and Europeans) was associated with reduction in cardiovascular disease mortality, and lower risk of coronary heart disease, and CVD. Dietary fiber is thought to lower the risk of CVD by improving glucose metabolism (Grooms et al., 2013). However, the influence of dietary fiber on weight gain is controversial, and researchers are still
working on this relationship. In fact, there are many factors that influence CVD such as age, obesity, central distribution of body fat, smoking, physical activity, hypertension, dyslipidemias, and abnormalities in blood clotting factors (Ludwig et al., 1999). Insulin resistance associated with hyperinsulinemia is common to many of these risk factors, but it is known that an adequate intake of dietary fiber increases post meal satiety and decrease subsequent hunger (Howarth et al., 2001).

Due to health concerns mentioned above, consumers are becoming health conscious when making their food choices in the marketplace and are searching for products with clean labels and products providing health benefits especially with dietary fiber and protein content without affecting flavor, aroma and texture (Tale & Lyle, 2017). Other than natural fruits and vegetables, the public is interested in on-the-go products, fast and tasty food containing beneficial nutrients such as fiber. Consumers are concerned about ingesting healthy, low-calorie food products that contain dietary fiber; therefore, they are searching for food packaging with detailed nutritional labels indicating the addition of dietary fiber and low energy content (Garcia-Amezquita et al., 2018). The increase in intake of processed foods that replaced unprocessed foods may have contributed to decreased dietary fiber intake. A solution to this problem is to find more ways to add dietary fiber to processed foods to reduce the gap between intake levels and recommended levels (Gordon & Okuma, 2002). For instance, synthetic dietary fiber could be easily added into formulations in order to improve physicochemical properties of food products and offer health benefits.
2.3. Practical application of adding dietary fiber

Food industries are investing in new product development efforts in order to please their consumers. In fact, young consumers are concerned about their personal health and they expect that food industries will create food products to be (beyond taste and attractive) safe and healthy (Fernández-Ginés et al., 2004). Therefore, nutritional information can serve as an instrument to influence healthier food choices (Miller & Cassady, 2015), and dietary fiber is on the top list of food trends for 2019 as an ingredient of innovation. However, dietary fiber often has a negative impact on food preference; if this were not so, intake of fiber containing food products would have increased by far more than it has in response to fiber health benefits clearly stated on the label (Spiller, 2001). According to Spiller (2001), one reason for this might be that high fiber-rich foods required more effort to chew. However, the author stated that there is an existing preference for dietary fibers used as texture modifiers. For instance, food industries have been using non-polysaccharides in jellies, candies, salad dressings and other food products to create viscosity, bulkiness, fat mimic, and others. The effective functionality of these fibers has created positive preference from consumers towards these products. As the dietary fiber intake of many people is below the suggested adequate intake level, strategies to successfully add fiber to foods may help alleviate this gap (Chen et al., 2010). However, increasing soluble fiber, in order to satisfy consumers health requirements and preferences at the same time, may challenge the processing, packaging, liking and acceptance of some products because it can negatively affect their physicochemical properties. Indeed, dietary fibers are particularly auspicious ingredients that have attracted
interest over the past few decades, due to their significant availability in fortified and functional foods. They are low in cost and provide positive effects for the prevention and treatment of a diverse range of diseases (Han et al., 2017).

In some studies, soluble fiber has been added to food products in order to modify their viscosity, and results demonstrated that the viscosity of a product can vary depending on the type of soluble fiber added. For example, the addition of resistant starch with high fiber content facilitates food functionalities and provides quality and health benefits such as thickening and emulsifying to control the flow of water and improve the quality and storage performance of foods (Liu et al., 2019).

2.4. Functional properties of dietary fiber in bakery products

Staple food products such as bread made with dough and varying ingredients have been studied to develop low-calorie bread by adding appropriate type of fiber in order to avoid changes on physicochemical properties, such as excessive weakening, and protein matrix disruption. But, the selection of the type of fiber depends on the color, dietary fiber content, cost, water absorption capacity, and water retention capacity of the product following baking. (Jarosław Wyrwisz, 2015). In general, studies determined that for gluten free products such as bread, fiber provides texture and water holding properties (Ziobro et al., 2012). Starch retrogradation, hardening, and aggregation of breads are critical properties in food products; for instance, maltodextrins were suggested to prevent unwanted texture of bread during storage.

Even though the importance of dietary fiber has been studied, food products are becoming more refined and fiber is still seen as negative impact on functional
properties of food affecting texture, color and mouthfeel. Brennand and Samyue (2007), stated that fiber can only be added to food if the product being manufactured has good sensory characteristics, irrespective of the nutritional benefits. Industries are finding ways to add dietary fiber in food products yet providing an acceptable sensory quality. However, dietary fibers such as flaxseed gum, chitosan, xanthan gum, are used as food additives but in amounts that cannot be claimed as good or high fiber sources, (< 2.5 grams/serving size) (Liu et al., 2019). The properties of some of these fibers mentioned before, include water absorption, viscosity, or thickness, which make food products acceptable or not. Particularly, fiber allows an increase in water-holding capacity during the bread production process, compromising starch gelatinization, protein denaturation and flavor formation due to the role of water in dough formation in the baking process (Jarosław Wyrwisz, 2015). Therefore, selecting the right fiber to obtain a better quality in bakery products is important. Possibly, fibers with a high water absorption may improve quality (Han et al., 2017); some fibers incorporated in food products such as bakery products, jams, and meat are capable of changing texture and other physical properties, avoiding syneresis (the separation of liquid from a gel caused by contraction), stabilizing high fat food and emulsions, and improving shelf-life (Elleuch et al., 2011).

2.5. Effects of dietary fiber on texture

Generally, in the product development process, characteristics such as optimum process, cost, and quality is preferred, rather than adding nutritional value to food products. It is common for food products to decrease their nutritional value in
order to increase an optimum process and quality. Sometimes, the addition of fiber to increase nutritional value without affecting sophisticated process and quality has been ineffective. For instance, Han et. al (2017) evaluated Chinese noodles fortified with dietary fiber and found that many properties such as hardness, adhesiveness, cohesiveness, chewiness, and resilience were significantly changed due to the functional characteristics of dietary fibers.

Moreover, during the process of baking, the formation of the dough is an important step. Serious problems associated with the rheological properties of dough include adhesiveness to processing materials and surfaces, and changes in shape, color, density and texture of the baked product (Canalis et al., 2017). Likewise, the addition of dietary fiber affects dough adhesiveness. Also, the water absorption during dough preparation may be affected as the porosity surface of dietary fibers could act as active carbon, which leads to high water absorption (Han et al., 2017). These alterations may create difficulties in the production process and in the sensory aspects of the product, such as color, texture and flavor. Bamboo fiber is now a common ingredient in breakfast cereals, fruit juices, bakery, and meat to increase fiber content. This bamboo fiber has been added to food formulations as a non-caloric, tasteless, non-irritating, aroma less and odor less ingredient with 97% of insoluble dietary fiber in a form of a white powder, affecting dough texture (Kučerová et al., 2013).

Overall, dietary fiber is known to change food texture, specially bakery products, starting by affecting dough stickiness and adhesiveness. This is one of the reasons why the introduction of high amounts of dietary fiber has been slow in the
industry. In order to conserve a good product quality, industries maintain a low amount of dietary fiber in popular products, just to obtain certain structure characteristics. Also, the expected texture for the final product, depends on the source and amount of the fiber used. However, it has been tested in baked food products, obtaining a good result in terms of consumers’ acceptability. When the baking process starts, heating causes water loss and foods with dietary fiber have texture alterations and consistency but the texture is not likely to change negatively. Previous studies showed that the used of high amounts of insoluble fiber in bakery products caused increased product firmness during storage (Jarosław Wyrwisz, 2015). However, some soluble fibers such as beta-glucan, fructo-oligosaccharides, galactooligosaccharides, gums, inulin, pectin, polydextrose, psyllium, hemicelluloses, and resistant maltodextrin used for bakery purposes have resulted in better quality than when insoluble fiber was used. In fact, Amir et al (2018) argued that incorporating dietary fiber from cocoa pod husk powder had a significant effect on firmness and volume of bread, so the type of fiber used impacts the physical properties. Also, oil-holding capacity was observed to impact the functionality of bakery products with high fiber content (Han et al., 2017). Furthermore, Witczak et al. (2010) proved that the higher the amount of maltodextrins in the formulation of gluten-free breads, the less effective the utilization by yeast resulting in lower the loaf volume.

More studies showed how dietary fiber improved the health benefits and nutritional value of food products, but also how it affected the dough rheology, overall bread quality, and the sensory characteristics (Gomez et al., 2003). For example, fiber added to bread at low percentage did not affect bread qualities and sensory
perception. Dietary fiber can be added during the baking process to improve nutritional value; however, adding fiber at a high percentage without affecting the food quality and sensory characteristics remain as an industrial challenge.

Gomez et al. (2003) stated that many authors have studied the use of high amounts of dietary fiber in baked products. There are many soluble and insoluble fibers in the market that can be used in baking but the main problems that scientists have found include reduction in loaf volume and texture changes. Some types of fiber are used by the food industry in small amounts to change the texture of certain products. In their research water absorption increased with the addition of fiber. With increased viscosity, dietary fiber demonstrated an effect on texture properties such as hardness and adhesiveness. In Asian countries, where noodles are commonly consumed, hydrolyzed guar gum, a soluble fiber has been added to Chinese noodles to improve the health benefits (more fiber) of this product. Recently, researchers reported that a soluble fiber level (1–5 g/100 g of flour) affected hardness, adhesiveness, and cohesiveness of noodles (Mudgil et al., 2016). Therefore, depending on the products, certain characteristics could be affected negatively or positively. In noodles, hardness could be a positive change, while in bread it could be a negative effect. Also, formulation plays a great role in texture when adding dietary fiber. It seems that adding more than 5 g of fiber per 100 g may affect hardness of food products.
2.6. Effects of dietary fiber on Color

Does color of food affect taste and flavor perception in humans? Researchers have been investigating this question for years. Some say that it can affect and others say that it has nothing to do with flavor and taste (Spence, 2015). Although this discussion remains necessary; we can assume that color impacts human perception of products and if the product has an unattractive color it is likely to be rejected. Usually, high fiber products have dark color; however, dietary fibers can create dull color, reducing acceptability (Han et al., 2017). Also, according to Singh et al. (2012), baked high fiber products had in decreased redness and yellowness of the crust. However, the fiber did not affect the Maillard browning reaction.

2.7. Effects of dietary fiber on Flavor

Flavor is one of the important factor consumers consider when accepting or rejecting a product. Consumers’ decisions of consuming a product start with the appearance, followed by flavor, which involves a combination of gustatory and olfactory stimulus. The International Standards Organization (ISO) defined flavor as a complex combination of the olfactory, gustatory and trigeminal sensations perceived during tasting (Spence, 2015). Sloan (2016) stated that 83% of consumers said that taste has a great impact on their food choices, followed by price. In general, there are six principal tastes, sweet, bitter, sour, salty, umami, and fat. Therefore, cereals and any baked food products could be perceived with any of the tastes mentioned (Grosch & Schieberle, 1997). Usually food industries make baked products either salty or sweet, because these two are the most acceptable tastes in the market (Drewnowski,
In fact, bakery products have a great acceptability in terms of flavor. However, when the amount of fiber increases in baked goods, sensory properties are adversely affected, resulting in a fibrous or gritty texture. Water holding capacity may change the finished mouthfeel, making it crisp or chewy (Hazen, 2006).

2.8. Weight loss content

The analysis of weight loss content in food products plays an important role for food industries. It is essential for quality control, food processing, and storage. To find out the loss after drying, the samples are heated and the weight loss due to evaporation of moisture is recorded. Previous researchers found that adding dietary fiber can significantly influence product moisture content and weight loss (Lebesi & Tzia, 2012) depending on the type and chemical structure of the fiber. Also, there is a possibility that the volume of the product would decrease when added fiber increases. However, adding dietary fiber may increase or decrease moisture content depending on the type and chemical structure of the fiber used. As mentioned earlier, the DE level of the fiber and type (soluble/insoluble) play an important role on its solubility and hygroscopicity (Valenzuela & Aguilera, 2015). Also, the carbohydrate composition of the fiber influences in its hygroscopic property (capacity to absorb moisture from the air). In fact, a carbohydrate with low-DE level has less hygroscopic capacity, such as maltodextrin, and a carbohydrate with high-DE level, such as maltotetraose has more hygroscopic properties (Clarke, 2003).
2.9. Consumers’ Acceptance

Food acceptability is a critical factor that influences the marketing and success of a food product. Acceptability involves the level of liking for a particular food, consumers’ pleasure of consuming this food, and the willingness they have to purchase it. An acceptability test has long been used to evaluate consumers liking and acceptance of food products. For instance, the 9-point hedonic scale is the most common scale to measure acceptability (Wichchukit & O’Mahony, 2015). Waffles are a product that are perceived as an appetitive food for breakfast, snack or dessert, usually consumed with syrups or/and fruits. Children, the most common consumer of waffles, tend to accept waffles when they provide a good visual look and flavor. Waffles, French toast and pancake consumption made from scratch has decreased in the past years (from 59% to 47%) (Sloan, 2016).

However, it is difficult for high fiber products to be accepted as tasty and healthy at the same time because their physicochemical properties such as texture and color are changed when adding fiber at high levels, thereby decreasing acceptability. But, compared with nonmodified food, high fiber food products have attracted consumer interest (Yang et al., 2017) especially in products containing flour such as rice, bread, and pasta. High fiber products tend to be perceived as healthy due to their benefits on gut and cardiovascular health. Therefore, if health claims are provided, consumers might be willing to consume high fiber products even though their physicochemical properties have changed. So, the food industry is challenged to provide the consumers a product that can contain the health beneficial properties of dietary fiber and is tasty and accepted by consumers. Baking is the most important part of bread
production and when fiber is added it may contribute to negative effects on bread quality affecting consumers’ acceptance. Some physicochemical changes in bakery products such as color, texture, and flavor are likely to change with addition of dietary fiber, affecting human perception. On the other hand, adults, children and young adults are more interested in healthy products that benefit and protect them from overweight, obesity, and CVD. Therefore, they are looking for products containing low sugar, low fat, low sodium, and high fiber. But, the impact of the changes on the physicochemical properties of any product with fiber added on consumers acceptability is the main challenge. So, many trials with new product’s supplemented with fiber are needed to provide simultaneously, great texture, taste, color, and flavor.

In this thesis research, four samples were provided in a consumer test, of which one sample was the control, the second sample had 5 g/serving, the third sample had 10 g/serving, and the fourth sample had 15 g/serving of dietary fiber. According to the regulations of the FDA, the three samples containing soluble fiber can be claimed as a high source of dietary fiber product. When the amount of fiber increases in baked goods, sensory properties, are adversely affected.

2.10. Sensory Perception

Sensory perception involves being aware of the internal and the external environment stimulus and how the brain perceives them. The stimuli can come from a variety of sources, and of different types and they are received and changed into the electrochemical signals which the nervous system perceived with the five senses of hearing, vision, taste, smell, and touch. When the stimulus hits the sense organ, it
is converted to a nerve signal that travels to the brain (Meilgaard et al., 2006). With previous experiences in memory, the brain then interprets, organizes, and integrates the incoming sensations into perceptions. Finally, a response is formulated based on the subject’s perceptions (Schiffman 1996). These responses generated by stimuli influence other senses. For instance, sight might influence taste, or smell can influence taste too. Also, sensory perception may influence appetite and food intake in humans (Sørensen et al., 2003). Sensory perceptions play an important role in determining the acceptance and rejection of foods and beverages" (Boesveldt et al., 2018).

2.11. Liking and Emotions

The 9-point hedonic scale is a scale of liking that was developed to measure food preferences and acceptability. It was developed by David Peryam and colleagues in order to measure food preferences for soldiers of the U.S Army. Then, it was adopted by the food industry in order to evaluate the acceptability of food, beverages, cosmetics, and other products. The 9-hedonic scale consists of nine verbal categories ranging from “like extremely” being a value of 9 to “dislike extremely” being 1. When it is used, consumers are required to assess a product and report how much they liked it or disliked it (Wichchukita & O'Mahony, 2014). The liking of a product can be affected by previous experiences and the sensory perception, explained above.
2.12. Influence of health claim on Purchase Intent

The intent to purchase a product is influenced by so many factors such as liking and acceptance. Sensory perception of a food product or beverage, including previous experiences, and liking of the shape, color, and taste are properties to consider when evaluating the purchase intent of a product. Previous studies showed that characteristics such as taste and content of nutrients such as salt influenced the purchase intent of a product (Mitchell et al., 2013). Moreover, health consciousness plays a significant role when purchasing foods and beverages. Hwang et al. (2016), examined the impact of different types of dietary fiber labels with health claims on consumers perception and purchase intent, and concluded that a food label with a fiber health claim can make consumers pay more for a product.

2.13. Conclusion

Dietary fiber consumption is associated with lowering risk for cardiovascular diseases and obesity (Grooms et al., 2013) and there are different ways to obtain dietary fiber. Due to the broad definition of dietary fiber by the FDA, natural, isolated, and synthetic dietary fiber are included. Therefore, the food industry may be able to add fiber to food products, without the need to use high technology. However, the dietary fiber intake among Americans is still below the daily adequate recommendation, and this is the reason why it has become a nutrient of public concern. Consequently, the food industry is attempting to develop healthy foods to meet the consumers’ demand. The young generations such as the Millennial
consumers, are more interested in healthy and innovative food products and are likely to purchase food products containing dietary fiber.

2.14. References


Han, Y. J., Tra Tran, T. T., & Man Le, V. V. (2018). Corn snack with high fiber content: Effects of different fiber types on the product quality. *LWT, Food Science and Technology* 96, 1–6. https://doi.org/10.1016/j.lwt.2018.05.014


3.1. Introduction

Dietary fiber intake in Americans is considered low even though consuming the recommended amount of dietary fiber (14g of fiber/1000kcal) may help to decrease the rates of cardiovascular disease and overweight (Slavin & Lloyd, 2012). Consumers are interested in consuming more fiber; however, increased intake of fruits, vegetables and whole grains, which are sources of dietary fiber is not occurring (Sloan, 2020). Therefore, this may motivate the food industry to incorporate dietary fiber to satisfy consumers’ interest and fill that gap. According to the US-FDA, a product containing ≥2.5 grams of fiber/serving it can be claimed as a “good source of fiber,” and when a product has ≥5 grams of fiber/serving it can be claimed as a “high-fiber product,” or “excellent source of fiber.” Since the FDA allows companies to add a claim “dietary fiber provides health benefits for humans”, adding dietary fiber to food products may be a solution. Usually, addition of dietary fiber affects the processing and the quality of the product, due to alterations in color, texture, aroma, and flavor.

The selected fiber to be used may affect product quality. For instance, baked products such as waffles, bread, and pasta may be a great option for consumers to obtain dietary fiber without affecting their palatability. In the current study, waffles were selected because of their popularity among Americans and the interest of Millennials in obtaining healthy nutrients such as dietary fiber in snacks and easy-to-prepare products. But the addition of dietary fiber may affect the properties of the waffles, the processing and the quality of the final product. Characteristics such as
color, texture, aroma, and flavor can be affected by the type and amount of dietary fiber used (Gomez et al., 2013). Though, dietary fiber affects the physicochemical properties and sensory quality, possibly leading to less acceptable product; consumers, especially Millennials, may be willing to consume and pay more for a product that provides them with health benefits. The objectives of this research were to assess the physicochemical properties of Belgian Waffles with four different concentrations of total dietary soluble fiber (<1, 5,10, and 15 grams/serving) and to evaluate consumers’ acceptance, liking, emotions, and purchase intent of high fiber Belgian Waffles before and after a health claim was provided.

3.2. Materials and Methods

3.2.1. Belgian waffles preparation

Belgian waffles were developed with the following ingredients: all-purpose flour (Great Value, Walmart Inc. Minnesota, USA), granulated sugar, whole milk, eggs (Great Value, Walmart Inc., Bentoville AR, USA), salt (Morton Salt Inc., Illinois, USA), Land O'Lakes unsalted butter (Land O'Lakes Inc., Minnesota, USA), Fleischmann's Instant Yeast (ACH Food Companies Inc, Mississauga, Ontario, Canada), and vanilla extract (McCormick & Co., Inc., Hunt Valley MD, USA). For the high fiber Belgian waffles, synthetic digestive resistant maltodextrin, a soluble corn fiber Fibersol-2AG (Fibersol ADM’s Clinton, IA, USA), was added in three different concentrations (5.40g, 10.80g, and 16.20g/serving size).

For the consumer test, waffles were prepared in four batches. The treatment that had no fiber added was labeled as the control or T1 and contained <1g of dietary
fiber contributed by all-purpose flour (Great Value, Walmart Inc. Minnesota, USA). However, the dietary fiber concentrations (T2, T3, and T4) of the three waffles were calculated with the data obtained from the product’s certificate analysis. Resistant maltodextrin, soluble corn fiber Fibersol-2AG contains 4.95% moisture, 92.5% dietary fiber, and 10.8 dextrose equivalent. Therefore, for 5g/serving size waffle, 5.40g of resistant maltodextrin was added; for 10g/serving, 10.80g, and for 15g/serving, 16.20g was added (Table 3.1). Each serving size weighed 73 grammes, similar to the commercial products (70-75g). Resistant maltodextrin, soluble corn fiber Fibersol-2AG was an analytical and nutritional dietary fiber that met the definition for nutrition labeling purposes, as published by the American Association of Cereal Chemists (AACC) and proposed by the National Academy of Sciences (NAS).

For the processing of the Belgian waffles, the ingredients were weighed, and mixed. First, dry ingredients including flour, sugar, and yeast were mixed for 60 seconds at low speed in a stand mixer (Pro 600™ Series 6, KitchenAid, Whirlpool Corporation, Michigan, US). For treatments with dietary fiber, the resistant maltodextrin was added while mixing the dry ingredients. Then, for each treatment, wet ingredients such as eggs, milk, vanilla and butter, were mixed together for one minute at a low speed and four minutes at a high speed creating a waffle dough for each batch. Then, each batch of dough was covered and left to rest for 150 minutes at room temperature. Afterward, 73 grams of each waffle was weighed and placed in a tray and stored under refrigeration until baking. On the day of the consumer test, the weighed waffle dough balls were left at room temperature for 60 minutes, then
baked for 3 minutes using a KRUPS GQ502 Belgian Waffle Maker, Waffle Maker with Removable Plates, 4 Slices, Black and Silver (KRUPS, Solingen, Germany).

Table 1. Description of four different treatments of formulated Belgian waffles.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sample description</th>
<th>grams of fiber/73g (serving)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Control</td>
<td>&lt;0.5/serving</td>
</tr>
<tr>
<td>T2</td>
<td>High fiber waffle</td>
<td>5g/serving^*</td>
</tr>
<tr>
<td>T3</td>
<td>High fiber waffle</td>
<td>10g/serving^*</td>
</tr>
<tr>
<td>T4</td>
<td>High fiber waffle</td>
<td>15g/serving^*</td>
</tr>
</tbody>
</table>

* High fiber waffles were formulated with resistant maltodextrin Fibersol 2-AG, containing 92.5% dietary fiber.

3.2.2. Measurement of physicochemical properties

3.2.2.1. Weight loss measurement

The waffles were weighed before and after baking in a balance to calculate moisture loss (Cole-Parmer Weight Balance, Cole-Palmer Instrument Company, LLC, Illinois, USA). The percentage (%) of weight loss was calculated with the following equation:

\[
\text{Weight loss (\%)} = \frac{(\text{Initial weight of dough} - \text{Final weight of waffle})}{\text{Initial weight of dough}} \times 100
\]

The weight loss of ten replicates for each different treatment was recorded, calculated, and reported as % weight loss.

3.2.2.2. Color measurement

The waffles’ surface color was measured in ten replicates by reflectance using a spectrophotometer (Baking Meter BC-10, Konica Minolta, Inc., Tokyo, Japan.)
Calibration with white and zero standards was performed before treatments were analyzed. Color measurements were reported L* (lightness), a* (+ for redness, - for greenness), and b* (+ for yellowness, - for blueness) values. Also, $\Delta E^*$ was calculated for each sample pair (T1 vs T2, T2 vs T3 and T3 vs T4) after obtaining the values L*, b*, and a* with the following equation:

$$\Delta E = \sqrt{(L1' - L2)^2 + (a1 - a2)^2 + (b1 - b2)^2}$$

where: $\Delta L$ is the difference in L* (brightness) between two vivid surfaces, and $\Delta a$ and $\Delta b$ are the differences in the color coordinates a* and b*, respectively (Wojciech Mokrzycki & Maciej Tatol, 2011).

$\Delta E^*$ (Delta E, dE) is the measure of change in visual perception of two given colors. Delta E was calculated in order to evaluate if the differences in color between samples were discerned by the human eye.

3.2.2.3. Texture Measurement

Texture Profile Analysis was evaluated (TPA, TA XT plus Texture Analyzer, Texture Technologies Corporation, MA, USA) in ten replicates of Belgian waffles for each treatment. After the waffles were baked, they were cut to a 3x3x1.5 cm piece before being analyzed for texture. The TPA test evaluated hardness (N), adhesiveness (N), cohesiveness (dimensionless), and chewiness (N) measurements (Thongudomporn et al., 2015). The texture analyzer was equipped with a 30 kg load cell and an aluminum cylinder probe of 2-inch diameter and 20 height. The test speed was set at 5 mm/s and the strain of 50%.
3.2.3. Microbiological analysis of Belgian waffles

Microbiological testing was performed the day the waffles were baked to make sure they were safe for consumption. One sample of each treatment was used for microbiology test including aerobic plate count (APC), yeast and mold, and *Escherichia coli* /coliforms count (EC). To prepare the sample, 25 g of product for each treatment was placed in a sterile bag (Whirl-Pak, Nasco LLC, Wisconsin, USA) with 25 mL of phosphate buffered saline (PBS). Samples were homogenized for 60 seconds using a stomacher (Easy Mix Biomerieux SA, France). Serial dilutions (10^0 to 10^-3) in phosphate saline buffer (PBS) were made and plated onto 3M™ Petrifilm™ (3M™ St Paul, Minnesota, USA). For APC and EC, the plates were incubated for 48±2 hours at 35 ± 2°C, whereas for yeast and mold the incubation time was 96±2 hours at 25 ± 1°C. Then, colonies were counted and expressed as Log CFU/g. All tests were made in duplicates for each treatment.

3.2.4. Consumer test and participants

The sensory evaluation and consumer test involving humans was approved by the Louisiana State University (LSU), Agricultural Center Institutional Review Board. A total of one hundred twenty (N=120) consumers between the age of 18 to 45 years (95% are Millennial consumers), females and males, students and faculty from LSU, participated voluntarily in this study. All the participants met the following criteria: they were at least 18 years old, they did not have any visual impairment or color blindness, and they had 10 to 15 minutes of available time to complete the consumer test. Both
the consumer test and physicochemical property analysis of the Belgian waffles were conducted at the LSU AgCenter Sensory Laboratory (Baton Rouge LA, USA).

The panelists provided demographic information on a Qualtrics Survey Software (Qualtrics, Provo, USA) and indicated if they regularly consumed waffles. First, consumers evaluated the acceptability of six attributes including overall visual liking (OVL), color, aroma, texture, flavor, and overall liking (OL) using a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike, and 9=like extremely). All questions were evaluated with the same format for each treatment (for example, Question 1: Please rate your liking of the OVERALL VISUAL QUALITY of the waffles (x). Also, brown-color, softness, and stickiness were measured with a Just-about-right (JAR) scale where 1 = not brown enough, 2 = just about right, and 3 = too brown; 1 = not soft enough, 2 = just about right, and 3 = too soft; 1 = not chewy enough, 2 = just about right, and 3 = too chewy.; Second, product-elicited-emotions were selected [check-all-that-apply]. The 25 emotions profile by Nestrud et al. (2016) was used and presented in an alphabetical order: active, adventurous, calm, enthusiastic, free, good, good-natured, happy, interested, joyful, loving, mild, pleasant, satisfied, understanding, and warm for positive emotion terms; aggressive, bored, disgusted, guilty, nostalgic, tame, unsafe (related to health), wild, and worried for negative emotion terms. Finally, overall liking (OL) using a 9-point hedonic scale and purchase intent (PI) using a binomial (yes/no) scale were measured before and after the following health claim was provided: “Dietary fiber has beneficial effects such as lowering bad cholesterol and protecting us against cardiovascular diseases. According to the FDA, a daily adequate intake of dietary fiber is 14 grams for every
1000 calories consumed per day; this product is considered HIGH in dietary fiber (5, 10, and 15 grams of dietary fiber per serving size).” For the control, the message was similar, except that it stated, “This product has less than 1 gram of dietary fiber”.

3.2.5. Statistical analyses

The physicochemical properties of Belgian waffles for all treatments, [weight loss, color measurement (L*, a*, b*), and texture measurements] were analyzed (α=0.05) with Analysis of Variance (ANOVA) to evaluate mean differences among treatments. To evaluate the acceptance/liking a one-way ANOVA (a Glimmix procedure) followed by a Post-hoc Tukey’s Standardized (HSD) range test (α = 0.05) for the six attributes [overall visual liking (OVL), color, aroma, texture, flavor, overall liking before (OLB), and overall liking after (OLA)]. To evaluate significant differences between OLB and OLA HFHC a paired t-test comparison was performed (α = 0.05). To evaluate results from the Just-about-right (JAR) scale, penalty analysis and mean drop analysis were applied to examine how both overall liking scores were affected when the evaluated attributes scores were not the ideal (Prinyawiwatkul, 2009). Also, the McNemar test was run to evaluate significant differences in the frequencies between purchase intent before health claim (PIB) and purchase intent after health claim (PIA) was provided to the consumers. Finally, to analyze emotion terms, just emotions with >10% frequency, were analyzed using Cochran’s Q test (Sheskin, 1996), which evaluated differences among discrete variables with frequencies (%).
3.3. Results and Discussion

3.3.1. Weight loss and color measurements

The calculated weight loss and color measurements for each treatment are presented in Table 3.2. During baking, dough was transformed into waffles after heating and evaporation of water. In order to calculate the weight loss of the waffles, the weight before and after baking was recorded, followed by calculation of the weight loss with the equation stated previously. Table 3.2 shows significant differences in weight loss after increasing dietary fiber. Incorporation of dietary fiber at 10g/serving size significantly increased the percentage of weight loss compared to the control. The weight before baking was always around 73 grams of dough; however, after baking, the samples lost between 10.53-14.03 % of their initial weights. According to Jarosław Wyrwisz (2015), during the baking process the observed weight loss observed occurred due to evaporation of the water that was absorbed into the dough during mixing. In fact, the dietary fiber used (resistant maltodextrin) in this study may have affected the loss of water, probably due to its DE level, which was <20 (low DE). Dextrose equivalent (DE) level, is known as the percentage of reducing sugar in a syrup calculated on a dry weight basis (Kennedy et al., 1995). Resistant maltodextrins with low DE have larger amount of longer straight- and branched-chain units polymers of glucose (Kuntz, 1997). Therefore, the lower the DE value of the maltodextrine the lower their solubility and their hygroscopicity. Therefore, possibly the loss of weight while increasing dietary fiber using low DE resistant maltodextrin could be due to the fact that the less the hygroscopicity capacity, the more evaporation of water and loss of weight. Similarly, addition of maltodextrin decreased the hygroscopicity of apple
leather strips (Valenzuela & Aguilera, 2015). In contrast, Nassar et al. (2008) observed an increase of water absorption during dough development and a decrease in stability and mixing tolerance of the dough when adding dietary fiber from orange peel and pulp to biscuits; the dietary fiber from orange peel and pulp was pectin, rich in soluble and insoluble fiber (Andrade et al., 2014). Therefore, the type of fiber may also influence its solubility and hygroscopicity and weight loss in the final product. Belgian waffles are known for their crispy texture, therefore, a moist product was not expected, so the resulting weight loss may not be undesirable. However, it is not efficient to have too much moisture loss, because the product would be so underweight and have a dry-crust (Tangprasertchai & Gray, 2009). In fact, similar results were found when dietary fiber was added to bread it reduced volume and moisture of the bakery product (Jarosław Wyrwisz, 2015).

Table 2. Effect of dietary fiber on weight loss and color measurements of Belgian waffles.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Description</th>
<th>WEIGHT LOSS (%)</th>
<th>L* (LIGHTNESS)</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>control</td>
<td>11.18±1.76&lt;sup&gt;B&lt;/sup&gt;</td>
<td>60.61±4.79&lt;sup&gt;BC&lt;/sup&gt;</td>
<td>8.03±1.87&lt;sup&gt;A&lt;/sup&gt;</td>
<td>14.10±4.34&lt;sup&gt;B&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>5g/serving</td>
<td>10.53±1.26&lt;sup&gt;B&lt;/sup&gt;</td>
<td>56.23±4.59&lt;sup&gt;C&lt;/sup&gt;</td>
<td>4.28±0.73&lt;sup&gt;B&lt;/sup&gt;</td>
<td>8.97±3.00&lt;sup&gt;C&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>10g/serving</td>
<td>14.03±1.87&lt;sup&gt;A&lt;/sup&gt;</td>
<td>66.00±3.78&lt;sup&gt;A&lt;/sup&gt;</td>
<td>7.61±1.97&lt;sup&gt;A&lt;/sup&gt;</td>
<td>17.96±2.49&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>15g/serving</td>
<td>12.09±1.66&lt;sup&gt;A&lt;/sup&gt;</td>
<td>64.91±4.00&lt;sup&gt;AB&lt;/sup&gt;</td>
<td>7.70±1.75&lt;sup&gt;A&lt;/sup&gt;</td>
<td>15.95±2.56&lt;sup&gt;AB&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Mean ± standard deviation from ten replications for each treatment

Mean values in the same column followed by different letters are significantly different (P < 0.05) based on ANOVA and Post-hoc Tukey’s Standardized (HSD) range test.

In addition, during the preparation of high fiber Belgian waffles, dough processing problems such as stickiness were observed, making waffles’ preparation
more difficult. According to Rosell et al. (2010), adding dietary fiber to bread formulation (similar to Belgian waffles) inhibits protein association in bread; some fibers added in the dough stimulated disruption of the viscoelasticity, producing a weaker dough. Moreover, it competed for water with the available starch hence influencing gelling and pasting. Also, studies showed that when preparing crackers’ dough with 30 grams of fiber added per serving size, the dough caused machine problems during mixing, hard texture and off-flavors (Karwoski et al., 2010) after baking. Karwoski et al. (2010) stated that ingredients such as fiber competes with water, creating these effects.

The addition of synthetic dietary fiber made the Belgian waffles color lighter and more yellow (higher L* and b*). Increasing dietary fiber concentration (from >1.0 to 15g/serving size) increased lightness (L*) values, possibly leading to a decrease in color liking. L* values indicate an increase in the lightness on the color of the waffle surface. This could be a possible physical effect in color changes. The actual color of the fiber source may influence the final product with fiber added (Jarosław Wyrwisz, 2015). Furthermore, the addition of resistant maltodextrin in the form of white powder likely caused a decrease in the Maillard browning reaction and an increase in lightness and yellow color (Table 3.2). Similar results were found when using maltodextrin in corn snack products as they became lighter-yellow (Han et al., 2018). As mentioned before, maltodextrins with low DE levels seem to decrease the Maillard browning reaction due to the decreased level of reducing sugars (Kuntz, 1997). A Maillard browning reaction occurs as a chemical reaction between an amino acid and a reducing sugar, after heating. Also, according to Lukinac et al. (2015) the decreased
Maillard browning reaction after adding dietary fiber could be due to the degree of polymerization and the presence of low molecular weight sugars in the formulation.

Additionally, results showed that $+a^*$ values, which mean redness, were not significantly affected by the addition of fiber, except at 5g per serving (Table 3.2). Again, possibly the type and color of the source of dietary fiber, and the temperature of baking may influence the color changes. Samples with a higher concentration of dietary fiber were more yellow (higher $b^*$) and lighter (higher $L^*$). Although the original color of ingredients have some influence on the bread crust color (Lukinac et al., 2015) and waffles without fiber were expected to be yellow brownish after heating, the brown color decreased with added fiber.

Table 3. Comparison of $\Delta E$ values between Belgian waffle samples.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Description</th>
<th>$\Delta E$ Delta E</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 vs T2</td>
<td>Control vs 5g/serving</td>
<td>7.72</td>
<td>observer notices two different colors</td>
</tr>
<tr>
<td>T2 vs T3</td>
<td>5g/serving vs 10g/serving</td>
<td>13.7</td>
<td>observer notices two different colors</td>
</tr>
<tr>
<td>T3 vs T4</td>
<td>10g/serving vs 15/serving</td>
<td>2.5</td>
<td>unexperienced observer also notices the difference</td>
</tr>
</tbody>
</table>

According to Wojciech Mokrzycki & Maciej Tatol, (2011) $0 < \Delta E < 1$ - observer does not notice the difference, $1 < \Delta E < 2$ - only experienced observer can notice the difference $2 < \Delta E < 3.5$ - unexperienced observer also notices the difference, $3.5 < \Delta E < 5$ - clear difference in color is noticed, $5 < \Delta E$ - observer notices two different colors

Delta $E$ was calculated in order to determine if the human eye could detect color differences of samples. Therefore, when comparing the treatment without dietary fiber added (T1) vs 5g/serving high-fiber waffle (T2), a value of 7.72 was obtained, meaning that the control sample color difference from the 5g/serving waffle’s color was noticeably detected at a glance by the human eye; so, it is possible to assume that the color difference between control sample and 10g/serving and 15g/serving samples will be perceived by the human eye, also. However, the delta $E$
calculated for samples 5g/serving vs 10g/serving had a higher value (13.7) which means that those two samples will be perceived as very different by the human eye. Also, it is possible to assume that sample 5g/serving and 15g/serving differences in terms of color could be perceived by the human eye. Finally, for treatments with 10g/serving vs 15g/serving, both high-fiber waffles, the delta E value was 2.5, indicating that the color sample differences between the two treatments can be perceptibly detected at a glance by the human eye, but the magnitude of the total difference was much less compared to that of 5g/serving vs 10g/serving (Table 3.3).

3.3.2. Texture profile analysis (TPA)

Texture plays an important role in acceptance and rejection of food products. Texture is well-known as one of the most important characteristics in determining the eating quality of foods and can have a strong influence on food intake and nutrition (Kilcast & Lewis, 1990). After TPA results were obtained, only hardness, adhesiveness, cohesiveness, and chewiness were reported (Table 3.4) because they demonstrated to have significant differences between treatments and were available to be compared between previous and similar studies. According to the TPA, hardness is defined as the force required for a pre-determined deformation and adhesiveness is the work required to overcome the sticky forces between the sample and the probe (Trinh & Glasgow, 2012). Table 3.4 reports that addition of dietary fiber did not impart significant differences in terms of hardness and adhesiveness. Hardness in baked goods is caused by starch retrogradation as well as differences in vapor pressure between crumb and crust resulting in moisture migration (Hager et al., 2011). Belgian waffles are not expected to be a hard product, and even when the
addition of dietary fiber changed some texture properties significant differences in hardness were not detected by TPA. The actual texture of all the treatment was expected to be soft inside and slightly crispy on the crust. However, the fiber type affects hardness of baked products significantly (Aydogdu et al., 2018). For instance, previous studies, reported that bread hardness was due to interactions between gluten and fibrous materials (Feili et al., 2013). Water absorption increased with added dietary fiber, hence increased viscosity. The products with added dietary fiber, demonstrated increased hardness and adhesiveness after baking (Gómez et al., 2003). However, Lebesi et al. (2011) found that dietary fiber enhanced crumb softness allowing more water to be available in the cake but did not affected firmness.

However, Pycia et al. (2018) found similarities to the current study (Table 3.4) after adding maltodextrine to bread; the crumb hardness and chewiness decreased when the content of the dextrose equivalent increased. This was possibly because when increasing the DE level, more reducing sugars are available to bind water and create a moist product, thereby decreasing hardness. In terms of adhesiveness, which corresponds to the rate at which the sample removes from probe (instrumental) or roof of mouth/teeth (organoleptic), no significant differences were found between samples (Table 3.4). Slightly but not significant changes in adhesiveness may be attributed to the higher levels of water-soluble carbohydrates (fiber) and slight reduction in wheat flour.
Table 4. Effect of dietary fiber on Belgian waffles texture parameters by TPA.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Description</th>
<th>Hardness (N)</th>
<th>Adhesiveness (N)</th>
<th>Cohesiveness (dimensionless)</th>
<th>Chewiness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Control</td>
<td>0.299±0.031</td>
<td>0.014±0.015</td>
<td>0.519±0.092^A</td>
<td>4.446±0.795^A</td>
</tr>
<tr>
<td>T2</td>
<td>5g/serving</td>
<td>0.291±0.018</td>
<td>0.010±0.013</td>
<td>0.454±0.078^A</td>
<td>3.696±0.433^B</td>
</tr>
<tr>
<td>T3</td>
<td>10g/serving</td>
<td>0.305±0.029</td>
<td>0.0±0.066</td>
<td>0.490±0.066^A</td>
<td>3.500±0.452^B</td>
</tr>
<tr>
<td>T4</td>
<td>15g/serving</td>
<td>0.297±0.029</td>
<td>0.002±0.020</td>
<td>0.331±0.125^B</td>
<td>1.788±0.467^C</td>
</tr>
</tbody>
</table>

ND refers to no significant different
N refers to the unit of measurement, newtons.
^Mean ± standard deviation from ten replication for each treatment
Mean values in the same column followed by different letters are significantly different (P < 0.05) based on ANOVA and Post-hoc Tukey’s Standardized (HSD) range test.

A significant decrease in terms of cohesion, which refers to strength of internal bonds in the sample was observed with increasing dietary fiber. The sample with the highest concentration of dietary fiber (T4) had significantly lower cohesion compared to other samples. Similarly, Frutos et al. (2008) showed that bread cohesiveness decreased significantly in the samples with the highest concentration of dietary fiber. Also, samples with added dietary fiber became less chewy; chewiness corresponds to the energy needed to disintegrate a semisolid food until it is ready to swallow (Trinh & Glasgow, 2012). With increased dietary fiber, samples became less chewy and cohesive, requiring less energy to break (chewiness) and lowering its ability to resist before the food structure deformed under the teeth (cohesiveness). Indeed, increasing dietary fiber from resistant maltodextrin affected these two texture properties of the final product, possibly because the product lost more weight (i.e., moisture, Table 3.2). As mentioned, a low DE value maltodextrin with longer straight- and branched-chain polymers units of glucose will not allow the creation of a moist product (Kuntz, 1997). Also, the formulation of the waffles with higher amount of
dietary fiber had less wheat flour, probably inhibiting the gluten network to form. As shown, samples T2 and T3 showed similarities in cohesion and chewiness. However, T1 and T4 showed significant differences for both cohesion and chewiness.

Compared to previous research, adding dietary fiber to bakery products such as bread, decreased cohesiveness as well, meaning that when the fiber was added, it lowered its ability to resist before the food structure deformed under the teeth.

3.3.3. Microbiological Testing

Microbiological evaluation was performed to guarantee the safety of the product before performing the consumer study. For APC, the minimum detection level was 20 CFU/g and for EC, yeast, and mold it was 2 CFU/g. No microorganisms were detected for APC, EC, yeas, and mold. Based on these results, the product was determined to be safe to proceed with the consumer test.

3.3.4. Influence of physicochemical properties of high fiber Belgian waffles on consumers’ liking and acceptance.

The need to improve healthy food choices has become popular for consumers but it is a challenge for the food industry. The U.S. dietary guidelines include recommendations to increase intakes of both dietary fiber and whole grain (McGill, Fulgoni, & Devareddy, 2015). Therefore, to investigate what Americans consumed is an interesting undertaking. In this actual study, results from Millennials consumers (N=120), where 60% were female and 40% were male, showed that the majority (80%) of them have consumed Belgian waffles before the consumer test.
Evidently, physicochemical properties of the product changed with increasing dietary fiber (Tables 3.2, 3.3 and 3.4). Probably, this contributed to a slight decrease of overall liking of the subjects, but no significant (Table 3.5). Consumers’ expectations and experiences have an effect on consumer perception of food quality (Fernqvist & Ekelund, 2014). Results in Table 3.5 showed that increasing fiber content from <1g to 15g/serving did not significantly affect liking of aroma, texture, flavor, or OLB of Belgian waffles, a product commonly consumed by Millennial consumers (Sloan, 2016). However, the addition of dietary fiber and the resulting physicochemical alterations may have had an effect on the consumers’ acceptability of overall visual liking (OVL), color, and overall liking after being presented with a health claim (OLA) among samples (Table 3.5). Similar results were found in waffles with increasing coconut powder (Kim & Lee, 2016). Major differences in percentages of purchase intent before (PIB) high-fiber health claim (HFHC) and purchase intent after (PIA) HFHC were observed.

Table 5. Consumer acceptability scores\(^{\dagger}\) and purchase intent of Belgian waffles

<table>
<thead>
<tr>
<th>Attributes</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>OVL</td>
<td>7.0±1.65(^A)</td>
<td>7.09±1.38(^A)</td>
<td>6.72±1.53(^{AB})</td>
<td>6.42±1.66(^B)</td>
</tr>
<tr>
<td>Color</td>
<td>7.0±1.58(^{AB})</td>
<td>7.13±1.40(^A)</td>
<td>6.58±1.69(^{BC})</td>
<td>6.21±1.80(^C)</td>
</tr>
<tr>
<td>Aroma(^{ND})</td>
<td>6.66±1.84</td>
<td>6.83±1.52</td>
<td>6.51±1.65</td>
<td>6.69±1.64</td>
</tr>
<tr>
<td>Texture(^{ND})</td>
<td>5.98±1.80</td>
<td>5.99±1.79</td>
<td>5.88±2.10</td>
<td>5.75±2.01</td>
</tr>
<tr>
<td>Flavor(^{ND})</td>
<td>6.13±1.77</td>
<td>6.3±1.59</td>
<td>6.19±1.88</td>
<td>6.08±1.82</td>
</tr>
<tr>
<td>OLB(^{ND})</td>
<td>6.13±1.78(^*)</td>
<td>6.19±1.66</td>
<td>6.09±1.96(^*)</td>
<td>5.93±1.83(^*)</td>
</tr>
<tr>
<td>OLA</td>
<td>5.66±1.95(^{B*})</td>
<td>6.48±1.67(^A)</td>
<td>6.67±1.82(^{A*})</td>
<td>6.41±1.90(^{A*})</td>
</tr>
<tr>
<td>PIB %(^{\dagger})</td>
<td>56.35(^*)</td>
<td>61.11</td>
<td>57.94(^*)</td>
<td>47.62(^*)</td>
</tr>
<tr>
<td>PIA %(^{\dagger})</td>
<td>45.24(^*)</td>
<td>65.08</td>
<td>69.05(^*)</td>
<td>61.11(^*)</td>
</tr>
</tbody>
</table>

\(^{\dagger}\)Mean and standard deviation from 120 consumer responses based on a 9-point hedonic scale.
Mean values in the same row followed by different letters are significantly different (P < 0.05).

PIB (Purchase Intent before) and PIA (Purchase Intent after), before and after, health benefit message was given to consumers. *Statistically significant p-values in bold print (P<0.05) based on McNemar exact probability. OLB* and OLA* mean values were significantly different according to a paired t-test comparison (α = 0.05).

3.3.4.1. Influence of increasing dietary fiber on overall visual liking (OVL)

Human perception influences consumers’ preferences, choices, and attitudes (Gellynck et al., 2008). Therefore, shape, color, and size may create the first impression on the food product evaluated, influencing panelists’ decisions. As shown in Table 3.5, OVL scores slightly decreased when the concentration of dietary fiber increased (7.0 vs 6.42). The sample with the highest concentration of dietary fiber (T4) was significantly different from T1 and T2 for the OVL scores. However, the samples with the highest concentration of dietary fiber were still acceptable as illustrated in Figure 1.

![Figure 1. Overall Visual liking (OVL) scores of high fiber Belgian waffles.](image)

*Means scores based on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely). N=120.*
3.3.4.2. Influence of increasing dietary fiber on color liking

Table 3.5 and Figure 2. show that color liking scores significantly decreased with the increase of the dietary fiber, but the color of the waffle with the highest concentration of fiber was still acceptable (6.21). As mentioned in the color instrumental measurements (Table 3.2), increasing dietary fiber increased color lightness, yellowness, and it resulted in a limited Maillard reaction. Also, delta E values demonstrated that the color differences among waffles can be perceived by the human eye. Possibly, these facts influenced consumers’ liking scores for color. In fact, the two samples with higher concentrations (T3 and T4) of dietary fiber showed similarities in instrumental color measurements and liking scores. Perhaps, there was a strong association between the color liking with the browning of the samples. In this case, the lower the brown color, the lower the color liking score.

![Figure 2. Color liking scores of high-fiber Belgian waffles.](image)

*Means scores based on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely). N=120

Color liking scores may be influenced by previous liking experiences (Shankar *et al.*, 2010). When consuming Belgian waffles consumers may have an expected
perception of brown color for waffles. Overall visual liking (OVL) had a score pattern similar to that of color liking. Consumers seem to prefer a brown color for Belgian waffles. However, adding the highest concentration of dietary fiber yielded a lighter waffle after baking, but liking scores only decrease from 7.13 to 6.21 when increasing the concentration from 5g to 15g per serving (Table 3.5). Similarly, Choi et al. (2013) reported slight changes in brown color and appearance liking scores when adding brown rice flour into waffles which in turn, affected overall acceptability by consumers.

3.3.4.3. Influence of increasing dietary fiber on aroma and flavor liking scores

Aroma and flavor are also important characteristics for determining consumers’ acceptance or rejection. Specially aromas may influence consumers choices for bakery products. The essential properties of food products are food aromas and volatile flavors (Lawless, 1991). The resistant maltodextrin used as a source of dietary fiber has no odor and no flavor. Results in Table 3.5., report that no significant differences were found among samples in terms of aroma and flavor liking scores. The addition of dietary fiber did not cause the aroma and flavors to be unacceptable (6.08-6.83). Usually, the source of the dietary fiber influences the aroma and flavor of the final product, but the commercial resistant maltodextrin used did not provide these effects. This is a beneficial effect when it is used to increase nutritional value without affecting aroma and flavor characteristics. Similar results for flavor liking scores were found in waffles after adding brown rice flour; liking of flavor did not affect significantly the consumers’ acceptance (Choi et al., 2013). Likewise, Almeida et al. (2013) demonstrated no linear, quadratic or interaction effect was significant (p>0.05) in
aroma acceptance between different types of dietary fiber added to bread. Moreover, other researchers such as Kranz et al. (2011), indicated that liking of flavor of products containing fiber did not influenced consumption or intakes of high fiber snacks by children. They concluded that the pleasure of eating a snack was stronger than the features of a product containing dietary fiber. However, in the present study the use of a no-odor and no-flavor dietary fiber ingredient was beneficial to maintain the original flavor of the waffles, but probably the pleasure of eating Belgian waffles was also stronger than the slight change in aroma or flavor.

3.3.4.4. Influence of increasing dietary fiber on texture liking scores

Instrumental texture properties changed significantly, particularly in the instrumental measurements in cohesiveness and chewiness; at 15g fiber/serving, waffles became significantly less cohesive and chewy which were analyzed by texture profile analysis (Table 3.4). When increasing dietary fiber, waffle dough tended to be stickier and after baking, waffles were less flexible and less easy to chew. Also, previous studies showed decreased loaf volume of bread when increasing bran level with fiber content (Al-Saquer et al., 2000). However, it did not affect consumer liking. Texture liking scores slightly decreased but not significant from 5.98 to 5.75 when increasing dietary fiber from <1g to 15g/serving, but the liking scores from the sample with higher fiber were still acceptable. Therefore, texture instrumental changes did not significantly affect texture liking scores (Table 3.5). However, in some cases, depending on the type of fiber source used, the product texture will be negatively affected. For example, Jackfruit rind flour (JRF) as a source of dietary fiber,
significantly influenced bread volume and texture attributes; increasing the level of JRF incorporated into wheat flour caused an increase in hardness and darkness of bread samples and a decrease in loaf volume compared to the control (Feili et al. 2013). Although, using resistant maltodextrin in the present study, resulted in decrease in cohesion and chewiness compared to the control treatment, it did not influence liking of texture. In another study, muffins, a popular product consumed by Millennials, with added dietary fiber from whole wheat grains were evaluated against white muffins; no significant differences in hedonic ratings were found for any of the tested attributes (appearance, flavor, texture, overall liking) (Mellette et al., 2018).

3.3.4.5. Influence of increasing dietary fiber on overall liking before (OLB) and overall liking after (OLA) high-fiber health claim (HFHC)

In this present study, an overall liking (OL) score was obtained from consumers both before and after they had been given information about the concentrations of dietary fiber in the product and its health benefits. Overall liking before health claim (OLB) was evaluated with the purpose of determine overall liking (OL) of the Belgian waffles without mentioning the health benefits that dietary fiber can provide, so consumers evaluation was based on the sensory liking and first impressions of the product. In general, products containing a higher amount of fiber had lower [but not significant (p>0.05)] liking scores than products without or less fiber. Therefore, the changes observed in the physicochemical properties of the waffles did not significantly influence OLB negatively.
Figure 3. Overall liking before vs overall liking after health claim of Belgian waffles.

Means scores based on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely) reported were not significantly different. (P < 0.4230). (N = 120).

OLB: overall liking before health claim and OLA: overall liking after health claim.

OLB and OLA mean values were significantly different according to a paired t-test comparison (α = 0.05), except for sample 5g/serving.

As reported in Table 3.5 a significant increase in OLA liking scores from 5.66 for T1 to 6.41 for T4 was observed. Additionally, a significant increase in the OLA scores was observed compared to OLB (Figure 3.), except for T2 (5g/serving) [not significant difference (p>0.05)]. Therefore, providing health benefit information generally resulted in significantly higher mean rating scores of OLA compared to OLB.

Poonnakasem et al. (2016) stated that a health benefit statement provided to consumer significantly increased overall liking.

3.3.4.6. Influence of high fiber health claim on purchase intent before (PIB) and after health claim (PIA)

After providing a High Fiber Health Claim (HFHC), all “high-fiber” samples outperformed the control, with OLA scores of 6.4-6.7 vs. 5.7 (Table 3.5). Although fiber information is increasingly used on food packaging, there are not enough studies
about the effect of fiber-related information on consumer’s perception reported in the literature (Baixauli et al., 2008). This current research was performed to demonstrate if consumers were willing to purchase Belgian waffles with a high-fiber content without and with knowing the HFHC. Purchase intent for Belgian waffles with <1g/serving size was significantly lower after providing HFHC (45.24% vs 56.35% respectively); consumers were aware that the control product did not comply with the FDA regulations of “a high source of dietary fiber” and the product may not be healthy. Millennials are more concerned about their diet and health, and purchasing foods that are minimally processed, organic, natural, and with “clean” labels. They prefer unique and interesting food and beverage experiences (Saulo, 2016). The impact of HFHC on the willingness to purchase a healthy product by the Millennials were observed in T3 and T4 when the PIB increased from 57.94% to 69.05% for 10g/serving of dietary fiber and from 47.62% to 61.11% for 15g/serving of dietary fiber (Figure 4). Consumers’ concerned of health is increasing among the Millennials population. Therefore, healthiness has much impact on Millennials lifestyle, creating an environment of selfcare regarding everything they eat. Human perception towards a health claim related to obesity and cardiovascular disease, leads to positive results even if the product was slightly changed in its physicochemical properties (Poonnakasem et al., 2016).
Figure 4. Purchase intent before (PIB) and after health claim (PIA) percentages of Belgian waffles.

T1: control sample, T2: 5g/serving size sample, T3: 10g/serving sample, T4: 15g/serving sample

PIB: purchase intent before health claim (%), PIA: purchase intent after health claim (%)

Purchase intent based on the McNemar's test (P < 0.05), comparing before and after consumers had been given information about dietary fiber concentrations and health benefits. N=120.

3.3.4.7. Just-about-right scores and penalty analysis for brown color

The JAR (Just-about-right) scale was used to determine the consumers’ perception of browning color intensity of the four different treatments of Belgian waffles (Table 3.6). The data collected from JAR help product developers to understand how specific product attributes need to be altered to achieve acceptability. A penalty analysis was used to describe the non-optimal sensory attributes affected by the addition of dietary fiber in the samples. An attribute should be considered critical when the percentage of consumers who selected the non-JAR responses was higher than 20% and the mean drop was greater or equal to 2.0 (a high number of consumers say the attribute level is not right, either too much or not enough, with a large impact on overall liking).
Table 6. Overall frequencies brown color intensity of Belgian waffles.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
<th>NE (%)</th>
<th>JAR (%)</th>
<th>TM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Control</td>
<td>6.35</td>
<td>71.43</td>
<td>22.22</td>
</tr>
<tr>
<td>T2</td>
<td>5g/serving</td>
<td>9.52</td>
<td>73.81</td>
<td>16.67</td>
</tr>
<tr>
<td>T3</td>
<td>10g/serving</td>
<td><strong>33.33</strong></td>
<td>55.56</td>
<td>11.11</td>
</tr>
<tr>
<td>T4</td>
<td>15g/serving</td>
<td><strong>53.97</strong></td>
<td>42.86</td>
<td>3.17</td>
</tr>
</tbody>
</table>

Bold and underlined values are for ≥20% of consumers.

NE= Not enough, JAR= just about right and TM= Too much

Table 7. Mean drop or penalty analysis for overall liking and color liking as affected by brown color.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>NE</th>
<th>TM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLB</td>
<td>Color</td>
</tr>
<tr>
<td>T1</td>
<td>1.06</td>
<td>1.92</td>
</tr>
<tr>
<td>T2</td>
<td>0.88</td>
<td>1.6</td>
</tr>
<tr>
<td>T3</td>
<td>0.87</td>
<td><strong>2.26</strong></td>
</tr>
<tr>
<td>T4</td>
<td>0.41</td>
<td><strong>2.14</strong></td>
</tr>
</tbody>
</table>

NE= Not enough and TM= Too much

Bold and underlined values are for ≥2.0 which refers to the high number of consumers saying the attribute level is not right with a large impact on liking scores.

As shown in Table 3.6, 53.97% of consumers rated brown-color to be [Not Enough] on a JAR scale for T4 (15g-fiber/serving product), the same sample that had the high value of lightness (L*, Table 3.2) and the low liking scores in terms of color and OVL (Table 3.5). The perception of [Not Enough] brown color for a waffle was related to a decrease in color and OVL liking scores. While 42.86% of consumers rated the T4, 15g/serving treatment as a “Just-about-right” brown color intensity, leading to decreased color liking scores but only down from 7.0 to 6.2. In fact, even if consumers rated OVL and color liking scores higher for T1, 22.22% of the consumers rated [Too Much] brown color intensity with a penalty concerned of 2.38 illustrated in Table 3.6, Table 3.7, and Figure 5. These results are consistent with the results shown
in Figure 2., where the treatments (T3/T4) with the lighter brown resulted in lower liking scores and higher percentages of [Not Enough] brown color intensity while the treatment with 5g/serving size (T2), which had a high liking score and the highest percentage in JAR scale (73.81%). Therefore, there is a relationship between the browning intensity perception (JAR scale) and color liking scores (9-point hedonic scale). Comparing instrumental results with panelists results, consumers seem to like brown color in Belgian waffles rather than lighter color.

Table 3.7 states the mean-drop calculated when the “percentage of consumers” was higher than 20% who selected the non-JAR responses such as [Not Enough] and [Too Much]. A calculated mean drop >2.0 was considered critical. No penalties of concern were found in overall liking before health claim (OLB) or in the category of [Not Enough] and [Too Much] (Table 3.7). This result is consistent with the OLB liking scores where no differences were found when increasing dietary fiber. However, a penalty of concern was found in sample T3 and T4 for color liking in [Not Enough] and [Too Much]. Consumers reported that T1, T2, and T3 had a penalty of concern by being [Too Much]. As stated earlier, a decrease in color liking was observed with increasing dietary fiber (Table 3.5).

To demonstrate the effects of brown color on color liking and overall liking before HFHC the penalty plots were created from the [Not Enough] and [Too Much] JAR responses (Figure 5 and 6).
Figure 5. Penalty plot for color liking as affected by brown color JAR scores. NE= Not enough and TM= Too much. T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample *Critical concern area refers to ≥20% of consumers and ≥2.0 penalty score which refers to the high number of consumers say the attribute level is not right.

Figure 6. Penalty plot for overall liking before HFHC as affected by brown color JAR scores. T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample *Critical concern area refers to ≥20% of consumers and ≥2.0 penalty score which refers to the high number of consumers say the attribute level is not right. NE= Not enough and TM= Too much.
Penalty analysis (mean drop) are presented in Figures 5 (browning over color liking) and 6 (browning over OLB). As shown, no penalties of concern (>2.0) were caused by brown color intensity (JAR scale) over OLB. In general, satisfaction from the Millennial consumers was higher when the color was just-about-right brown (71.43%-73.8%) and they expressed less satisfaction in terms of brown color intensity with high fiber waffles perceived as [Not Enough] (33.33%-53.97%) for the treatment with the higher concentration of dietary fiber, which may be attributed to the lightness of the samples (higher L* values).

3.3.4.8. Just-about-right scores and penalty analysis for texture properties (softness and chewiness)

Increasing the fiber content from <1g to 15g/serving did not significantly affect liking of texture (Table 3.5). However, there was a slight decrease from T1 to T4 in liking scores (5.99 to 5.75) when increasing dietary fiber (Table 3.5). Subsequently, specific attributes (softness and chewiness) were evaluated with a JAR scale to determine if those qualities influenced the liking scores of textures for each treatment. For instance, at 15g fiber/serving, waffles became significantly less cohesive and chewy based on instrumental measurements; however, the texture liking score did not significantly decrease compared to the 1g-fiber/serving product (5.75 vs. 5.98). A popular product consumed by Millennials such as waffles tended to influence overall liking even though physical characteristics changed slightly. As observed in Table 3.8, all samples had ≥20% of consumers considering that the waffles were [Not soft enough]; a penalty of critical concerned (>2.0) was found for texture liking for all the samples except for T2 (5g/serving) (Table 3.9).
Table 8. Overall frequencies of softness and chewiness of Belgian waffles.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Description</th>
<th>Softness</th>
<th>Chewiness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NE</td>
<td>JAR</td>
<td>TM</td>
</tr>
<tr>
<td>T1</td>
<td>Control</td>
<td>38.1</td>
<td>53.97</td>
</tr>
<tr>
<td>T2</td>
<td>5g/serving</td>
<td>26.98</td>
<td>57.94</td>
</tr>
<tr>
<td>T3</td>
<td>10g/serving</td>
<td>20.63</td>
<td>61.9</td>
</tr>
<tr>
<td>T4</td>
<td>15g/serving</td>
<td>23.81</td>
<td>45.24</td>
</tr>
</tbody>
</table>

T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample

NE= Not enough, JAR= just about right and TM= Too much

Bold and underlined values are for ≥20% of consumers.

Table 9. Mean drop or penalty analysis for overall liking and texture liking affected by JAR softness score.

<table>
<thead>
<tr>
<th>Softness</th>
<th>Treatments</th>
<th>Description</th>
<th>OLB</th>
<th>Texture</th>
<th>OLB</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>NE</td>
<td></td>
<td>TM</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T1</td>
<td>Control</td>
<td>1.44</td>
<td>2.09</td>
<td>1.70</td>
<td>1.94</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>5g/serving</td>
<td>1.30</td>
<td>1.36</td>
<td>1.75</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>10g/serving</td>
<td>2.08</td>
<td>2.41</td>
<td>2.68</td>
<td>2.91</td>
</tr>
<tr>
<td></td>
<td>T4</td>
<td>15g/serving</td>
<td>1.52</td>
<td>2.42</td>
<td>2.49</td>
<td>2.64</td>
</tr>
</tbody>
</table>

T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample

NE= Not enough and TM= Too much

Underlined values are for ≥2.0 penalty score which refers to the high number of consumers saying the attribute level is not right with a large impact on liking scores.

However, when the softness was rated as [Too Much] by more than 20% of the consumers, the mean drops for OLB and texture liking scores were of concern, particularly for T4 sample (2.49 and 2.64, respectively; Table 3.9). In fact, there is a positive correlation between sensory attributes such as softness with overall liking (Gacula et al., 2008).

From the penalty plot (Figure 7 and Figure 8) the treatments with the highest concentrations (T3 and T4) of dietary fiber rated as [Too soft] were critically concerned over OLB and texture liking.
Figure 7. Mean drop plot for overall liking before health claim as affected by softness JAR scores.

T1: control sample, T2: 5g/serving size sample, T3: 10g/serving sample, T4: 15g/serving sample

*Critical concern area refers to ≥20% of consumers and ≥2.0 penalty score which refers to the high number of consumers say the attribute level is not right.

Figure 8. The mean drop plot for texture liking as affected by softness JAR scores.

T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample

*Critical concern area refers to ≥20% of consumers and ≥2.0 penalty score which refers to the high number of consumers say the attribute level is not right.
Table 3.10 and Figure 9 and 10 report penalty analysis in chewiness scores, pointing out that just the treatment (T4) with the highest dietary fiber concentration influenced negatively with almost half of the consumers (45.24%) stating that it was [Too chewy] (Table 3.7) with a mean drop of 2.08 for OLB and 2.01 for texture while T3 had 22% of consumers perceiving it was also [Too chewy] with a penalty of critical concern of 2.59 for OLB and 2.97 for texture. However, for T3 the mean drop did not have any significant association with the texture liking scores, because the percentage of JAR were higher (60.32%).

Table 10. Mean drop or penalty analysis for overall liking and texture liking as affected by JAR chewiness scores.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>NE OLB</th>
<th>NE Texture</th>
<th>TM OLB</th>
<th>TM Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.48</td>
<td>2.25</td>
<td>1.28</td>
<td>1.28</td>
</tr>
<tr>
<td>5g/serving</td>
<td>1.5</td>
<td>1.6</td>
<td>1.65</td>
<td>1.11</td>
</tr>
<tr>
<td>10g/serving</td>
<td>2.14</td>
<td>2.22</td>
<td>2.59</td>
<td>2.97</td>
</tr>
<tr>
<td>15g/serving</td>
<td>1.47</td>
<td>1.82</td>
<td>2.08</td>
<td>2.01</td>
</tr>
</tbody>
</table>

T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample
NE= Not enough and TM= Too much
Bolt values are for ≥2.0 penalty score which refers to the high number of consumers say the attribute level is not right with a big impact on liking scores.
Figure 9. Mean drop plot for overall liking before health claim as affected by chewiness JAR scores.
T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample
Values ≥2.0 are penalty score which refers to the high number of consumers say the attribute level is not right with a big impact on overall liking.
Percentage of consumers ≥20% is critically concerned.

Figure 10. Mean drop plot for texture liking as affected by chewiness JAR scores.
T1: control sample, T2: 5g/serving sample, T3: 10g/serving sample, T4: 15g/serving sample
Penalty values ≥2.0 penalty score which refers to the high number of consumers say the attribute level is not right with a big impact on overall liking.
Percentage of consumers ≥20% is critically concern.
3.3.5. The emotion profile of the high fiber waffles

Baking products can generate positive and negative emotions, depending on the person’s perspective. Emotions terms were evaluated in order to detect consumers’ feelings when consuming Belgian waffles with different dietary fiber concentrations before providing a high-fiber health claim (HFHC). The EsSense® Profile terms were screened and selected for this task. The list of emotion terms was modified by adding the emotion term unsafe, related to the nutrition of the product and the safety of the intake of high fiber Belgian waffles. Therefore, 25 emotion terms EsSense profile by Nestrud et al. (2016), was selected to be evaluated by (N=120) all the panelists for each treatment of Belgian waffles.

The emotion terms were reported as a percentage of selection. The most common criteria used in emotion term selection is if ≥20% of the consumers selected the emotion term (King et al., 2013). In the present study, results in Table 3.11 showed that good, satisfied, pleasant, mild and calm (except the control sample with 18.9%). were the emotions that met this criterion. Therefore, the four treatments were related to positive emotions, with some slight inclination towards a few negative emotions such as disgusted and bored for the samples with the highest concentrations of dietary fiber. It is stated that humans’ behavior and food choices are associated with their emotions (Desmet & Schifferstein, 2008).

Figure 3.10. shows that regardless of the four treatments the “good” emotion term had the highest percentages of selections than other terms. Therefore, the increase of dietary fiber and liking of the product affected positively the positive emotion including good, mild, pleasant, satisfied and calm. No differences among
samples were found for these terms. However, some negative emotion terms were selected, such as disgusted, guilty, and bored (higher than 5%). All the positive emotions, such as good, good-natured, happy, pleasant, satisfied, mild and interested that were reported, were strongly (although not significant) associated specially with T2 and T3. Normally, eating a meal will reliably alter mood and emotional predisposition, typically reducing arousal and irritability, and increasing calmness and positive affect (Gibson, 2006). The negative emotions towards the samples with the highest concentration of dietary fiber were associated with the slightly decreased liking scores. Likewise, the positive emotions observed were strongly associated with the liking scores of the treatments.

Therefore, the satisfaction of eating promotes positive feelings. When consuming a popular product such as waffles, it could be assumed that without any physicochemical changes, the sample would be rated with positive terms. However, providing four treatments with differences among them, including texture, flavor, color, and health claim, significantly differences in emotion would be expected.
Table 11. Frequency* (%) of emotion terms selected by consumers elicited by Belgian waffles with different concentrations of dietary fiber

<table>
<thead>
<tr>
<th>Attributes</th>
<th>control (%)</th>
<th>5 g/serving (%)</th>
<th>10 g/serving (%)</th>
<th>15 g/serving (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>5.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Adventurous</td>
<td>4.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.1&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Aggressive</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bored</td>
<td>15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Calm</td>
<td>18.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Disgusted</td>
<td>8.7&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>10.2&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>16.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Enthusiastic</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Free</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Good</td>
<td>44.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>40.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>44.1&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Good-natured</td>
<td>7.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Guilty</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Happy</td>
<td>26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Interested</td>
<td>18.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.4&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Joyful</td>
<td>8.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.2&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Loving</td>
<td>6.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mild</td>
<td>25.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nostalgic</td>
<td>9.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.9&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>11&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Satisfied</td>
<td>31.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>22&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Satisfied</td>
<td>28.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>25.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28.3&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Tame</td>
<td>7.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Understanding</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.1&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unsafe</td>
<td>2.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Warm</td>
<td>12.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Wild</td>
<td>0</td>
<td>0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Worried</td>
<td>3.1</td>
<td>5.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.7</td>
<td>3.9&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Frequency obtained before consumers had been given information about the concentration of dietary fiber and HFHC.

<sup>a</sup> and <sup>b</sup> indicate significant differences based on Cochran’s Q with multiple pairwise-comparison-critical difference among treatments in the emotion selected.
Figure 11. Emotion Term frequencies selected by consumers for the Belgian waffles.
Emotion terms elicited by Belgian waffles obtained from N = 120 consumer responses.

3.4. References


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CHAPTER 4. CONCLUSION

Nutritional Guidelines and the FDA suggest that dietary fiber intake must increase, and the food industry needs to be part of this effort. Probably, consumers may be more willing to consume and buy popular products as a high-fiber source that provide health benefits, such as high-fiber waffles. After analyzing consumers’ interest, liking, purchase intent, and emotions regarding Belgian waffles, this study can conclude that although added synthetic fiber (resistant maltodextrin) in the waffle formulation altered color, texture, and weight (loss) of waffles, the high-fiber products were acceptable to consumers. No rejection and significant differences in terms of liking were observed for aroma, flavor, texture, and overall liking of high-fiber Belgian waffles before health claim. However, overall visual liking and color demonstrated slight but significant differences among the four treatments of the high-fiber waffles when increasing dietary fiber from <1g to 15g per serving. These decreases in color were supported by results from the JAR analysis that determined that consumers prefer brown color in Belgian waffles, rather than yellow color. Also, an increase in overall liking was observed after providing a high-fiber health claim. A great difference between PIB and PIA was observed between the lowest and the highest concentrations of high-fiber waffles. Certainly, providing a high-fiber health claim increased consumers’ willingness to purchase healthier products even if the added fiber altered the sensory properties. Moreover, from the twenty-five emotions selected, positive emotions were found to be related with the four concentrations of high-fiber Belgian waffles; just a few negative emotions (disgusted and bored) were slightly and negatively associated with the highest concentrations of high-fiber
Belgian waffles. Therefore, the high-fiber product developed in this study had a positively effect on consumers’ acceptance, elicited emotions, and purchase intent. This could encourage the food industry to develop high-fiber, popular food products, targeting the Millennial consumers since dietary fiber helps to reduce bad cholesterol (LDL), prevent obesity and cardiovascular diseases, and the intake is currently below the US nutritional guidelines. Strategies and technologies should be investigated in order to continue developing high-fiber products that may reduce the risk for chronic disease in US consumers.
Appendix A.

APPENDIX A. RESEARCH CONSENT FORM

LSU AgCenter Institutional Review Board (IRB)
Dr. Michael J. Keenan, Chair
School of Nutrition & Food Sciences
209 Knapp Hall
225-578-1708
mkeenan@agcn.lsu.edu

Application for Exemption from Institutional Oversight

All research projects using human 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 part 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 & 3).
  - (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://grant.nih.gov/grants-policy/hsrnow.htm)

1) Principal Investigator: Dr. Waisan Prasayawisutti
   Rank: Professor
   Student? Y/N NO
   Dept: School of Nutrition & Food Sciences Ph.: (225)578-5184
   E-mail: wpprasay@lsu.edu

2) Co-Investigator(s): please include department, rank, phone and e-mail for each
   - If student as principal or co-investigator(s), please identify and name supervising professor in this space
     Ashley Gutierrez, Research Associate, School of Nutrition & Food Sciences
     (225)578-5424

3) Project Title: Consumer Acceptance and Perceptions of New and Healthier Food Products
   - 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.

4) Subject pool (e.g., Nutrition Science, LSU Faculty, Staff, Students and off-campus consumers)
   - Circle any “vulnerable populations” to be used: (children<18, the medically impaired, pregnant women, the aged, others)
   - Projects with incarcerated persons cannot be exempted

5) PI signature: ____________________________ (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 □
                            HEF 18-22

Reviewer: Michael Keenan Signature ______________ Date 9-5-2018
Research Consent Form (EXAMPLE)

I, ________________________, agree to participate in the research entitled “Consumer Acceptance and Perception of New and Healthier Food Products” which is being conducted by Dr. Vidoon Priyawiswatkul, Professor of the School of Nutrition and Food Sciences at Louisiana State University, Agricultural Center, phone number (225) 578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. Up to 300 consumers will participate in this research. For this particular research, about 15-20 minutes 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 to participation to the investigator any food allergies I may have.

2. The reason for the research is to gather information on sensory acceptability, emotion and purchase intent of new and healthier food products. The benefit that I may expect from it is a satisfaction that I have contributed to quality improvement of these products.

3. The procedures are as follows: 3-5 coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.

4. Participation entails minimal risk. The only risk which can be envisioned is that of an allergic reaction toward common food ingredients (red beans, bell pepper, onion, garlic, celery, thyme, cayenne pepper, bay leaf, pork products, rice and rice products, milk and dairy products, yogurt or fermented milk products, peanuts, mayonnaise products, wheat flour, tapioca flour, eggs, table sugar, vanilla, soy products, sweet potato, salt (sodium chloride) and salt substitute (potassium chloride and common amino acids such as glycine and lysine), and plain unsalted crackers). However, because it is known to me beforehand that the food to be tested contains common food ingredients, the situation can normally be avoided.

5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.

6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University, Agricultural Center, which 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, Chair of LSU AgCenter IRB, (225) 578-1708. I agree with the terms above and acknowledge.

Signature of Investigator ___________________________  Signature of Participant ___________________________

Witness: __________________________________ Date: ______________________________
### APPENDIX B. PROCEDURE FOR PHYSICOCHEMICAL ANALYSIS AND CONSUMER TEST

<table>
<thead>
<tr>
<th>Disease</th>
<th>% (2015-2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypercholesterolemia</td>
<td>29.6</td>
</tr>
<tr>
<td>High Total Cholesterol</td>
<td>12.5</td>
</tr>
<tr>
<td>Hypertension</td>
<td>33.2</td>
</tr>
<tr>
<td>Overweight</td>
<td>71.6</td>
</tr>
<tr>
<td>Obesity</td>
<td>39.8</td>
</tr>
</tbody>
</table>

Figure A 1. Cardiovascular diseases in the USA. CDC, 2011.

![Weight recorded before baking](image)

Figure A 2. Weight recorded before baking.
Figure A 3. Color measurements.

Figure A 4. Texture measurements
Figure A 5. Mean values for Texture Profile Analysis.

Figure A 6. Percentage of consumption of Belgian waffles.
Figure A 7. Percentages of Elicited-Emotion terms of high fiber Belgian waffles (N=120)
Figure A 8. Consumer test

Figure A 9. Panelist in sensory evaluation
Figure A 10. Sampling preparation

Figure A 11. Processing of Belgian waffles
Figure A 12. Preparation of samples for consumer testing

Figure A 13. Waffles after baking
APPENDIX C. QUESTIONNAIRE FOR SENSORY EVALUATION

ANDREA PROJECT

Start of Block: Welcome

WELCOME to the LSU Sensory Lab  Click the right arrow button below to begin the test.
CONSENT Research Consent Form  I, _________________________, agree to participate in the research entitled “Consumers’ Acceptance, Liking, Emotions, and Purchase Intent (PI) of Belgian Waffles” conducted by Dr. Witoon Prinyawiwatkul, Professor of the School of Nutrition and Food Sciences at Louisiana State University, Agricultural Center, phone number (225) 578-5188. I understand that participation is entirely voluntary and whether or not I participate will not affect
how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed.
Up to 200 consumers will participate in this research. For this particular research, about 10-15 minutes 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 to participation to the investigator any food allergies I may have.
2. The reason for the research is to gather information on sensory acceptability, liking, emotion, and purchase intent of new and healthier food products. The benefit that I may expect from it is a satisfaction that I have contributed to quality improvement of these products.
3. The procedures are as follows:
4 coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.
4. Participation entails minimal risk: The only risk which can be envisioned is that of an allergy to wheat, milk, or eggs; or intolerance to lactose or gluten; or adverse reaction to common food ingredients [whole milk, flour, eggs, butter, salt, vanilla, yeast, dietary fiber and sugar]. However, because it is known to me beforehand that the food to be tested contains common food ingredients, the situation can normally be avoided.
5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.
6. The investigator will answer any further questions about the research, either now or during the course of the project.
The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University, Agricultural Center, which 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, Chair of LSU AgCenter IRB, (225) 578-1708. I agree with the terms above and acknowledge.

Please, type your first and last name:
________________________________________________________________

End of Block: Consent

Start of Block: Demographics
GENERAL Gender:

- Female (1)
- Male (2)

AGE:

- 18-25 (2)
- 26-35 (3)
- 36-45 (4)
- 46-59 (5)
- 60+ (6)

EDUCATION Please select your education level

- Below undergraduate degree (1)
- Undergraduate Degree (2)
- Master's degree (3)
- PhD degree (4)
CONSUMPTION Have you ever consumed Belgian waffles?

☐ Yes (1)
☐ No (2)

End of Block: Demographics

Start of Block: Sample 291

Q96 Please drink water and eat unsalted crackers to cleanse your palate.

Q213 PLEASE CLOSELY OBSERVE WAFFLE 291. Please answer the following questions BY VISUAL EVALUATION ONLY (DO NOT TASTE THE SAMPLE YET):

Q214 Please rate your liking of the OVERALL VISUAL QUALITY of the waffle 291

☐ Dislike extremely (60)
☐ Dislike very much (61)
☐ Dislike moderately (62)
☐ Dislike slightly (63)
☐ Neither like nor dislike (64)
☐ Like slightly (65)
☐ Like moderately (66)
☐ Like very much (67)
☐ Like extremely (68)
Q215 Please rate your liking of the **COLOR** of the waffle

- Dislike extremely (60)
- Dislike very much (61)
- Dislike moderately (62)
- Dislike slightly (63)
- Neither like nor dislike (64)
- Like slightly (65)
- Like moderately (66)
- Like very much (67)
- Like extremely (68)

Q216 Based on your preference, please rate the **BROWN COLOR** of the waffle

- Not brown enough (1)
- Just about right (2)
- Too brown (3)
SMELL PLEASE TAKE A PIECE OF SAMPLE 291 AND SMELL IT. AFTER THIS, ANSWER THE FOLLOWING QUESTION:

SMELL Please rate your liking of the **AROMA** of sample 291

- Dislike extremely (60)
- Dislike very much (61)
- Dislike moderately (62)
- Dislike slightly (63)
- Neither like nor dislike (64)
- Like slightly (65)
- Like moderately (66)
- Like very much (67)
- Like extremely (68)
Q222 PLEASE TASTE A PIECE OF SAMPLE 291 AND ANSWER THE FOLLOWING QUESTIONS:

Q223 Please rate your liking of the TEXTURE of sample 291

- Dislike extremely (1)
- Dislike very much (2)
- Dislike moderately (3)
- Dislike slightly (4)
- Neither like nor dislike (5)
- Like slightly (6)
- Like moderately (7)
- Like very much (8)
- Like extremely (9)

Q224 Based on your preference, please rate the SOFTNESS of sample 291

- Not soft enough (1)
- Just about right (2)
- Too soft (3)

Q225 Based on your preference, please rate the CHEWINESS/STICKINESS of sample 291

- Not chewy/sticky enough (60)
- Just about right (61)
- Too chewy/sticky (62)
Q226 Please rate your liking of the **FLAVOR** (taste and aroma) of sample 291

- Dislike extremely (1)
- Dislike very much (2)
- Dislike moderately (3)
- Dislike slightly (4)
- Neither like nor dislike (5)
- Like slightly (6)
- Like moderately (7)
- Like very much (8)
- Like extremely (9)

Q227 Please rate your **OVERALL LIKING** of sample 291

- Dislike extremely (1)
- Dislike very much (2)
- Dislike moderately (3)
- Dislike slightly (4)
- Neither like nor dislike (5)
- Like slightly (6)
- Like moderately (7)
- Like very much (8)
- Like extremely (9)
Q75 After visual, aroma and taste evaluations of sample 291, how does this waffle make you feel? Select the emotions that you associate with this Belgian waffle. Check all that apply.

- [ ] Active (1)
- [ ] Adventurous (2)
- [ ] Aggressive (3)
- [ ] Bored (4)
- [ ] Calm (5)
- [ ] Disgusted (6)
- [ ] Enthusiastic (7)
- [ ] Free (8)
- [ ] Good (9)
- [ ] Good-natured (10)
- [ ] Guilty (11)
- [ ] Happy (12)
- [ ] Interested (13)
- [ ] Joyful (14)
- [ ] Loving (15)
- [ ] Mild (16)
- [ ] Nostalgic (17)
- [ ] Pleasant (18)
- [ ] Satisfied (19)
- [ ] Tame (21)
Q228 Please look at the sample 291. How likely would you purchase this product?

- Yes (70)
- No (71)

Q90 Dietary fiber has beneficial effects such as lowering bad cholesterol and protecting us against cardiovascular diseases. According to the Food and Drug Administration (FDA), a daily adequate intake of dietary fiber is 14 grams for every 1000 calories consumed per day.

This product has less than 1 gram of dietary fiber.
Q92 Knowing this additional information, please rate your **OVERALL LIKING** of sample 291

- Dislike extremely (1)
- Dislike very much (2)
- Dislike moderately (3)
- Dislike slightly (4)
- Neither like nor dislike (5)
- Like slightly (6)
- Like moderately (7)
- Like very much (8)
- Like extremely (9)

Q93 Knowing this additional information, how likely would you purchase this product?

- Yes (70)
- No (71)

End of Block: Sample 291
Vita
Andrea Lucia Velasquez De Luca was born in Panama City, Panama. She received her bachelor’s degree in Nutrition and Dietetics from Interamerican University of Panama, Panama, in May 2015. Prior to entering the program in Food Science and Technology at Louisiana State University (LSU) she spent two years working as a public health community manager and nutritionist consultant at Nestle under the Healthy Kids Program Centro America and one year working as a Nutritionist consultant in Nutrition and Dietetics private clinics in Panama City, Panama. She expects to graduate with her master's degree in August 2020 and pursue a career as R&D Sensory Scientist.