ABSTRACT

KIM, MINA KYUNGMIN. Application of Sensory Techniques to Evaluate Sodium and Fat Reduction in Dairy Foods. (Under the direction of MaryAnne Drake.)

A current trend in the food industry is focused towards health conscious consumers. Consumers are paying more attention to their health and wellness and seeking healthier options for their food choices. As part of healthier alternatives for consumers, the food industry has offered reduced fat and reduced sodium options. However, the main challenges for reducing fat and/or sodium in food are flavor and texture. Among all other factors affecting purchase intent and consumption, flavor remains by far the most influential driving force, especially for dairy products. This research focused on the challenges with sodium and fat reduction in dairy foods, and solutions to overcome these drawbacks using sensory evaluation techniques.

The first study investigated the sensory response of Cheddar cheese flavor compounds in model full-fat and 75% reduced-fat cheeses. Based on sensory responses and odor activity values of 23 key volatile compounds, 12 key flavor compounds were identified to mimic aged Cheddar cheese flavor in low fat cheese models. The perceived aged Cheddar cheese aroma intensity of reduced-fat model cheeses with these added compounds was not different ($P > 0.05$) from the perceived Cheddar cheese aroma intensity of commercial aged full-fat cheeses.

The objective of the second study was to characterize consumer knowledge and awareness of sodium reduction in foods using an internet survey (n=489). A quantitative internet survey was designed to gather knowledge and attitudes towards dietary sodium,

sodium in foods and health, and Kano analysis was conducted. Salt and sodium knowledge indices were calculated based on correct responses to salt levels in food products. Consumers were aware of the presence of sodium in "salty" foods, and that sodium was part of salt. People who had a family history of certain diseases associated with a higher intake of dietary sodium did not necessarily have more knowledge of the relationship between sodium intake and a specific disease compared to consumers with no family history. Sodium content on the food label panel did not influence consumer satisfaction or dissatisfaction. The addition of a healthy nutrient (i.e. whole grain, fiber) into a current food product was appealing to consumers. For nutrient labeling, a "reduced" claim was more appealing to consumers than a "free" claim for "unhealthy" nutrients such as fat, sodium, and sugar.

The third study evaluated the influence of package and brand name on liking and purchase intent of chocolate milk using a consumer acceptance test, emotional measurements, conjoint analysis and Kano analysis techniques. Package and brand influenced overall liking and purchase intent for chocolate milks to differing degrees ($p<0.05$). Chocolate milks made with whole milk were positively influenced, and those with lower fat content (1% or fat free) were negatively influenced by brand and packaging information ($p<0.05$). Organic labeling had no effect on liking or purchase intent of chocolate milk ($p>0.05$). Positive emotions were positively correlated with high purchase intent of products and overall liking of products ($p<0.05$). Conjoint analysis further confirmed that fat content on the packaging label was the driver of choice in chocolate milk.

These three studies investigated challenges associated with sodium and fat reduction in dairy foods and implemented both traditional and new techniques in sensory science to evaluate solutions for flavor problems associated with sodium and fat reduction. The findings from these studies can aid the dairy industry in a practical way by providing guidance for mimicking aged Cheddar cheese flavor in reduced-fat Cheddar cheese, by demonstrating the current state of consumer knowledge on sodium and salt reduction and by identification of information that contributes to consumer satisfaction on nutrition panel labels, and by identifying the drivers of choice in chocolate milk.

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Application of Sensory Techniques to Evaluate Sodium and
Fat Reduction in Dairy Foods

by
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DEDICATION

To my heavenly father who give me wisdom and strength every moment of my life

BIOGRAPHY

Mina Kyungmin Kim was born December 12, 1980 in Evanston, Illinois to her father, Hho-jung Kim, and her mother, Hye-Gyung Hwang. She spent her first five years in Evanston while her father pursued his Ph.D. degree at Northwestern University. After her father finished his studies, the family moved to Korea. Mina spent her teenage years in Dae-Duk Science Valley in Daejeon, and then moved to Seoul to pursue her college degree, spending two and a half years studying applied biochemistry at Konkuk University. In her junior year, she decided to study abroad in the United States and enrolled in the ESL (English as a Second Language) program, INTERLINK, at the University of North Carolina at Greensboro. While she was in the ESL program, Mina decided to transfer to the Department of Food Science at North Carolina State University (NCSU) in Raleigh, North Carolina. Mina was on the Dean's List her senior year and graduated cum laude in May 2004. In addition, Mina was inducted into Sigma Phi Thau, the Honor Society for Food Science, and continues her membership.

Mina decided to continue her studies in Food Science at NCSU and began her Master's program in fall 2004 under the guidance of Dr. MaryAnne Drake and Dr. Dana Hanson. During her Master's studies, Mina minored in Food Safety to broaden her knowledge in food microbiology and also took Extension courses to gain Food Safety Manager certification and HACCP certification. Upon graduation in December, 2006, Mina worked as a Sensory Technologist at NomaCorc LLC., a synthetic wine closure company located in Zebulon, NC. After a year at NomaCorc, Mina decided to study sensory science in depth and began her Ph.D. program under the guidance of Dr. MaryAnne Drake. While Mina was in the Sensory Science Ph.D program, she also pursed a Ph.D. minor in Statistics in order to understand the statistical theory behind sensory science more comprehensively. It was a tough road, but she made it through.

At NCSU, Mina also led various consumer-related projects that involved team management, design and implementing sensory tests, client interface, scientific report writing and professional conduct as part of her work at the NCSU Sensory Service Center. Her experience at the Sensory Service Center provided a unique opportunity to apply her knowledge, in all its forms, to business processes. While she was pursuing her advanced degrees, Mina was awarded third place in the graduate student poster competition in the Food Microbiology Division of the Institute of Food Technologists (IFT) in 2006, an outstanding paper award by KAIFT (Korean-American Institute of Food Technologists) in 2006, second place in the graduate student poster competition in the Dairy Food Division of the IFT in 2011, and finalist in the graduate student poster competition in the Dairy Food Division of ADSA in 2011. While she was in graduate school, Mina was also very active in church activities. She was a piano accompanist and keyboardist at Duraleigh Presbyterian Church and also served as a leader of a weekly bible study group.

Recently, Mina accepted an offer as a Research Scientist in the Sensory Department at CJ Foods, Inc., located in Seoul, Korea. After many long years away from her home country, she is returning to Korea with a big smile on her face. She is excited and looking forward to contributing her advanced knowledge and experience to the food science community in Korea.

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I would like to acknowledge my family. Without their sacrifice and endless love, I could not have made it to this point in my life. Earning a Ph.D. degree, just as my daddy earned his, has been my childhood dream, and I thank my family for making my dream come true. I thank my dad for his financial support, I thank mom for her continuing prayers, and I thank my sister for just being there and listening to me. You are my one and only baby sister!

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COMPREHENSIVE REVIEW OF LITERATURE

1.1. Current Trends in the Food Industry

A current trend in the food industry is gearing towards health conscious consumers. Consumers are paying more attention to their health and wellness and seeking healthier options for their food choices. Consumers believe that limiting processed foods are important for healthy eating (Mintel, 2009). Processed foods are known to have higher amounts of sodium, preservatives, flavor enhancers, and artificial ingredients than home-cooked, unprocessed food sources (Mattes and Donnelly, 1991). Unfortunately, US food consumers have heavily depended on processed foods rather than home cooked meals. The recent economic crisis in 2009-2010 drove consumers to practice conservative food spending and eating habits, and as a result, more meals were prepared at home in 2010 (FMI, 2010). However, only 30 % of meal preparers cooked from the scratch, and 60% of consumers prepared meal from a frozen entrée and or purchased frozen entrées (Tarnowski, 2011). The total time of meal preparation for home-cooked meals is longer than commercial foods (Beck, 2007), and due to the convenience and time savings, consumers chose commercial foods over home-cooked meals (Beck, 2007).

As part of healthier alternative options for consumers, the food industry started to offer reduced fat and reduced sodium options for consumers. Fat reduction in the food industry has been of interest since US consumers try to limit their caloric intake from fat, and this trend gained more interest since 2003, as the United States Food and Drug Administration (FDA) mandated food manufacturers to list trans-fat on the nutrition panel. In addition, the national salt reduction initiatives in 2010 led by The American Heart

Association and City of New York have increased the interest in salt reduction in processed food. Food companies voluntarily pledged to reduce sodium by 25% in the next five years (NSRI, 2011). Many previously published scientific studies documented correlations between a diet high in saturated fat and increased risk of getting cancer and coronary heart disease (Woteki and Thomas, 1993). Also, there is an established link between excessive sodium intake and a risk of getting chronic diseases such as high blood pressure (hypertension), stroke, bone diseases and stomach cancer (Leshem, 2009; Wardlaw and Kessel, 2002). Due to the adverse health effects from high intake of fat and sodium, the food industry started to offer lower fat and/or lower sodium alternatives for consumers. However, the main challenges for reducing fat and/or sodium are the flavor and texture profiles. Among all other factors affecting purchase intent, flavor remains by far the most influential driving force for purchase intent and consumption, especially for dairy products (Childs and Drake, 2009). This research focused on the challenges with sodium and fat reduction in dairy foods, and solutions to overcome these drawbacks using sensory evaluation techniques.

1.2. Flavor research in Dairy Foods

1.2.1. Milk

1.2.1. a. Fluid Milk

According to the Code of Federal Regulations from the US FDA, milk is defined as the lacteal secretion, practically free from colostrum, obtained by the complete milking of one or more healthy cows. Milk that is in final package form for beverage use shall have been pasteurized or ultra pasteurized, and shall contain not less than 8.25 percent milk solids not fat and not less than 3.25 percent milk fat (21 Code of Federal Regulations [131.110]). The consumption of total milk products in the US has decreased from 51 billion lbs per year in 1986 to 48 billion lbs per year in 2005, however low fat milk consumption has increased from 22 billion lbs in 1986 to 23 billion lbs in 2006 (Gould, 2011). Milk has unique nutritious properties, but is also highly perishable. Heat treatment and/or proper refrigeration storage is necessary to preserve milk for safe consumption. During processing and storage of milk, off-flavors can develop that not only negatively impact the consumer acceptability of fluid milk, but also potentially carry over to other dairy products that are sold or distributed (Alvarez, 2009). The ideal milk flavor should be a neutral flavor profile that is pleasantly sweet, with no distinct aftertaste (Alvarez, 2009).

The sensory attributes that negatively impact consumer liking of fluid milk have been studied. Classen and Lawless (1992) reported that light-oxidized, metallic, and rancid flavors were negatively associated with milk quality. Chung (2009) also reported metallic and grassy aromatics as negative drivers of liking (Chung, 2009). Barrefors et al. (1995) reported that milks with oxidized flavor contained higher levels of linoleic acid in the neutral fat fraction, and those were also low in α-tocopherol and β-carotene. Early milk flavor research was focused on light-activated flavor (light oxidation) in milk packaged in plastic jugs (White and Bulthaus, 1981). Light-induced oxidized milk flavor is characterized as “burnt protein”, “burnt feathers”, “Cabbage”, and “mushroom.” Later, Cadwallader and Howard (1998) reported that light oxidized milk contained higher concentrations of the following compounds: acetaldehyde, pentanal, hexanal, heptanal, 2,3-butanedione, dimethyl disulfide, and 1-octen-3-one. Bradley (1980) reported that light oxidation triggered the chemical conversion of methionine to methional, along with a partial loss of vitamins B2 and C and some amino acids. Marsili (1999) compared dynamic headspace and solid-phase microextraction methods for gas chromatographic-mass spectrometric analysis of light induced lipid oxidation in milk, and found similar volatile compounds that were responsible for light oxidized off-flavor as reported by Cadwallader and Howard (1998) including, pentanal, hexanal, dimethyl disulfide, 2, 3-butadione, and 1-octene-3-one. Karatapanis et al. (2005) also reported dimethyl disulphide, pentanal, hexanal, and heptanal as potential markers of milk quality which were highly correlated with light-induced off flavors in pasteurized whole milk. These compounds were formed mainly because of oxidative breakdown of unsaturated fatty acids, especially phospholipids, and proteins (Aardt et al., 2005).

Oxidative reactions in milk not only deteriorate the flavor of milk, but also impact the nutritional value of milk, and eventually impact the shelf life (Aardt et al., 2005). In the last 10 years, researchers investigated prevention of the oxidation of milk. Jung et al. (1998) suggested that addition of ascorbic acid could significantly reduce the formation of dimethyl disulfide, which they also reported as the most responsible compound for off-flavor development in skim milk. Naturally occurring antioxidants, such as α-tocopherol, was also suggested to use for delaying oxidation in milk. Charmley and Nicholson (1993) suggested injecting α-tocopherol into the muscles of dairy cows and Focant et al. (198) added α-tocopherol to the feed to reduce light-induced off flavor development during fluid milk storage. Zygiyra et al. (2004) investigated packaging materials for longer shelf-life as packaging materials can directly influence the development of light-oxidized flavor. Several packaging materials currently in the market include traditional glass bottles, coated paperboard cartons, all-plastic containers with high density polyethylene, and with polycarbonate and with polyethylene terephthalate (Zygiyra et al., 2004). Zygiyra et al. (2004) reported that the best overall protection for whole pasteurized milk was a package with multilayer and monolayer pigmented HDPE in comparison to milk packaged with coated paperboard (Zygoura et al., 2004).

One important thing to keep in mind is that the feed of the dairy cow influences the flavor of fluid milk, even after processing steps (Randby et al., 1999), and off-flavor formation can start from the time of milking at the dairy farm (Ishler and Roberts, 1991), therefore thorough process control is necessary step in order to minimize off-flavor formation in milk.

1. 2.1. b. Organic Milk

Consumer interest for organic milk has increased. In 2005, organic milk represented less than 1% of milk market; however the demand for organic milk has increased steadily. For example, between 2000 and 2005, the number of certified organic milk cows in US dairy farms increased by approximately 25 percent each year (USDA-ERS, 2006). The consumer typically links organic milk as healthier, environment-friendly, and consistent with animal rights protection, therefore the demand for organic milk continues to increase despite the higher cost than that of the conventional milk (Alvarez, 2009). According to the guidelines from the U.S. Department of Agriculture, "USDA Organic milk" should meet the following

4 requirements: 1. Cows cannot be treated with bovine growth hormone (BGH); 2. Cows cannot be treated with antibiotics; 3. Cow feed is grown without pesticides, whether the feed is grass or grain; and 4. Cows must have access to pasture (Schultz, 2006). Kiesel and Villas-Boas (2007) demonstrated that USDA organic seal in the food label increased the probability of purchasing organic milk, and they concluded that the consumer value the labeling regulations for organic production (Kiesel and Villas-Boas, 2007). Organic milk that requires use of pasture for dairy cattle has shown increased unsaturated fatty acid content, including conjugated linoleic acid (Croissant et al., 2007; Ellis et al., 2006). Ellis et al. (2006) demonstrated that organic milk had a higher proportion of polyunsaturated fatty acid in comparison to monounsaturated fatty acids than conventional milk. It is known that higher intake of polyunsaturated fatty acids and conjugated linoleic acids have protective effects against coronary heart disease (Bucher et al., 2002; Hu and Willett, 2002), which could lead to perception to consumers that consumption of organic milk has potential health benefits compared to traditional fluid milk consumption. In addition, Croissant et al. (2007) reported that the greater percentages of unsaturated fatty acids in milk from pasture-fed cows and these compositional differences between conventional and pasture-based milk were reflected in the flavor of milk: milk from pasture-fed cows had higher grassy and fecal/mothball aromatics as well as higher intensities of sweet taste and sweet aromatic. However this difference did not affect consumer acceptance (Croissant et al., 2007). Healthier perceptions towards organic milk as well as distinct flavor and compositional differences of organic milk in comparison to traditional milk make it more appealing to US consumers.

Despite higher consumer awareness in organic food, product knowledge on organic product is still poor (Naspetti and Zanoli, 2009). Naspetti and Zanoli (2009) conducted a study in Italy to investigate consumer perception on organic milk in 4 different dimensions in quality perception: taste, appearance, health, convenience and process. Organic consumers in Italy showed an implicit confidence in the better taste of organic food regardless of its scientific validity. By means-end-chain analysis of concept of health, the chain for organic milk perception in regard to health was following: less additives/chemical-> naturally produced-> eating healthy-> avoid health problems-> Staying healthy, which led in various ways to own health and wellbeing (Naspetti and Zanoli, 2009). Overall, organic consumers responded that organic foods were perceived as less processed, minimum additives, produced without chemicals, using natural production process, minimum added substances harmful to health (Naspetti and Zanoli, 2009). Convenience quality dimension was related to time-saving and less effort in cooking for household, and convenience quality showed more important for occasional organic users (Naspetti and Zanoli, 2009). In fact, Smith et al. (2009) demonstrated that single family or family with children under six pay slightly higher prices for milk due to the time constraints in US. Stolz et al. (2011) conducted study to investigate consumer attitude towards organic versus conventional food with specific quality attributes. The goal of the study was to see the differences between consumer segments regarding their price sensitivity and attitude towards food. They revealed that one of two segments strongly preferred organic products in Europe, and consumers in the segment prefer organic products were less price sensitive on purchasing organic products (Stolz et al., 2011). Consumer perceptions on organic milk in relation to its price premium were investigated.

Study from Smith et al. (2009) showed that consumer attitude toward organic label increased the price of milk significantly. They investigated on actual retail purchases from the 2006 Nielsen Home scan panel data, and found the price variation among organic milk based on fat content of milk. Overall the price for organic milk showed about 60% above conventional counterpart (Smith et al., 2009). Chang et al. (2010) also demonstrated the price variation between organic milk based on fat content (whole, 2%, 1% and skim). Chang et al. (2010) mentioned that people lived suburban in Ohio purchase more organic and/or lower fat conventional milk, were more price-sensitive to organic milk or lower fat conventional milk compared to resident of inner-city in Ohio. Inner-city consumers were price-sensitive towards conventional whole and/or conventional 2% milk, and those products constitute 89% of milk expenditure of inner-city consumers in Ohio State (Chang et al, 2010). In fact, several studies using consumer survey data find that purchase of organic products have no relationship to income level (Dettmann and Dimitri, 2007; Dimitri and Venezia, 2007; Whelan, 2002), and Barry (2004) reported that about 40% of organic consumers have incomes below $40,000. Rather, Akaichi et al. (2010) mentioned that purchase of organic milk is related to consumers' willingness to pay for a food product. They revealed that the consumers' willingness to pay for organic milk decreases with the number of purchase units per shopping trip (Akaichi et al., 2010). Overall, consumer awareness on organic milk has increased, however consumer knowledge on health benefits were still poor and the consumption of organic milk is still dependent on price variation.

1. 2.1. c. Flavored Milk

Fluid milk production is 17,000 million lbs per year, and flavored milk accounts for 4,451 million lbs (International Dairy Foods Association, 2010). Flavored milk is gaining popularity amongst children as well as adults due to its special taste along with meeting dietary requirements for dairy food. American Dairy Council and the American School Food Service Association revealed that offering flavored milk could be one way to increased milk consumption among children and adolescents (Anonymous, 2003; Murphy et al., 2008). Of the flavored milk products, chocolate milk is the most popular flavor in the US (Thompson et al., 2004; Bermudez-Aguirre et al., 2010). In fact, Garey et al., (1990) and Yon et al. (2012) concluded that school children are more likely to drink milk if offered chocolate flavored milk at school. Servings of plain milk and chocolate milk (flavored milk) provide similar amounts of nutrients including essential macronutrients, calcium, magnesium, phosphorus, vitamins A, B-12, D, and riboflavin, zinc and potassium (Murphy et al., 2008). Due to the nutrient rich properties of fluid milk, milk has been reported as an effective post-exercise rehydration drink (Shirreffs et al., 2007). Similar to fluid milk, Karp and others (2006) reported the benefit of chocolate milk as a post-exercise recovery aid, that the time to exhaustion, and total work for endurance training were significantly greater ($p<0.05$) for those who drank chocolate milk than typical carbohydrate replacement drinks (Karp et al., 2006). Gilson et al. (2010) reported the high efficiency of chocolate milk consumption as a muscle recovery aid after soccer training using a randomized cross-over study. Although flavored milk has similar nutritional benefits as regular milk, flavored milk, especially chocolate milk, has been criticized for its high sugar content, and higher calorie and fat content than regular milk (Johnson et al., 2002; Murphy et al., 2008). In 2005, the New York City, Department of Education recommended to replace whole milk with low- fat and/or fat free chocolate milk to reduce fat intake (CDC, 2010), and the following year, in 2006, New York City implemented a ban of whole milk and reduced the availability of sweetened flavored milk in the school lunch system (Golub et al., 2011) as well as District of Columbia, California, and Florida (Severson, 2010). This implementation was based on the earlier study by Wechsler et al. (1998) where they concluded that intervention in elementary school cafeterias could promote the selection of low fat milk rather than whole milk among elementary school children. Due to the demand in the public school system as well as the current healthier alternative trend, lower fat chocolate flavored milk consumption has increased, however the flavor of it is still distinctively different from chocolate milk made with whole milk.

There are several varieties of commercial chocolate milk available in the market, and they vary in flavor, color and viscosity. According to Thompson et al. (2004), cocoa aroma/flavor, cooked/eggy, and malty flavor are the positive drivers of liking for commercial chocolate milk. Later Thompson et al. (2007) further revealed the chocolate flavor liking was differentiated vastly between two different ethnic groups: Hispanic group consistently scored higher in chocolate flavor liking on chocolate milk than that of Caucasian (Thompson et al., 2007). Many attempts have been made to enhance chocolate flavor including addition of adjuncts to chocolate milk such as malt, salt, vanilla, cinnamon, nutmeg or other spices (Alvarez, 2009). Also, different sweeteners were used to enhance the flavor of chocolate milk (i.e. molasses, corn syrup). These sweeteners used in chocolate milk included nutritive sweeteners such as table sugar (sucrose), or high fructose corn syrup, or non-nutritive ones such as artificial sweeteners, but the exact formulation and the ingredients are different depending on the brand. On average, an 8 oz. serving size of low fat chocolate milk contains about 4 teaspoons of added sugar which equates to about 20-25g of sugar (USDA-ARS, 2008). Typically, cocoa powder or chocolate syrup is added to regular milk during chocolate milk processing, and the precipitation of chocolate and cocoa solids are observed frequently. To improve this condition, a small percentage of stabilizers are added, which result in a thick texture (higher viscosity) in chocolate milk compared to regular fluid milk (Alvarez, 2009). Addition of stabilizers or chocolate flavor can influence the chocolate milk quality. Aardt et al. (2001) reported that the Best Estimate Threshold (BET) for acetaldehyde were higher in chocolate milk in comparison to BET of spring water, skim milk and low fat milk, possibly suggesting the masking of acetaldehyde flavor by chocolate flavor in the chocolate milk medium. Chapman et al. (1998) studied the effects of carrageen and chocolate on light oxidized flavor development and vitamin A degradation of milk, and concluded that vitamin A degradation was reduced by the addition of carageenan in chocolate flavored milk. They concluded that decrease in vitamin A degradation could be due to the increase light scattering by additional particulate matter in the chocolate milk. Vitamin A and its precursor beta-carotene were light sensitive, therefore the loss of vitamin A increases with exposure to light. Vitamin A, especially beta-carotene was known to have inhibiting effect on development of light-oxidized flavors (Bossett et al., 1994). Examples of light-oxidized flavors include: burnt protein (burnt feather/burnt hair), burnt cabbage, cooked cabbage, mushroom, medicinal or plastic like flavor. These are primarily from photodecomposition of methionine to methional and subsequently led to sulphur compounds. Chapman et al. (1998) also concluded that light oxidized flavors could be masked by the chocolate flavor in chocolate milk (Chapman et al., 1998). Prakash et al. (2010) investigated the effect of different carrageenans (kappa and lambda) and sugar concentrations in chocolate milk on ultra high temperature (UHT) treated milk. They found that kappa-carrageenan provided more stability against fouling during UHT processing than lambda-carageenan (Prakash et al., 2010). Also they reported that viscosity and sedimentation of UHT chocolate milk increased significantly with increased concentration of carageenan and sugar (Prakash et al., 2010).

Besides ingredient modification to improve quality defects, consumer preference of chocolate milk was influenced by fat content in the chocolate milk (Hampton et al., 1969). Hampton et al. (1969) concluded that the 2% and whole fat chocolate milk was highly accepted at all levels of solids-non-fat chocolate milk, in comparison to fat free chocolate milk (Hampton et al., 1969). Later, Thompson et al. (2007) reported differences of preference in milk fat level among chocolate milk drinking Caucasian and Hispanic adults. They reported that the ethnicity influenced fat level choices for drinking chocolate milk: 71% Hispanic adults consumed milk with 2% milk fat or higher and rarely drank chocolate milk less than 2% or less milk fat, while Caucasians (67%) tended to choose lower fat milk and/or skim milk when drinking chocolate milk (Thompson et al., 2007). Hough and Sanchez (1998) conducted descriptive analysis on appearance, texture and flavor for powdered chocolate milk and correlated the sensory results to instrumental analysis. They found that appearance and texture were dependent on cocoa powder concentration, and visual viscosity. In fact, Thompson et al. (2007) reported that consumers associated darker and thicker texture with high in chocolate flavor in chocolate milk (Thompson et al., 2007). Previous researches revealed highly accepted chocolate milk among consumers, and also identified the drivers of liking of commercial chocolate milk. More research needs to be done in order to improve the quality and flavor of lower fat chocolate milk, as lower fat flavored milk consumption is projected to increase steadily.

1.2.2. Cheese

Cheese is the generic name for a group of fermented milk based food products produced throughout the world in a great diversity of flavors, texture and forms (Fox et al., 2000; Singh et al., 2003). More than 500 varieties of cheeses are listed by the International Dairy Federation (IDF, 1982), and if counting minor and local varieties, more than 1000 varieties of cheese exist around the world (Fox et al., 2000). Lactic Acid Bacteria (LAB) are commonly used in the production of a wide range of fermented milk products, and the most common species are: Lactococcus, Lactobacillus, Streptococcus, Enterococcus, Leuconostoc and Pediococcus spp. (Fox et al., 2000). Using different starter cultures and bacterial strains result in different cheese flavor profiles. Flavor remains a driving force for cheese purchase and consumption (Childs and Drake, 2009) and understanding flavor is an important aspect to effective and strategic research and marketing (Drake et al., 2006). Therefore, extensive research has been conducted to understand Cheddar cheese flavor with different instrumental analysis and sensory analysis techniques (Piggot and Mowat, 1991; Anderson et al., 1993; Dacremont and Vickers, 1994 a, b; Roberts and Vickers, 1994; Christensen and Reineccius, 1995; Muir et al., 1995; Milo and Reineccius, 1997; Drake et al., 1994, 1996, 2001, 2002, 2004, 2006, 2008 and 2010; Qian and Reineccius, 2002; Whetstine et al., 2003, 2005, 2006, and 2007; Avsar et al., 2004; Young et al., 2004; Cadwallader et al., 2006; Dabour et al., 2006; Agawal and Hassan, 2007; Kim et al., 2011).

1. 2. 2. a. Flavor Chemistry of Cheese

Many studies have attempted to identify the key volatile compounds responsible for cheese flavor. Many volatile flavor compounds in cheese originate from degradation of milk constituents, including lactose, citrate, lipids and milk proteins (mainly caseins) during the ripening process (Singh et al., 2003). Extensive research was conducted to understand the primary degradation pathways of milk constituents in cheese curd. The major chemical and biochemical pathways that impart the flavor of cheese include glycolysis (lactose and citrate), lipolysis (milk lipids) and proteolysis (caseins) (Singh et al., 2003). Early flavor chemistry research focused solely on instrumental evaluation of amino acids and fatty acids (Aston, 1982; Griffith and Hammond, 1989; Grosch, 1993; Christensen and Reineccius, 1995; Qian and Reineccius, 2002). More recent research has focused on establishing relationships between sensory and instrumental analysis. The breakdown of aromatic amino acids via Strecker degradation pathways cause the formation of many aroma-active compounds such as phenyl acetaldehyde, 2-phenethanol, phenyl ethyl acetate and phenylacetic acid, which can cause rosy off flavor (Whetstine et al., 2005), and 2/3 methyl butanal and 2- methyl propanal cause nutty flavor (Avsar et al., 2004). Christensen and Reineccius (1995) isolated the volatile compounds from 3 year old Cheddar cheese and identified the aroma active compounds using aroma extract dilution analysis (AEDA). They identified 16 aroma active compounds responsible for aged Cheddar cheese flavor: ethyl acetate, 2/3- methyl butanal, diacetyl, α-pinene, ethyl butyrate, ethyl caproate, 1-octen-3-one, acetic acid, methional, propionic acid, butyric acid, valeric acid, caproic acid, capric acid and lauric acid (Christensen and Reineccius, 1995), however sensory analysis was not conducted in this study; therefore the specific sensory characteristics of the cheese were unknown.

Early flavor research focused on the identification and quantification of key volatile compounds responsible for cheese flavor. Recent studies have addressed the role of partition coefficients and sensory thresholds for compounds and their odor activity value. Odor activity value (OAV) is the ratio of concentration in the food of interest to orthonasal threshold for a particular compound (Nursten and Reineccius, 1996). The OAV considers both the concentration found in the food matrix and the sensory threshold value, and it has been suggested that OAV is a more accurate indication of aroma/flavor contribution of volatile compounds in the food matrix (Milo and Reineccius 1997; Karagul-Yuceer et al. 2004; Qian and Reineccius 2003). Qian and Reineccius (2003) quantified the aroma compounds in Parmigiano Reggiano cheese by GC-MS techniques. They not only used instrumental analysis technique (GC-MS) but also calculated odor activity values from previously reported threshold values to incorporate sensorial perspectives on the flavor characterization process. They identified the following chemical compounds as important aroma contributors to Parmigiano Reggiano cheese: 3-methylbutanal, 2-methylpropanal, 2-methylbutanal, dimethyl trisulfide, diacetyl, methional, phenylacetaldehyde, ethyl butanoate, ethyl hexanoate, ethyl octanoate, acetic, butanoic, hexanoic, and octanoic acids. Milo and Reineccius (1997) and Drake et al. (2010) also used OAV approaches to identify the important aroma contributors to Cheddar cheese, especially low fat Cheddar cheese. Milo and Reineccius (1997) reported homofuraneol, furaneol, butyric acid and methional had higher OAV and greater impact on reduced fat cheese flavor than full fat cheese, and Drake et al. (2010) and Kim et al. (2011) confirmed that these compounds were important flavor contributors in low fat Cheddar cheese.

Whetstine et al. (2003) identified and quantified characteristic aroma compounds responsible for Fresh Chevre-style goat cheese using GC-O followed by AEDA and GC-MS. They found more than 80 aroma-active compounds that were responsible for Fresh Chevre-style goat cheese, and more importantly they also conducted subsequent sensory analysis with a model cheese system, and confirmed that 4-methyl and 4-methyl ocanoic acids were responsible for the characteristic waxy flavor in goat milk cheeses (Whestine et al., 2003). Their study was valuable as they used both sensory analysis and instrumental analysis to link instrumental results to sensory characteristics. Also, Cadwallader et al. (2006) identified the compounds responsible for beefy/brothy notes in aged Cheddar cheese using instrumental analysis including GC-O and GC-MS, followed by descriptive analysis of model cheeses. The significance of this study was that they also used a model system approach where they spiked cheese with a combination of methional, furaneol, and 2-methyl-3 furanthiol to confirm the results from instrumental analysis. Later Kim et al. (2011) conducted a confirmation study using a model system approach on 23 aroma active compounds previously identified as important flavor contributors in Cheddar cheese from Drake et al. (2010).

The current interest towards lowering the fat content in cheese has increased due to its high fat content. Therefore manufacturing and consumption of lower fat cheese has been increasing. Reduced-fat cheese is defined as having at least 25% fat reduction from the full-fat counterpart, and low-fat cheese is defined as having 3 g of fat or less per reference amount (21 Code of Federal Regulations [101.62b]), which equates to and approx. 83% fat reduction in Cheddar cheese. Fat reduction in cheese results in appearance, flavor and texture changes (Mistry, 2001; Banks, 2004), and consumer perception towards reduced fat products are still poor (Childs and Drake, 2009). Lower fat cheeses are made from lower fat milks; therefore they have higher protein to fat ratios than full fat counter parts (Drake et al., 2010). One of the common strategies for the manufacture of reduced-fat cheese is increasing the moisture content to partially replace fat and for texture improvement (Drake and Swanson, 1995; Mistry 2001). Addition of starter/adjunct cultures and enzyme additions and/or make-procedure modifications were applied with moderate success for fat reductions up to 50% (Anderson et al., 1993; Drake and Swanson, 1995; Nelson and Barbano, 2004; Debour et al., 2006; Agawal and Hassan, 2007). Milo and Reineccius (1997) suggested that the flavor differences documented in reduced fat cheese were not solely due to the texture alteration and changes in volatile compound release pattern, but also from the altered biochemistry and lack of balance of volatile compounds produced during ripening process. Drake et al. (2010) confirmed the altered biochemistry of reduced fat cheeses in comparison to full fat counterparts.

The release of flavor compounds is a key parameter of perceived flavor in food. Upon ingestion of food, it undergoes a phase change from a semisolid to a liquid by temperature increase in the mouth and dissolution with saliva (Relkin et al., 2004). During the physicochemical phase change, flavor compounds are released, and the rate is dependent on the partition coefficient of volatile flavor-contributing compounds (Leksrisompong et al., 2010). The change in biochemistry of reduced fat cheese resulted in changes in partition coefficients, and influenced flavor release patterns. Partition coefficient is defined as the ratio of the concentration of each aroma compound in the gaseous phase (ng/ml) to its concentration in the liquid phase (ng/ml) (Meynier et al. 2003) and it describes the potential extent of the release of the compound (Haahr et al. 2000). For instance, the presence of lipid in the food matrix can influence the partition coefficient of a flavor compound (Haahr et al., 2000; Meynier et al., 2003; Leksrisompong et al., 2010). Most flavor compounds are non-polar, thus fat is a flavor carrier of these hydrophobic compounds (Relkin et al., 2004).

Frost et al. (2005) conducted a study on flavor release patterns in ice cream with different fat levels. The compounds used in this study were β-nonanone, δ- nonalactone, isopentylacetate, and vanillin at fat level 3.5% and 2%. They found that the melting rate of ice creams was different from 3.5% and 2.0% fat level, and that the fat content increased the duration of perceived flavor. Also, they showed that the compounds with lower partition coefficients took less time to reach maximum intensity compared to compounds with higher partition coefficients ($p<0.05$), because compounds with higher partition coefficients associated with the fat in the ice cream matrix more. Roberts et al. (2003) compared the nosespace, headspace, and sensory intensity ratings for the evaluation of 5 different aroma compounds at 3 different concentrations in 4 different matrixes with varying fat contents: water, whole milk, reduced fat milk, and skim milk. The objective of their study was to find the correlation between sensory perception and nose and headspace concentration based on different fat levels in the diluents matrix. They found that the higher fat in the matrix reduced the aroma intensity sensory ratings in comparison to other matrix with lower fat levels, especially for compounds with higher partition coefficient values (Roberts et al., 2003). These previous studies showed that the fat in the matrix influenced the flavor release patterns as well as the rate of release, and also the partition coefficient of the volatile flavor played a role in the flavor perception in the sensorial experience. Therefore, it is essential to use sensory analysis approaches as well as instrumental approach in order to completely understand low fat cheese flavor and/or any food product flavor.

Milo and Reineccius (1997) evaluated aroma-active compounds from commercially available full fat and 40% reduced fat Cheddar cheese purchased from retail market. They suggested that fat reduction in cheese could impact the imbalance of flavor-contributing compounds (Milo and Reineccius, 1997). However, more validation was necessary as they used cheeses purchased from local grocery stores, therefore the differences found between reduced fat and full fat cheeses could not be solely attributable to fat reduction. For further understanding, Drake et al. (2010) evaluated pilot plant manufactured full fat, 50% reduced fat and 83% reduced fat cheeses manufactured from the same milk source, and the same processing conditions to confirm cheese flavor alterations due to fat reduction in cheese. They concluded that cheese ripening biochemistry and volatile compound profiles were altered as fat content was reduced. Their results showed that fat reduction in Cheddar cheese led to flavor changes, not only due to the compositional changes in the cheese matrix and subsequent different volatile compound release patterns, but also due to distinct changes in cheese biochemistry (Drake et al., 2010). The aroma active compounds identified in low fat cheddar cheese from Drake et al. (2010) were selected for further investigation by Kim et al. (2011). Kim et al. (2011) used a model cheese system approach to validate the 23 aroma active compounds identified and quantified by Drake et al. (2010), and to identify the impact of those compound concentration differences in the cheese model system both in low fat (~83% reduced fat model) and full fat cheese model (Kim et al., 2011). While many researchers focused on identifying and quantifying the aroma active volatile compounds in cheese flavor, a complete understanding of cheese flavor is still challenging because of the versatile nature of cheese.

1. 2. 2. b. Sensory Analysis of Cheese

The dairy industry has recognized sensory quality as an important factor for marketing and consumer acceptance. The traditional way to determine sensory quality involves a grading system with a score card established by the federal government with the founding of the Office of Markets (currently known as the Agricultural Marketing Service)(USDA-AMS, 2012). The products are scored on overall flavor or texture quality based on an idealized concept and a predetermined list of defects. This grading system is defect-oriented; therefore it allows grading experts to evaluate a large number of samples in a short amount of time (Singh et al, 2003). However, the limitation of grading system exists, as it does not necessarily differentiate specific flavor differences or use a standardized language. Descriptive analysis is an analytical, objective technique to overcome these shortcomings. Descriptive analysis is an analytical technique that uses trained panelists whose responses are treated like instrumental data (Singh et al., 2003). A panel of highly trained individuals identifies and quantifies sensory attributes with established sensory languages (lexicons) including appearance, aroma, flavor, texture or any single aspect (Meilgaard et al., 1999). The responses from descriptive panels and judges from dairy judging do not necessarily agree, as the objective of the two approaches is different (Classen and Lawless, 1992; Roberts and Vickers, 1994).

In Cheddar cheese flavor, a flavor lexicon was established in 2001 by Drake et al. (2001). The lexicon is a sensory language, and is a basis for descriptive sensory analysis. A flavor lexicon is defined as a set of words to describe the flavor of a product or commodity (Drake and Civille, 2003). Several sensory languages have been developed for Cheddar cheese, however only a few have been published with definitions and references for each descriptor. Piggot and Mowat (1991) determined 23 descriptive flavor and aroma terms for Cheddar cheese and Muir et al. (1995) also described 9 aroma terms to characterize the aroma profiles of hard and semi-hard cheese. Drake et al. (2001) developed a descriptive language for Cheddar cheese using 240 commercially available representative Cheddar cheeses. Fifteen individuals from industry, academia and government established the language including 27 terms with definitions and references such as, cooked, whey, diacetyl, milkfat/lactone, fruity, sulfur, free fatty acid, brothy, nutty, catty, cowy/phenolic, age, yeasty, moldy/musty, methyl ketone/blue, oxidized, waxy/crayon, fecal, bell pepper, rosy/floral, scorched, bitter, salty, sweet, sour, umami, and prickle/bite. Later, the sensory language was validated using panels at 3 different sites for the same cheeses (Drake et al., 2002). The results showed similar differentiation among the three different sites. This study demonstrated the analytical characteristic of descriptive analysis: responses from trained panelists could be treated as instrumental data.

One of the key advantages of characterizing products with a standardized descriptive lexicon is the ability to relate to consumer acceptance and instrumental or physical measurements (Drake and Civille, 2002). While many studies have been focused on volatile compounds that are responsible for Cheddar cheese flavor, Yang and Vickers (2004) investigated the importance of non-volatile components to Cheddar cheese flavor. They used 3 different model systems: dairy, nondairy, and Mozzarella model system, and sodium chloride (salty), lactic acid (sour), citric acid (sour), and monosodium glutamate (umami) were added to the model system. This group used mixture designs and response surface methodology to determine optimum levels of these 3 taste components in the model system. Trained panelists evaluated this model system for a variety of taste attributes and Cheddar-like taste. They concluded that less sodium chloride and acids were required to mimic the taste of mild Cheddar cheese in comparison to aged Cheddar cheese. At the end of this study, they were able to identify the most Cheddar-like taste in the Mozzarella model system, and the salt and acids in the model system were almost indistinguishable from real Cheddar cheese (Yang and Vickers, 2004).

Consumer acceptance tests are employed to understand the consumer. One big difference between consumer acceptance tests and descriptive analysis is that consumer tests use untrained consumers, and descriptive analysis uses trained panelists. Consumer acceptance tests are usually performed towards the end of product development or reformulation cycle (Lawless and Heymann, 1999). Young et al. (2004) conducted consumer acceptance tests at 2 different locations (North Carolina State and Oregon State) on Cheddar cheese with varying maturity levels. They found relationships between overall liking, overall flavor liking, overall texture liking and overall Cheddar cheese intensity with both groups of consumers. Dacremont and Vickers (1994a) attempted to measure how closely a specific product or aroma component matched the concept that people had of it (concept matching techniques) using cheese aroma matrices. They used untrained 18 judges to find the correlation between the odor, texture and taste and their own concept of Cheddar cheese and concluded that the taste and texture of the cheeses were more useful information for untrained panelists than the odor for classifying cheese as Cheddar cheese (Dacremont and Vickers, 1994a). However they used untrained consumers to draw this conclusion, therefore the results need to be validated and confirmed, as untrained consumers are not as objective at evaluating as trained judges. Later, the same group also investigated the optimum mixtures that mimicked Cheddar cheese flavor using concept matching techniques with sixteen untrained consumers (Dacremont and Vickers 1994b). They screened 15 volatile compounds for importance for Cheddar cheese aroma using a factorial design and concluded that butyric acid, diacetyl and methional were the most important chemical compounds that contributed to Cheddar cheese aroma. They found an optimum concentration of these compounds that were close to Cheddar cheese aroma (Dacremont and Vickers 1994b). Throughout the experiment, they used untrained judges to evaluate the cheese aroma. Again, this group used untrained judges, therefore the study need to be validated as untrained consumers have higher subject-to-subject variation.

Previous studies have documented that texture is also an important part of factors that influence overall liking: if the texture is atypical of the cheese, the overall liking and purchase intent of cheese can be negatively influenced. Previous studies reported that cheese texture is highly influenced by the fat content and age of the cheese (Hort et al., 1997; Yates and Drake, 2007; Rogers et al., 2009). Hort et al. (1997) showed the significant decreases on springiness, increase in firmness, hardness, crumbliness, and creaminess after 50 weeks of ripening period, and suggested that significant textural differences in English Cheddar cheeses were influenced by cheese age. Also, they showed correlations between pH and springiness, crumbliness, and creaminess, and suggested a strong correlation between cheese texture and the extent of proteolysis (Hort et al., 1997). During aging/ ripening process, large chemical and structural changes occured, mainly proteolysis. Hydrolysis of proteins degrades the casein network over time, which could lead to less firm and more deformable cheese (Banks, 2007). Yates and Drake (2007) reported the distinct textural differences associated with cheese age and fat content by descriptive panelists as well as consumers in Gouda cheese. They found that most consumers preferred a smooth, cohesive texture in Gouda cheese attributes, which were negatively associated with fracturability, firmness and springiness of cheese texture (Yates and Drake, 2007). Recently, Rogers et al. (2009) evaluated the texture and rheological properties of Cheddar cheese with different fat content (low fat, reduced fat and full fat). They manufactured Cheddar cheese using identical procedures, rennet and starter culture, so that the documented differences in texture were solely due to the difference in fat content. They reported that texture of low fat Cheddar cheese was not as largely influenced by 9 month aging period compared to the role that fat content differences played. Also, they reported the textures of low fat cheeses were more firm, and had higher springiness (Rogers et al., 2009). The molecular structure of cheese showed more weak spots in the network structure of higher-fat cheese, which results in smoother texture in mouth (Dabour et al., 2006). However the fewer weak spots are observed as the fat level decreases, which results in firm and rubbery texture. Also, more protein content in low fat cheese compared to protein content of full fat cheese played a role on firm and rubbery texture on lower fat cheese as well (Emmons et al., 1980). These structural differences influenced the flavor release pattern as well as changes in flavor threshold, and overall influence the low fat cheese quality being atypical of full fat cheese counterpart.

Combining consumer acceptance tests and descriptive analysis test to further understand the consumer is a powerful tool in sensory analysis, and is called preference mapping. Preference mapping assists scientists in understanding the descriptive sensory attributes that influence consumer preferences (Murray and Delahunty, 2000). Internal preference mapping is a principal component analysis (PCA) of the matrix of hedonic scores across the products to characterize product grouping and drivers of liking (Guinard, 1998; Lawless and Heymann, 2010; Meilgaard et al., 2007), therefore the perceptual product map (product space) is based entirely on the acceptance data from consumer acceptance tests (Lawless and Heymann, 1999). Internal preference mapping can differentiate the strength of consumer preferences (Guinard, 1998; Drake et al., 2008). External preference mapping links the descriptive sensory profile of a product and the hedonic scores given by consumers (Riviere et al., 2006). Consumer preferences are regressed onto the principal components of the covariance matrix of descriptive analysis data across products (Ares et al., 2006). Therefore the perceptual product map (product space) is obtained from analytical sensory or instrumental data, as well as consumer acceptance results (Lawless and Heymann, 1999).

External preference mapping is a very powerful tool to predict and/or identify the sensory characteristics that are associated with consumer liking and/or disliking (Meilgaard et al., 2006; Drake et al., 2008; Lawless and Heymann, 2010). Ritvanne et al. (2005) conducted a study on cheeses to determine correlations between sensory attributes to consumer liking in cheeses with different fat content. They used 70% Finnish and 30% imported Harvarti-type, Edam and Emmental type cheeses and their reduced fat counter-parts for their study. Chemical composition was also determined including concentrations of dry matter, fat, salt, and free amino acids. Consumer acceptance tests (n=120) were conducted on overall liking, pleasantness of appearance, mouthfeel, and flavor. They found that the cheeses appealing to consumers had a sticky consistency, and a creamy, full and salty flavor (Ritvanne et al., 2005). Roberts and Vickers (2006) investigated changes in sensory attributes of Cheddar cheese during the aging process, especially how such changes relate to consumer acceptance. Sensory attributes of 14 cheeses were documented using descriptive analysis every month through 9 month aging by 6 trained panelists, and consumer acceptance tests were conducted (n=120 each time) after 3, 6, and 9 months. They found that intensity of strong flavors (sweaty, sharp, and smokey), off-flavors (astringent, soapy and chemical), and "young" flavors (buttery, milky and sweet) increased as the cheese aged from 3 mo to 9 mo (Roberts and Vickers, 2006). Off-flavors correlated negatively with liking, and "young" flavors were highly correlated with consumer liking regardless of cheese age (Roberts and

Vickers, 2006). Caspia et al. (2006) also evaluated 7, 9, 12 month aged Cheddar cheese by descriptive sensory analysis of flavor and texture, instrumental volatile analysis and consumer acceptance testing using 140 consumers. The trained panelists identified “young” flavors such as cooked, buttery, and creamy flavor in 7 month old cheese, and also identified “aged/developed” flavors including fruity, sulfur, earthy, and free fatty acids in 12 month aged cheese (Caspia et al., 2006). They also linked descriptive terms and consumer results, and they found 6 different clusters of consumers; however they did not report the specific drivers of liking of those cheeses. In 2008, Drake et al. applied internal and external preference mapping techniques to identify the drivers of liking of mild Cheddar cheese. They evaluated a representative array of commercial Cheddar cheeses labeled as “mild” in the market (n=22), and conducted descriptive analysis using the previously established cheese flavor lexicon (Drake et al., 2001). From descriptive analysis, 9 representative Cheddar cheeses were selected for consumer acceptance tests, and by external preference mapping, they found the drivers of mild Cheddar liking: color, cooked/milky, whey, brothy flavor, and sour taste (Drake et al., 2008). Later, Drake et al. (2009) conducted a study to determine consumer perception and liking of commercial sharp or aged Cheddar cheese. They first documented 29 commercial sharp Cheddar cheese using descriptive analysis with cheese lexicon established by Drake et al. (2001). From descriptive analysis result, 9 representative Cheddar cheeses were selected to proceed on consumer tests. Consumer acceptance tests were conducted in 3 regional locations including east coast (Raleigh, NC) with 100 consumers, Midwest (Champaign Il) with 75 consumers, and West coast (Pullman, WA) with 100 consumers. The consumer liking scores for same 9 cheeses were compared in three locations, and external preference mapping were conducted and revealed 5 distinct consumer segments. They found that the drivers of liking on sharp Cheddar cheese were different in west coast consumers compared to Midwest and east coast consumers ($p<0.05$). West coast consumers preferred intense cheese flavors including high in free fatty acid, brothy, and nutty flavors and salty and sour taste (Drake et al., 2009). Consumer preference for the East and Midwest consumers, was associated with sensory attributes that were typically regarded as young/mild Cheddar cheese flavor: whey flavor and milk fat flavor (Drake et al., 2009). They also concluded that sharp cheddar / aged cheddar cheese labeling had different meanings to different consumers (Drake et al., 2009).

1.2.2. Summary

Dairy foods are made from fluid milk, and the flavor of fluid milk influences the flavor of the dairy food. Process control from farm to fork is necessity in order to improve the flavor of dairy foods. Many studies have been conducted to improve or to understand the characteristic flavor of cheese.

1.3. New Techniques in Sensory Analysis

Traditional consumer sensory analysis involved consumer hedonics followed by additional analytical testing at the end of the product development or reformulation cycle. Consumer acceptance tests were designed by sensory analysts with the assumption that a product with a low acceptance score will not perform well in the real market. However, a high acceptance score is not the only factor to drive market success, since other factors such as price, market image, packaging and niche play a role (Lawless and Heymann, 1999). Therefore marketing tools and/or tools from other disciplines have been adopted, and are widely used in the food science field to completely understand consumer language and the consumer market to assist the product development process. In this chapter, new techniques that are emerged in the sensory and consumer science field are introduced, such as emotion measurement, conjoint analysis and Kano analysis.

1.3.1. Emotion measurement

Measuring emotions has been researched extensively in many fields including clinical psychiatry (POMS; McNair, 1989), social science (Russell, 1991), health and nutrition (Gibson, 2006) and consumer research (Desmet, 2004; Laros and Steenkamp, 2005; Desmet and Hekkert, 2007; King and Meiselman, 2009). Researchers have continuously investigated the definition and classification of the multidimensional nature of emotional characteristics. Recently, product developers in food science started to pay more attention to emotional change, as they found the need to investigate missing information: why do products fail while consumer acceptance score were high? Higher liking scores do not necessarily influence the purchase intent of consumers (Kemp et al., 2009). Porcherot et al. (2010) reported that the information from acceptability was not identical with the information from emotion testing. Therefore, emotion measurements can be used as another tool in addition to traditional hedonic testing to understand the consumer during the product development process.

Emotions are defined as "short-term affective responses to appraisals of particular stimuli, situations or events having reinforcing potential" by Gibson, 2006. The basic dimensions for emotion were positive and negative (Gibson, 2006; Laros and Steenkamp, 2005). Moods are psychological arousal states lasting at least several minutes and usually longer, and may persist in the absence of stimuli. The basic dimensions in moods are energy, tension and pleasure (Gibson, 2006). One thing to note is that emotion is involved in particular stimuli, however mood is objectless. Even though there is a difference, both moods and emotions are reactions to the surrounding environment (Lazarus, 1991), and it means that both moods and emotions can influence product choice and food consumption behavior. Macht and Dettmer (2006) in fact, looked into the effect of eating a chocolate bar or an apple on everyday mood and emotions. They observed 37 healthy, normal weight women after 5, 30, 60 and 90 min after eating a chocolate bar, an apple or nothing, and subjects were asked to score their subjective mood status each time point. Eating chocolate or an apple reduced hunger and elevated mood as well as increased activation, however eating chocolate induced guilt as well as joy (Macht and Dettmer, 2006). Macht et al. (2002) reported that emotion affected product choice, and food consumption affected the emotions during the product experience (Macht et al., 2002). Specifically, they experimentally induced the 4 emotions (anger, fear, sadness and joy) and measured the motivation to eat chocolate of forty-eight healthy men ages between 19 – 45 years old. They found that sadness and joy affected motivation to eat in opposite directions, where joy increased the motivation significantly, and sadness decreased appetite significantly. These studies showed the close relationship between everyday eating behavior and emotion/mood, and justified the need for emotion research in food science field. Emotions are generated by the brain upon sensing environmental stimuli, however, understanding emotion and environmental stimuli (in this case, food) are a lot more complicated because of the multidimensional nature of emotion, which are influenced by human thought processes and perceptual biases.

In order to measure emotions, an emotion "lexicon" needs to be developed to standardize the emotional terms. In 1987, Ortony et al. developed their emotion lexicon starting with 585 emotion words, and their study is considered as one of the most complete and original treatment of this topic (Meiselman, 2011). A total of 585 emotion words were selected based on the origin of the words, including 357 adjectives, 101 verbs, 20 nouns, 53 noun forms of adjectives, and 54 noun forms of verbs. They classified the emotional terms, and formed an "emotion taxonomy" (Figure 1).

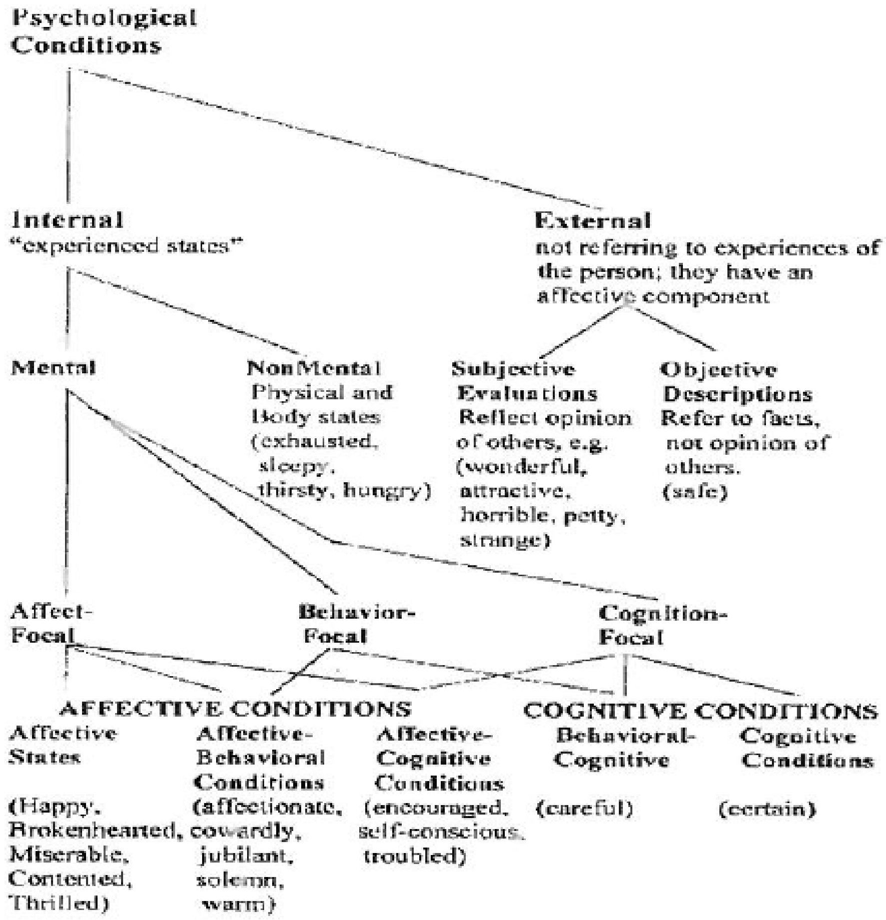

Figure 1-1 Emotion Taxonomy (Ortony et al., 1987)

The basic classifications for emotions according to Ortony et al. (1987) are: 1. emotions must be internal, not external; 2. mental, not physical body status; 3. all mental terms further classified into either affect, behavior, and cognitive. Earlier emotion works were developed and/or mainly adopted from clinical psychiatry. Profile of Mood States (POMS) involved an evaluation of transient mood states, which proposed 6 mood factors: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue- inertia and confusionbewilderment (McNaire et al., 1971). POMS was originally designed for mid-high school level, therefore it is a self-administrable, relatively short test (takes about 3-5 mins). In POMS, participants rate their mood during the past week, including right now, today, and used a 5 point scale anchored from 1= not at all, and 5 = extremely (McNaire et al., 1971).

Watson et al. (1988) reported the bipolar dimensions of emotion: positive and negative dimension. They proposed to evaluate feelings in eight different time frames: right now, today, during the past few days, during the past week, during the past few weeks, during the past month, during the past year and in general. Participants were asked to rate 10 emotions that were proven to be representative of each positive and negative effects on a 5-point scale anchored from 1= not at all, to 5= extremely (Watson et al., 1988). Plutchik (2001) presented a wheel of emotions to describe the relationship and interconnections among emotions. The wheel of emotions contained 8 primary bipolar emotions: anger-fear, joy-sadness, trust-disgust, and surprise-anticipation. Laros and Steenkap (2005) developed 39 basic emotion terms based on a hierarchial approach. They started with a list of 173 negative and 140 positive emotions from previous literature. They proposed a three level hierarchical model: superordinate level including positive and negative affects; basic level including 4 negative (anger, fear, sadness, and shame) and 4 positive (contentment, happiness, love and pride) emotions; and subordinate levels contained the rest of emotions (Figure 1-2).

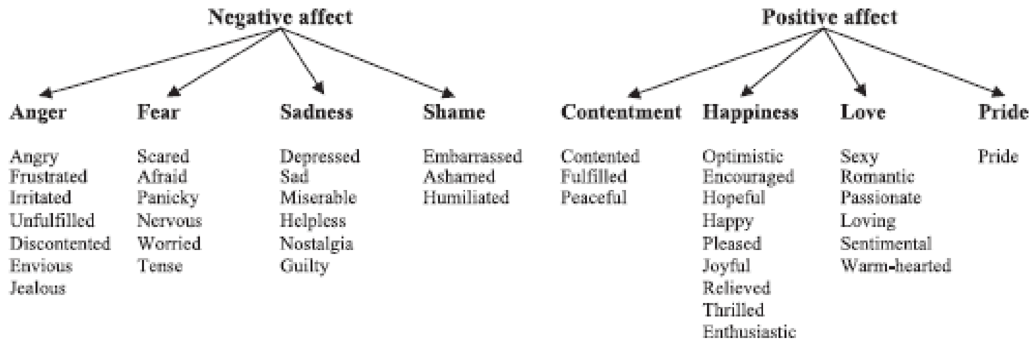

Figure 1-2 Hierarchical Mode of Consumer Emotions (Laros and Steenkamp, 2005)

They conducted a preliminary test across food types (genetically modified food, functional food, organic food, and regular food) by asking consumers to rate whether they experienced these feeling using a 5-point scale, anchored 1=I feel this motion not at all, 5 being I feel this emotion very strongly (Laros and Steenkamp, 2006). They found that the basic emotions (anger, fear, sadness, shame, contentment, happiness, love, and pride) provided more information for better characterizing emotions that consumers experienced (Laros and Steenkamp, 2006).

Rousset et al. (2005) investigated the relationship between negative emotions towards meat and low meat intake among French female subjects. They used 26 emotion words towards foods, which were adopted and selected from the database of Niedenthal et al. (2004). Niedenthal et al. (2004) developed a French emotion word database containing 237 words denoting emotional states, and these words were translated from Italian words developed by Zammuner (1998). Rousset et al. (2005) showed differences in emotions between the low and high meat-eating women: low meat-eating women felt more disappointment, indifference, and less satisfaction towards meat. Overall, low meat consumption was associated with specific negative emotions regarding meat and other foods (Rousset et al., 2005). It is an interesting finding because Desmet and Schifferstein (2008) concluded that positive emotions were reported more frequently than negative emotion terms in food products, because food products are designed to be satisfying, in other words, consumers chose food products because they want to consume (called "hedonic asymmetry") (Desmet and Schiffersten, 2008). Desmet and Schiffersten (2008) established a framework of product experiences including all emotions involved in every human-product interactions. Thomson (2008) reported 197 positive and 310 negative emotion terms using best-worst scaling on conceptual profiling of unbranded dark chocolates (Thomson, 2008). EsSense Profile™ methodology was presented in 2008 and published in 2010 by King and Meiselman. This methodology measures short and relatively intense emotional responses about consumer products by incorporating consumer overall acceptability scores and emotion measures (39 emotion attributes) during the consumer test questionnaire. They first used the existing emotion terms (81 emotion terms) from a previously developed list (POMS; Mcnair, 1971). They asked consumers to select emotional terms that described their most favorite and least favorite meal and/or food products. Based on the results, 39 emotional terms were selected by following criteria: 1. frequency of usage (>20% usage), 2. Clear bipolarity (positive or negative), 3. Suitability/applicable of term to food consumption (King and Meiselman, 2010). In Essence Profile, Consumers were asked to evaluate these 39 emotion terms on a constructed emotion questionnaire using a 5-point intensity scale from 1=not at all, and 5 = extremely.

Other than the methodologies mentioned above, indirect tools to measure emotions are available. Emotions involve a set of interacting components such as behavioral reactions (action tendency), expressive reactions (facial expressions), physiological reactions (pulse rate and blood pressure) and subjective feelings (Rousset et al., 2009). Ekman (1994) also mentioned that each emotion comes with particular pattern of expression, such as anger comes with a fixed stare, contracted eyebrows, compressed lips, vigorous and brisk movements, and a raised voice (Ekman and Friesen, 1975). Measuring facial expression approach is also available, and it is called the Facial Action Coding System (FACS: Ekman and Friesen, 1978). In FACS, the measurements were made based on the anatomy of facial movement: each distinguishable visible action of facial muscles was assigned to a single action unit (AU), and the most intense facial expression of the first facial reaction after food consumption was measured, and then again after swallowing (Ekman and Friesen, 1978). PrEmo™ is also a non-verbal, self-administered instrument to measure emotions (Desmet, 2006). Participants evaluated a picture on the computer screen, and were instructed to use a 3-point scale: I do feel the emotion, To some extent, I feel the emotion, or I do not feel the emotion expressed by this animation. During the test, respondents were first seen from picture of a product, and subsequently instructed to use the animations to report their emotions evoked by the product, and 12 basic emotions (6 positive and 6 negative) choices were given (Desmet, 2006).

The use of electrodermal activity (EDA) was proposed by Kreibig (2010), to measure electrodermal responses to emotions. Historically, electrodermal responses showed higher in response to unpleasant and/or unpleasant stimulations compared to neutral stimulations;

therefore Kreibig (2010) proposed to measure the resistance of the skin (1/conduciveness) as well as a measure of quantity of the sweat secreted by sweat gland located in the hypodermis of the palmar and plantar regions. The advantage of using non-verbal measurement of emotion is that they are language-independent, meaning they are applicable to different cultures and less subjective compared to self-reporting measurement (Desmet, 2003). Disadvantages are mainly due to the measuring instruments with current technology: current instrument cannot measure complicated/mixed emotions, and only reliably evaluate "basic" emotions such as anger, fear and surprise (Desmet, 2003).

Measuring emotion is not an absolute solution to solve the problem with current consumer tests: products with similar and higher hedonic scores in consumer acceptance tests failed in the market. However, information from emotion measuring can further differentiate one product from the other; therefore it could assist product developers in food industry.

1.3.2. Conjoint Analysis

Conjoint analysis has been used in marketing for years to measure the factors that influence consumer choice. The original word "conjoint" came from marketers that this analysis allows respondents to evaluate features of products or services "<u>CON</u>sidered <u>JOINT</u>ly" (Orme, 2006). According to Green and Srinivasan (1978), conjoint analysis is "any technique that estimates consumer preference by evaluating all possible products defined by varying levels of product attributes." As it is stated, the goal of conjoint analysis is to understand the attributes that drive consumer choice or purchase behavior. In other words, it examines trade-offs that consumer make at the time of purchase (Orme, 2006;

Childs and Drake, 2009; Melo et al., 2010). It has been one of the most extensively used quantitative methods in market research (Orme, 2006; Melo et al., 2010). Conjoint analysis first measures the consumer overall judgements about a set of complex alternatives, the decomposed levels are evaluated that were originally evaluated as part of a concept (attributes) (Green and Wind, 1975). By separating overall concept into small components, conjoint analysis provides valuable information (utility value) about the relative importance of attributes of a product. There are three main types under conjoint analysis based on how participants make choices when taking the survey: traditional full profile conjoint analysis (conjoint value analysis: CVA), choice based conjoint (CBC) and adaptive conjoint analysis (ACA). A fourth approach, use of Adaptive choice based conjoint (ACBC) was proposed.

The traditional full profile conjoint analysis was the first method developed, and involved a carefully constructed deck of conjoint cards based on an orthogonal design plan. Respondents used paper ballot to fill out their answers, and they were asked to sort conjoint cards in order from best to worst (Orme, 2006). This method had a major limitation: a large number of attributes and number of levels cannot be constructed. Full profile conjoint analysis was recommended to include less than six attributes in order to minimize fatigue (Orme, 2006). Later, researchers found that rating rather than ranking followed by ordinary least squares regression analysis, would give better discriminating power. In the 1980s and the spread of computer usage, it became possible to add more attributes and more levels in conjoint analysis (Orme, 2006). Adaptive conjoint analysis (ACA) was developed to improve the limitation from full-profile conjoint analysis. It allowed for more attributes to be measured by using a two step approach: 1. Respondents rank the levels within each attributes,

2. Then respondents give importance values to each attribute (Orme, 2006). Therefore ACA customizes the conjoint questionnaire for each consumer based on their previous responses to decide which question to ask (Orme, 2006). However, the main disadvantage of ACA is that ACA cannot measure attribute interactions. Choice based conjoint analysis (CBC) became popular in the 1990s, and is currently a widely used method (Orme, 2006). In CBC, respondents are presented with different product concepts, reflecting how consumers actually make decisions on product purchase and are asked to choose the concept that is the most appealing (Orme, 2010). Each choice task includes a "none of these" option to reflect the natural process of making purchase decision (Orme, 2010). The main advantage of CBC over ACA is that CBC allows measuring the interactions between all attributes (Orme, 2010).

Besides the three types of CBC mentioned earlier, adaptive choice-based conjoint (ACBC) analysis has been suggested recently. As the name suggests, ACBC is adapted from CBC to strengthen the weakness of CBC. It was reported that respondents do choice tasks very quickly (12-15 sec per choice task), meaning that respondents may simplify their thinking procedures for making choices, not typical behavior as if buying a real product (Johnson and Orme, 2007). Adaptive CBC survey is more engaging than conventional CBC to improve utility estimation, and to better predict real-world preferences (Cunningham et al., 2010). ACBC require fewer participants and fewer questions, as the survey itself adapts the choice task based on previous responses (Cunningham et al., 2010). In ACBC, consumers were asked to build their own product based on their criteria (Build your own tasks) that they use to choose products. Then, consumers were asked to select must-have and unacceptable attributes to further tailor the survey to their own interest. Finally, a series of choice tournaments were presented to consumers including at least one level from each attribute (Cunningham et al., 2010). In fact, Chapman et al. (2009) reported that the median time respondents took to finish the survey was much longer in ACBC than what it took in CBC, indicating that respondents pay more attention to the ACBC survey than CBC. Also, the respondents found the ACBC survey to be less boring in comparison to the CBC survey (Chapman et al., 2009).

Murphy et al. (2000) conducted full-profile conjoint analysis on Irish consumer preferences for honey using 153 Irish consumers. They selected 5 attributes based on results from a focus group: texture (2 levels: thick and runny), color (2 levels: dark golden and light golden), source (2 levels: mass produced and made by a small producer), price (IR₤1.95, IR₤2.15 and IR₤2.45) and packaging (227g shaped glass jar and 454 g plain glass jar). They concluded that the ideal honey for Irish consumers was a product with a thick texture, a dark golden color, made by a small-scale produce, at a price of IR₤1.95 and packaged in a 454g plain glass jar (Murphy et al., 2000). Jones et al. (2008) applied ACA conjoint analysis specifically for that reason (questionnaire customization) to determine consumer perception and preference about health benefits, and product claims associated with whey and soy proteins in meal replacement bars in US and New Zealand. They chose 4 attributes including protein source (whey, soy, and combination of soy and whey), amount of protein (high level (30g), moderate level (15g), and low level (3g)), health claim, (regulates appetite, enhances immune defenses, decreases chances of heart disease, helps to develop and maintain healthy bones, and helps to develop muscles), and product claim (fat free, cholesterol free, lactose free and contains calcium). They found that New Zealand consumers showed higher preference for whey protein as their choice of protein source, while US consumers did not have a strong preference for their choice of protein sources (Jones et al., 2008). Later, Childs et al. (2008) used ACA to assess the consumer perception of protein content, protein type, and product claims for meal replacement products in the US to further investigate the findings from Jones et al. (2008). They included 10 attributes for their study. They concluded that consumers valued products with low fat/fat free, calcium, all natural, protein, vitamin/mineral, heart health, and muscle building claims, regardless of their exercise habits.

Childs and Drake (2009) used CBC to determine the consumer perception of fat reduction in cheese. They selected 4 attributes from focus groups, including fat content, flavor, texture and price of cheese, and confirmatory consumer acceptance tests (n=101) were also conducted on Cheddar and Mozzarella cheeses with different fat levels. They found that 2% milk fat Cheddar cheese was the most appealing among fat reduction in Cheddar cheese, and a part-skim Mozzarella was the most appealing in Mozzarella cheeses. Deliza et al. (2010) also used CBC to evaluate the influence of product appearance, price and information about the use of irradiation on consumer choice of papaya. It was unique because they actually used real fruit, and data collection was made by consumer intercepts with a sampling of 169 consumers from the market (Deliza et al., 2010). They found that Brazilian consumers did not reject papaya due to information about irradiation (Deliza et al., 2010). Melo et al. (2010) investigated attitudes and acceptance between diabetics and non-diabetics on sugar and calorie reduction of milk chocolate. They used CBC to determine which levels of sugar reduction, sweetener type and calorie reduction in milk chocolate were the most important and most appealing to diabetic and non-diabetic consumers. They proceeded with consumer acceptance tests based on the findings from CBC to confirm that actual products matched consumer expectations. Melo et al. (2010) reported that the sugar claim attribute was more important to diabetics than to nondiabetics, and within sugar claim, reduced sugar and sugar-free levels were more important to diabetics ($p<0.05$), and no differences were found between two groups for sweetener type and calorie reduction ($p>0.05$). Jervis et al. (2012) conducted a CBC analysis on latte-style coffee beverages with 721 consumers, with 5 attributes: location, lightener type, fat content, sweetener, and additional flavor. They determined that the most important attributes in determining latte beverage purchase intent were location and milk type. Later, Jervis et al. (2012) conducted a study to compare ACBC to CBC to determine the driving attributes for purchase intent of sour cream. They conducted CBC and an ACBC with a three month delay between the surveys. Seven-hundred and seventy seven responses were collected for CBC, and 250 responses were collected for ACBC and the data were analyzed for overall utility scores, importance values, and cluster analysis. They concluded that ACBC and CBC results were in agreement. Fat content was the most important attribute followed by price. They reported that CBC results using only 250 respondents overestimated the importance of brand compared to CBC with 777 responses and ACBC with 250 respondents. Also, they concluded that ACBC could be a better estimating tool for consumer perception of sour cream brand than CBC (Jervis et al., in press). Conjoint analysis is advancing to improve the strength and estimating power of analyses. No method is claimed to be a “golden standard” on conjoint analysis, because each has its own strength and weakness. To maximize the power of differentiating attributes, many factors need to be considered when designing conjoint analysis.

1.3.3. Kano analysis

Kano and others (1984) suggested that the attributes driving acceptance were not necessarily associated with consumer satisfaction. They concluded that the relationship between the fulfillment of a need and satisfaction/dissatisfaction of a product were not linear, and proposed a model to establish the importance of product attributes in terms of consumer satisfaction. There were four categories of this model: must-have, one-dimensional, attractive, and indifferent (Berger et al., 1993; Xu et al., 2008; Ullah and Tamaki, 2011). Must-be attributes are the ones that lead to consumer extreme dissatisfaction if absent, however these attributes does not increase the satisfaction if met. This attribute can be further diagnosed by customer complaint report, internet quality process measures, lost customer surveys, and win/loss reports (Stroud, 2012). For example, punctuality of a train: when average punctuality exceeds a certain level, there is no increase in customer satisfaction, however extreme customer dissatisfaction occurs if punctuality does not occur (Matzler and Hinterhuber, 1998). Having good brakes in an automobile do not increase customer satisfaction, however having poor brakes cause great customer dissatisfaction (Berger et al., 1993). Punctuality of a train and good brakes in an automobile are considered Must-have attributes. One-dimensional attributes are the ones that show linear increment of customer satisfaction with fulfillment of them. One dimensional attributes are particularly of interest, because these attributes are considered drivers of consumer satisfaction. Typically, requirements for one-dimensional attributes are not hard to find, as customers are explicitly demanding these requirements (Sauerwein et al., 1996). Gas mileage of a car is a good example: the better it is, the more satisfied the customer is (Matzler and Hinterhuber, 1998).

The price that customers are willing to pay more for a product and/or service is closely tied to one-dimensional attributes; therefore further analysis such as customer satisfaction surveys, perceptual surveys, transaction reports and focus groups can identify and confirm the one-dimensional attributes (Stroud, 2012).

Attractive attributes are the unexpected attributes but can lead to greater satisfaction if present; therefore they are also called “exciters” as they surprise consumers unexpectedly. Matzler and Hinterhuber (1998) mentioned that an airline that offers an in-flight telephone service may provide a great satisfaction to people who travel for their business by giving them an opportunity to communicate with their respective customers and/or home office. However, absence of the telephone service will not necessarily result in customer dissatisfaction because it was not expected. In this case telephone service is considered an attractive attribute. This attribute has the greatest influence on how satisfied a customer could be with a given product (Matzler and Hinterhuber, 1998). However, it is not very easy to find, because attractive attributes are neither explicitly expressed nor expected by the customer (Matzler and Hinterhuber, 1998). To capture the attractive attributes in a product, focus groups, customer loyalty programs, advisory groups, “Leading Edge” forums, and similar programs can assist (Stround, 2012). Indifferent attributes are those that do not influence consumer expectation of products. Ullah and Tamaki (2011) suggested that it is important to keep must-be attributes, add a good number of one-dimensional and attractive attributes, and avoid indifferent attributes for successful and meaningful integration of the voice of the consumer to the product development process. The relationship of these four attributes and customer satisfaction and dissatisfaction is graphically illustrated in Figure 1-3.

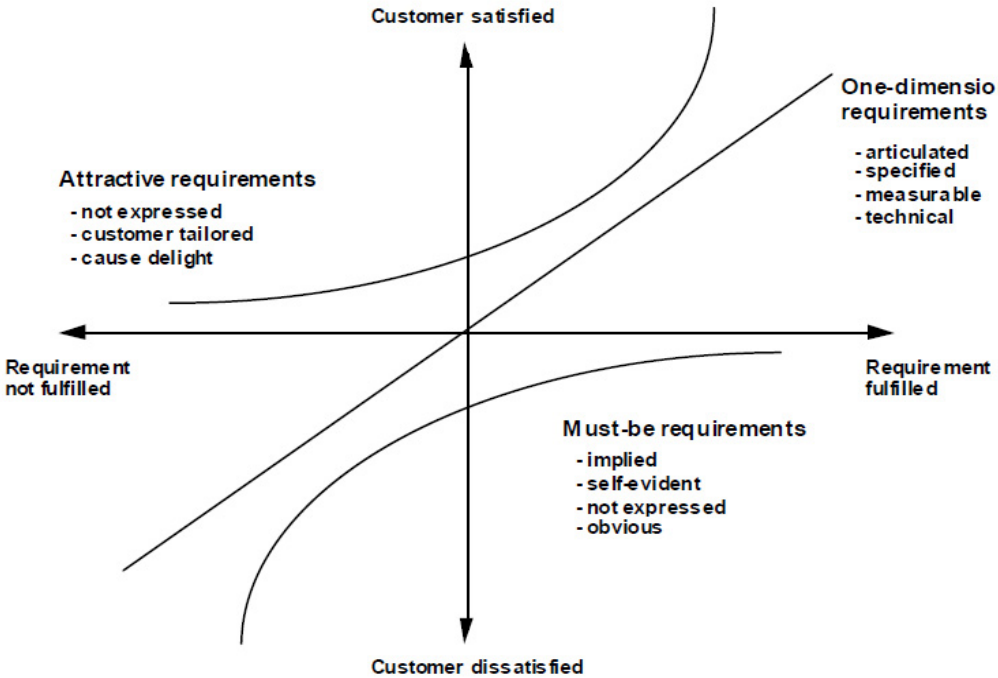

Figure 1-3 Kano's Model of Customer Satisfaction (Berger et al., 1993; Sauerwein et al., 1996)

Kano analysis can be done by consumer surveys with a carefully designed questionnaire. Constructing Kano analysis questionnaires typically starts from identification of customer problems and expectations. By asking customers about their product expectations, hidden needs and problems can be identified, which can lead to instructive information in the product development process (Sauerwein et al., 1996). Once the voice of customers is fully heard, product developers need to identify the expectations and desires which have not been fulfilled by the current product range. Identified features from this process are the basis for the Kano questionnaire. For each product feature, a pair of questions is generated: a functional and a dysfunctional form of the question, and customers need to answer both the functional and the dysfunctional question. An example of such questions and possible answer options are found in Figure 1-4.

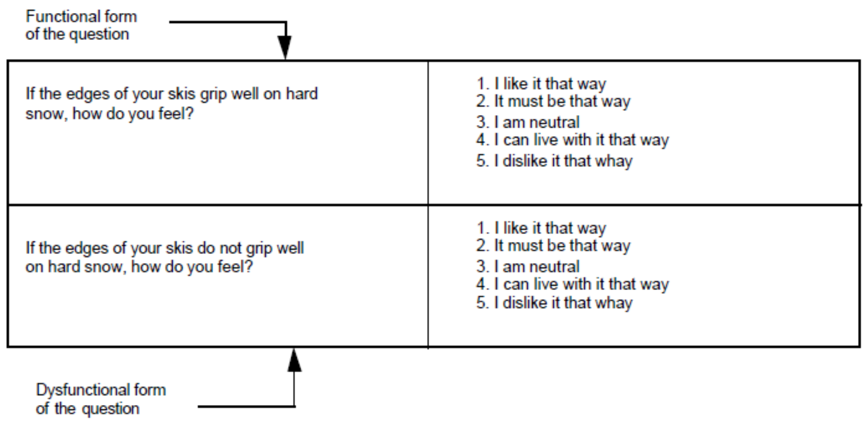

Figure 1-4 Functional and Dysfunctional Question in the Kano Questionnaire (Sauerwein et al., 1996)

A Kano evaluation table can explain further how to categorize the attributes based on responses (Figure 5). If a person who answered one attribute "like it" on functional question, and "dislike it" on dysfunctional question, this particular attribute is considered as a "one-dimensional" attribute for this particular individual. For each attribute, an individual Kano evaluation table is generated for each participant. Then tabulation of responses are made as following (Table 1). The Kano classification for each feature (category column in Table 1) is made according to frequencies: corresponding classification of most frequently found number on each feature (each row in Table 1) is the Kano classification for the feature.

Customer requirements → ↓		Dysfunctional (negative) question				
		1. like	2. must be	3. neutral	4. live with	5. dislike
Functional (positive) question	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Customer requirement is ...

A: Attractive
M: Must-be
R: Reverse

O: One-dimensional
Q: Questionable
I: Indifferent

Figure 1- 5 Kano Evaluation Table for Kano Classification (Sauerwein et al., 1996)

Table 1-1 Tabulation of Responses for Each Customer Requirement in a Kano Questionnaire for Kano Classification (Sauerwein et al., 1996)

Product requirement	A	O	M	I	R	Q	Total	Category
Edge grip	7	32.3	**49.3**	9.5	0.3	1.5	100%	M
Ease of turn	10.4	**45.1**	30.5	11.5	1.2	1.2	100%	O
Service	**63.8**	21.6	2.9.	8.5	0.7	2.5	100%	A

Browning (2003) emphasized that adding one activity that contributes to consumer satisfaction is more value-added than removing one non-contributing activity (attribute) and/or changing the focus of a product. In order to find one activity (attribute) that contributes to consumer satisfaction, identifying the hidden customer needs is important (Browning, 2003). Ullah and Tamaki (2011) suggested Kano analysis as a solution for identifying hidden customer needs. By identifying the attributes that are strongly associated with consumer satisfaction, product developers as well as food marketers can incorporate this information more efficiently. In addition, Kano analysis can provide valuable guidance in trade-off situations in the product development process (Colkin et al., 2004; Chen and Chuang, 2008).

1.4. Summary

Measuring emotion, conjoint analysis and Kano analysis are new techniques that are now adopted for use in food science/food marketing fields. Measuring emotions can assist product developers to further differentiate products with similar consumer liking scores. Kano analysis measures product features that contribute to customer satisfaction and dissatisfaction. Conjoint analysis finds attributes that are most important to consumers when making purchase decisions. Kano and conjoint analysis results should be in agreement, as satisfied customers have a higher chance to re-purchase the product. Combining Kano analysis and conjoint analysis can provide powerful information to understand features that consumers care about the most for their purchase intent as well as satisfaction of the product.

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CHAPTER 2

EVALUATION OF KEY FLAVOR COMPOUNDS IN REDUCED AND FULL FAT CHEDDAR CHEESE USING SENSORY STUDIES ON MODEL SYSTEMS

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2.1. Abstract

Recent flavor chemistry studies have identified flavor compounds at different concentrations in full and low fat Cheddar cheeses. The specific flavor contributions of these compounds in full and low fat cheese matrices have not been established. The purpose of this study was to evaluate the sensory response of Cheddar flavor compounds in model full fat and 75% reduced fat cheeses. Odor activity values (OAVs) for each compound in full and reduced fat cheese were calculated. Each compound was then added to model cheeses created from 3-week old full and reduced fat Cheddar cheese. A trained sensory panel (n=8) evaluated the sensory properties of the cheese models. The final combination of compounds was incorporated into reduced fat cheese models and consumers (n=85) evaluated perceived aged Cheddar cheese aroma. Based on OAVs and perception of the individual compounds in cheese models, 12 key flavor compounds were identified. Target ideal concentrations of specific cheese flavor compounds in 75% reduced fat cheese were determined. Perceived aged Cheddar cheese aroma intensity of reduced fat model cheese with these added compounds was not different ($p>0.05$) by consumers from the perceived Cheddar cheese aroma intensity of commercial aged full fat Cheddar cheeses.

Key words: reduced fat cheese, threshold, model systems

2.2. Practical Application

The market for reduced fat Cheddar cheese is increasing as consumers become more health conscious. The structure and biochemistry of reduced fat Cheddar cheeses are altered and flavor and texture remain a challenge. This study established the role of 23 volatile compounds using descriptive analysis of cheese model systems. The impact of key compound concentration differences and how these differences affect sensory perception of cheese flavor in full and 75% reduced fat Cheddar cheese were determined. These results provide guidance for mimicking aged Cheddar cheese flavor in reduced fat cheeses.

2.3. Introduction

Consumer awareness of the health benefits of reducing dietary fat consumption has been increasing steadily. Interest towards lowering the fat content in cheese has concurrently increased due to its high fat content. Reduced fat cheese is defined as having at least a 25% fat reduction from the full fat counterpart, and low fat cheese is defined as having 3 g of fat or less per reference amount (21 CFR [101.62b]) which equates to an 83% fat reduction in Cheddar cheese. The main challenge for fat reduction in cheese is the flavor and texture profile (Childs and Drake 2009; Drake and Swanson 1995; Mistry 2001; Yates and Drake 2007). Studies have suggested that consumers would change their cheese consumption patterns to reduced fat cheese only if fat-reduced cheeses are similar in flavor and texture to full fat cheese (Childs and Drake 2009). Previous studies have demonstrated that a variety of make-procedure modifications, additives or starter/adjunct cultures and enzyme additions can be applied with moderate success for fat reductions up to 50% (Anderson et al. 1993; Agrawal and Hassan 2007; Dabour et al. 2006; Drake et al. 1994; Drake et al. 1996; Mistry 2001; Nelson and Barbano 2004). One of the common strategies for manufacture of reduced-fat cheese is increasing the moisture content to partially replace fat and for texture improvement (Drake and Swanson 1995; Mistry 2001). By decreasing fat and increasing moisture, the cheese matrix is changed from a largely non-polar matrix (full fat cheese) to a more polar matrix (low fat cheese); thus the texture and the flavor release pattern of fat-reduced cheeses are altered (Drake and Swanson 1995; Drake et al. 2010; Rogers et al. 2009). Drake et al. (2010) recently demonstrated that in addition to altered texture and flavor release, the biochemistry and actual volatile compound profile was also altered in fat-reduced cheeses compared to their full fat counterparts.

Release of flavor compounds is a key parameter of perceived flavor in food. Upon ingestion of food, it undergoes a phase change from a semi-solid to a liquid by temperature increase in the mouth and dissolution with saliva (Relkin et al. 2004). During the physicochemical phase change, flavor compounds are released, and the rate is dependent on the partition coefficient of volatile flavor-contributing compounds (Haahr et al. 2000; Meynier et al. 2003). Partition coefficient is defined as the ratio of the concentration of each aroma compound in the gaseous phase (ng/ml) to its concentration in the liquid phase (ng/ml) (Meynier et al. 2003) and it describes the potential extent of the release of the compound (Haahr et al. 2000). For instance, the presence of lipid in the food matrix can influence the partition coefficient of a flavor compound (Haahr et al. 2000; Meynier et al. 2003; Leksrisompong et al. 2010). Most flavor compounds are non-polar, thus fat is a flavor carrier of these hydrophobic compounds (Relkin et al. 2004). Leksrisompong et al. (2010) recently demonstrated the role of fat on partition coefficients of three flavor-contributing compounds in cheese: diacetyl, furaneol, and δ-decalactone. For example, diacetyl is a moderately hydrophilic flavor compound, whereas δ-decalactone is more hydrophobic. The performance of each compound in different matrices (oil, water and an emulsion) was different. Thus, with a fat reduction of 50% or more in cheese it seems logical to expect that partition coefficients of volatile compounds may be altered which will impact sensory thresholds and flavor perception.

Previous work with flavor of reduced fat cheeses suffered from several shortcomings including: lack of evaluation of fat reductions greater than 50%, lack of appropriate sensory analysis, lack of thorough flavor chemistry approaches and/or lack of replicated controlled experimental treatments. Instrumental volatile analysis alone is not necessarily indicative of flavor compound roles in sensory perception due to interactions in the food matrix and with other compounds. Studies have demonstrated that cheese biochemistry is also altered with fat reduction. Milo and Reineccius (1997) first suggested that fat reduction in cheese resulted in an imbalance of flavor-contributing compounds. They studied two cheeses purchased at a local store from potentially different manufacturers, so differences noted could not be directly associated with fat reduction. More recently, Drake et al. (2010) evaluated full fat, 50% reduced fat and 83% reduced fat cheeses manufactured from the same milk source and make-procedure and confirmed that cheese ripening biochemistry and volatile compound profiles were altered. Cheeses with 83% fat reduction had different concentrations of aroma-active compounds compared to full fat Cheddar cheese. These results demonstrated that fat reduction in Cheddar cheese, particularly greater than 50%, resulted in changes in flavor that were not solely due to changes in the cheese matrix and volatile compound release, but also due to distinct changes in cheese biochemistry.

To our knowledge, the impact of key compound concentration differences and how these differences affect sensory perception of cheese flavor in reduced fat Cheddar cheese has not been determined. The objective of the study was to characterize the specific role of key aroma-active compounds from full fat and 75% reduced fat Cheddar cheese by the application of threshold testing in oil, water, and pH 5.5 buffer and by descriptive sensory analysis of model cheeses. Finally, consumers evaluated similarity of model cheese aromas to natural reduced and low fat Cheddar cheeses and full fat Cheddar cheeses.

2.4. Materials and Methods

2.4.1. Selected odor-active compounds

Twenty-one volatile compounds were selected based on previous flavor chemistry studies of Cheddar cheeses. These selected compounds included high aroma impact compounds as well as aroma-active compounds with concentration differences between low fat and full fat cheeses (Avsar et al. 2004; Christensen and Reineccius 1995; Milo and Reineccius 1997; Whetstine et al. 2006b; Drake et al. 2010). All chemicals were obtained from Sigma-Aldrich chemical company (St. Louis MO).

2.4.2. Orthonasal threshold analysis

Sensory analysis was conducted in compliance with North Carolina State University Institutional Review Board (NCSU-IRB) for human subject regulations. A modification of the ASTM procedure E679-9 (ASTM 1992), an ascending forced choice method of limits, was used to determine orthonasal threshold values for each compound. Three separate media were tested: deodorized water, pH 5.5 buffer, and vegetable oil. Deodorized water was prepared by taking deionized water and boiling to 2/3 of the original volume. The buffer was prepared according to Whetstine et al. (2005): 250 ml of 0.2M Tris acid maleate (24.2 g of Tris and 23.2 g of maleic acid/L) and 66 ml of 0.2N NaOH (Sigma-Aldrich) were made up to 1 L in deodorized water. Vegetable oil (100% soybean oil) was purchased from a local grocery store. These three matrices were selected to compare the impact of a polar matrix, a non-polar matrix and cheese pH (buffer) on sensory threshold of each compound.

Stock solutions of key compounds were prepared in 95% ethanol (Luxco, Inc. St. Louis, MO). Aliquots of these stock solutions were placed into each media (water, pH 5.5 buffer and oil). The orthonasal detection thresholds of each of these compounds were evaluated individually in each of three different matrices. These solutions were serially diluted (factor of 3), and 15 ml of each was poured into clean, labeled 56 mL plastic cups (Solo cup company, Lake Forest, Il). Seven ascending series were tested. Series were presented in ascending concentration, and each series was presented in a randomized order. For each series, the blank samples of the appropriate matrix were prepared with the same amount of 95% ethanol. The samples for each threshold test were prepared 3 h before the test to achieve equilibrium for each compound in the cup (Leksrisompong et al. 2010).

Subjects (n=29) were instructed prior to testing. Subjects were instructed to sniff the solution in each cup in the series. Subjects were asked to choose the different sample from the three and to give a certainty judgment (sure/not sure). The individual best estimate threshold (BET) was taken as the geometric mean of the last concentration with an incorrect response and the first concentration with a correct response except for the following sequence: if the subject indicated a "not sure" response for the correct choice, that concentration was increased by a factor of 1.41, to adjust for the possibility of a chance correct response (Lawless et al. 2000). The estimated group BET was taken as the geometric mean of the individual BET values. Orthonasal threshold tests were conducted in duplicate on different days for each compound in each different matrix.

2.4.3. Odor Activity Value calculation

The odor activity value (OAV) is the ratio of compound concentration in the food matrix to the sensory odor threshold for a particular compound (Nursten and Reineccius 1996). Since both concentrations found in the food matrix and sensory threshold are considered for calculation of OAVs, OAV may provide a more accurate indication of aroma/flavor contributions of volatile compounds in a food matrix (Milo and Reineccius 1997; Karagul-Yuceer et al. 2004; Qian and Reineccius 2003). OAVs were calculated for each compound in each matrix (water, pH 5.5 buffer, and oil), in full fat and 75 % reduced fat cheese using the compound concentrations reported by Drake et al. (2010) and the BET values generated from this study.

2.4.4. Descriptive Analysis of Cheese Models

Commercial full fat or 75 % reduced fat Cheddar cheeses (<1 mo) were purchased as 22 kg blocks from the same supplier. Upon arrival, base cheeses were screened by three experts, who each had more than 1000 h of experience in sensory analysis of cheese flavor to confirm the absence of strong or atypical flavors. These cheeses were then used as the base for model full fat or reduced fat cheeses. Cheese was stored at 3˚C to prevent any further ripening and used within 6 weeks of receipt. Cheese models were prepared using the method described by Whetstine et al. (2005). Briefly, the cheese was grated and portioned to 100 g, and placed into commercial vacuum-seal bags (Food Saver; San Francisco, CA; 8” x 8”; 5 layers of polyethylene and nylon). Chemicals were introduced by a clean, disposable micropipette. Stock solutions of each chemical were prepared in 95% ethanol. Not more than 1 ml of the compound of interest was added to 100 g of grated cheese, to ensure that ethanol aroma did not interfere with aroma or flavor perception. After addition of the compound of interest, the cheese in the bag was kneaded 30 times to make sure the compound(s) were evenly distributed throughout the cheese matrix. Control or “blank” cheese models were prepared using the same method, including volume of liquid addition, but without the added volatile compound. Then the cheese was formed into logs by pressing the cheese to the bottom of the vacuum-seal bag, and the bags were vacuum-sealed. Vacuum-sealed cheese logs were stored at 4˚C for 24 h to allow for equilibration. Cheese models were then evaluated by descriptive sensory analysis. For cheese model system evaluation, each compound was evaluated in each cheese matrix (full fat and reduced fat) at the concentration range reported in that matrix (Table 4). Subsequently, compound concentrations from full fat cheese were evaluated in reduced fat cheese models to further clarify the role of decreasing fat on flavor perception.

Descriptive sensory analysis was conducted in duplicate on model cheeses by eight panelists (7 females, 1 male, ages 23-48 y). Panelists each had greater than 200 h of experience with the evaluation of cheese flavor using the Spectrum™ method (Meilgaard et al. 1999) and the established Cheddar cheese flavor language developed by Drake et al. (2001, 2010). Model cheeses were presented in 2.5 x 2.5 cm cubes in 56 ml soufflé cups with lids, coded with 3- digit random codes. All samples were lidded and tempered at room temperature for 1 h prior to sensory evaluation. Panelists first evaluated the aroma of the headspace and then placed the sample in their mouths. During evaluation, panelists had free access to spring water and unsalted crackers. Panelists expectorated samples following evaluation. Each sample was evaluated in duplicate by each panelist using paper ballots or Compusense Five (Compusense, Guelph, Canada).

Once the role of individual compounds and their corresponding concentrations in the cheese model were determined, 12 compounds were selected, based on OAVs and sensory responses, to create an aged full fat Cheddar cheese-like flavor. All 12 compounds were added to full fat or reduced fat cheese models and adjustments were made empirically until a model with high similarity to aged full fat cheddar cheese was achieved. For example, if panelists noted that the cheese aroma and flavor was imbalanced due to high rosy/floral notes, the concentration of phenyl acetaldehyde was decreased and a new cheese model was presented to the sensory panel. Following the selection of the most similar model, a model subtraction study (N-1) was conducted to confirm that each of 12 compounds selected previously were crucial to mimic the aroma and flavor of aged full fat Cheddar cheese. Model subtraction was conducted by subtracting one compound at a time from the "optimum" flavor formulation using the 12 compounds previously selected (Karagul Yuceer et al. 2004; Whitson et al. 2010). Each full fat and reduced fat model was evaluated for its overall similarity to the reference cheese, where the reference was the corresponding cheese model with all 12 compounds added. Trained panelists scored model cheeses using a 10-point scale with 0 being not similar at all, and 10 being identical to reference. Followed by evaluation of overall similarity, descriptive flavor analysis of each model was conducted using the method described above. The full fat and reduced fat cheese models were evaluated in duplicate for overall similarity and descriptive analysis.

2.4.5. Consumer test

Based on descriptive analysis of model cheeses, a combination of twelve compounds in 75% reduced fat Cheddar cheese was deemed similar to aged full fat Cheddar cheese. In order to understand the consumer perception of the identified cheese model, a consumer acceptance test was conducted. Consumer acceptability and consumer perception of "aged Cheddar cheese aroma" of the 75% reduced fat cheese model with all 12 compounds were compared to those of 75 and 83% reduced fat Cheddar cheeses (3 wk old cheese with no compounds added, a low fat cheese aged 12 mo, and an experimental 83% reduced fat Cheddar cheese aged 9 mo) and full fat Cheddar cheeses. The aroma of cheeses (rather than flavor) was evaluated to prevent textural influence on consumer responses (Yang and Vickers 2004). Each cheese was hand-grated using a cheese grater and portioned (10 g) into

125 ml amber jars (Fisher Scientific, Pittsburgh, PA). The jars used for this study were previously washed with odor-free detergent, and dried in an oven (180˚C) for 2 h to remove any residual aromas. All samples were prepared the night before the test, and stored at 3˚C overnight to allow equilibration of aroma.

On the day of the test, sniff jars were tempered to 25˚C 2 h prior serving. For consistency of cheese aroma intensity, each sniff jar was served no more than 3 times, and had a minimum of 15 min between each presentation to consumers. Self-reported cheese consumers (n=85) were recruited from university faculty, staff and students. Compusense® Five (Compusense) was used for data collection, and panelists were compensated with snacks for their participation. Consumers first answered a brief questionnaire containing 8 demographic questions and were then presented with 8 sniff jars in a randomized balanced order of presentation. The consumers evaluated the samples for overall aroma intensity liking, aroma similarity to Cheddar cheese aroma, aged Cheddar cheese aroma intensity liking, and aged Cheddar cheese aroma similarity. Panelists used a 9-point category scale anchored on 1 being “dislike extremely” and 9 being “like extremely” for aroma liking. For aroma similarity, the scale was anchored with 1 being“not similar at all” and 9 being “Extremely similar”. A 3 min rest was enforced between presentation of each sniff jar and consumers were instructed to sniff their sleeves to clear their nasal passageways following presentation of each sniff jar.

2.4.6. Statistical analysis

For threshold BET values, the delta method was used for the pair-wise comparison for group BET values among different matrices, using the formula $Z= (BET_2 - BET_1) / (\sqrt{(SE_1^2 + SE_2^2)})$ (Leksrisompong et al. 2010). Descriptive sensory data were analyzed by analysis of variance (ANOVA) followed by Tukey's Honestly Significant Difference (HSD) post hoc test. For the consumer test, ANOVA followed by Tukey's HSD were used for aroma intensity and aroma similarity. All data analysis was performed in XLSTAT (Version 2010. 2.02; Addinsoft, Paris, France).

2.5. Results and Discussion

2.5.1. Orthonasal Thresholds

The BET values of the 23 key volatile compounds from Cheddar cheese were impacted by matrix (Table 1), and the values were within the range of previously published BETs (van Gemert, 2003; Leksrisompong et al., 2010). Hydrophobic compounds such as octanoic acid and decanoic acid, DMTS, gamma-octalactone, homofuraneol, 1-octene-3-one, skatole and aldehydes showed higher BET values in oil than in water and/or pH 5.5 buffer ($p<0.05$), suggesting that fat reduction would have a large impact on threshold and potentially flavor perception and release. Previous studies have also demonstrated that the aroma intensity and headspace concentration of hydrophobic compounds were more affected by the presence of fat than that of hydrophilic compounds (Leksrisompong et al., 2010; Roberts et al., 2003). Within aqueous diluents (water vs. pH 5.5 buffer), there were pH effects on thresholds for some acidic compounds (i.e. acetic, octanoic, decanoic and phenyl acetic acid) as well as for several other compounds (methional, DMTS, δ-decalactone, γ-octanolactone, sotolone, 1-octene-3-one, skatole, phenyl ethanol, and 2/3-methyl butanal). While statistically significant in some cases, pH 5.5 effects compared to water were small compared to water versus oil effects. Since the objectives of this study were focused on the role of fat in flavor, OAV values were compared using water and oil thresholds.

2.5.2. OAV

Instrumental analysis can provide useful information about concentrations of compounds present. However, it does not pinpoint the human sensory responses to specific compounds in the food matrix (Qian and Reineccius 2003). Similarly, BET values do not reflect concentrations in the food matrix. Therefore OAV is another process that can be applied to estimate the contributions of each volatile compound to flavor since both concentration in the food matrix and sensory threshold are taken into account. The OAV is not an absolute measurement but an indicator to determine important odorants in foods (Audouin et al. 2001). Clearly, OAVs are an estimate or indicator, since the threshold values from a model matrix are typically used in the calculation, and instrumental quantification values also have variability and shortcomings. In the case of full fat Cheddar cheese, an oil threshold may be more appropriate while in a low fat Cheddar cheese, a water matrix may be more appropriate. In this study, acetic, butyric, hexanoic, and octanoic acid, sulfur compounds (i.e. methional, DMTS and 2-acetyl thiazoline), sotolone, homofuraneol and δ-decalactone, diacetyl, phenyl acetaldehyde, and 3-methyl butanal and 2 methyl propanal were identified as high impact volatile compounds in full fat and low fat Cheddar cheeses after 9 mo aging (Tables 2 and 3). 1-octene-3-one was exclusive to low fat Cheddar cheese (>9 mo), and 2-acetyl thiazoline was exclusive to full fat Cheddar cheese (>9 mo). Homofuraneol and phenyl acetaldehyde were identified as high impact compounds in both full fat and low fat Cheddar cheese, but they had higher impact (higher OAV) in low fat Cheddar cheese compared to full fat cheese. Milo and Reineccius (1997) also reported that homofuraneol, furaneol, butyric acid and methional had higher OAV and greater impact on reduced fat cheese flavor than full fat cheese. Similarly, Drake et al. (2010) attributed the atypical burnt/brothy flavor present in lower fat Cheddar cheese to higher concentrations and lower sensory thresholds of homofuraneol in low fat Cheddar cheese compared to full fat Cheddar cheese. Sensory thresholds for many compounds are impacted by decreased fat (compare oil to water BET values) and concentrations of many key compounds are also distinct between full fat and fat reduced cheeses (Milo and Reineccius 1997; Drake et al. 2010). The combination of these changes results in distinct OAV values for specific compounds for full fat cheese compared to low fat cheese. Once again, these values are suggestive and should be confirmed by model addition studies which were the next series of experiments.

2.5.3. Descriptive analysis of model cheeses

There were three parts to the sensory analysis of model cheeses. First, each compound was added individually to young, mild cheese (<3 wk old), free of age-related flavors in order to examine the specific sensory impact of the previously identified compounds at their relative concentrations in cheeses. This process was conducted for reduced fat and full fat cheeses. The second part of the study determined the optimum combinations of compounds that mimicked "aged-Cheddar cheese" flavor. Once the combination was identified, a compound omission study (n-1 subtraction) was conducted with the full and reduced fat cheese model to identify the volatile compounds with the highest impact on aged Cheddar cheese flavor.

Each compound was evaluated in each cheese matrix (full fat and reduced fat) across the concentration range previously reported in full and low fat Cheddar cheeses (Drake et al. 2010; Milo and Reineccius 1997; Cadwallader et al. 2006; Whetstine et al. 2006a). The sensory effects of each compound in cheese were consistent with previously published literature (Avsar et al. 2004; Christensen and Reineccius 1995; Drake et al. 2010; Milo and Reineccius 1997, McGorrin 2002; Whetstine et al. 2005, Whetstine et al. 2006a). Volatile compounds that were previously identified as potent odorants in each cheese matrix from flavor chemistry flavor dilution factors and OAVs were confirmed by individual compound addition to cheese models (Table 4).

Compounds generally elicited a sensory response when the compound was added to the cheese within the concentration range reported (Table 4). For full fat cheese, three exceptions were δ-decalactone, furaneol and 3-methyl butanal. In the case of δ-decalactone, the presence of milkfat and naturally present lactones – and lactone flavor -- may have prevented a specific response. For furaneol and 3-methyl butanal, these compounds may not play a direct role in cheese flavor. Milo and Reineccius (1997) indicated that furaneol did not play a role in aged Cheddar flavor, although model addition studies were not conducted.

3- methyl butanal had a very low odor activity value in the full fat matrix (Table 2) which suggests it does not play a large or direct role (if any) on flavor.

Whetstine et al. (2005) reported that phenyl acetic acid and phenyl acetaldehyde were found at higher concentrations in Cheddar cheeses with rosy/metallic off-flavor. Similarly, sensory panelists confirmed rosy and brothy flavors and aftertastes in model cheeses with added phenylacetaldehyde or phenyl acetic acid. Phenyl acetaldehyde played a much larger role in eliciting rosy flavor and aftertaste in cheese than phenyl acetic acid, which is also consistent from results reported by Whetstine et al. (2005). Avsar et al. (2004) and Whetstine et al. (2006) reported that the addition of Strecker aldehydes such as 2/3 methyl butanal, and 2 methyl propanal to aged Cheddar cheeses (>1 yr) caused nutty flavors. When these individual compounds were added to young cheese models, as expected "malty/nutty" flavor and aroma were reported in full fat and low fat cheese models.

Sulfur compounds have traditionally been associated with the age-related flavors in Cheddar cheeses (Drake et al. 2001; Avsar et al. 2004; Burbank and Qian 2008; Drake et al. 2010). Qian and Burbank (2007) showed the linear relationship of increased volatile sulfur compounds with cheese aging by instrumental analysis. Drake et al. (2010) reported decreased sulfur flavor in low fat Cheddar cheeses compare to full fat cheeses after 9 mo ripening as did Milo and Reineccius (1997). In the current study, panelists also noted lower sulfur flavor in 75% reduced fat Cheddar cheese models compared to sulfur flavor in full fat Cheddar cheese models (Figure 1 and 2). Cheeses with added sulfur compounds such as DMTS, methional and 2-acetyl thiazoline were strongly associated with sulfur and brothy attributes. Methanethiol had been reported as one of the key sulfur compounds found in cheese (Dacremont and Vickers 1994; Christensen and Reineccius 1995; Dimos et al. 1996; Milo and Reineccius 1997; Singh et al. 2003; Burbank and Qian 2008; Drake et al. 2010). Methanethiol was initially incorporated in this study (results not shown) and the presence of this compound in addition to other compounds (parts 2 and 3 of descriptive analysis) increased the perception of cheese-like flavor in the full fat and low fat model systems, as reported previously (Dimos et al. 1996; Singh et al. 2003). However, Chin and Lindsay (1994) previously reported the possibility of oxidation of methanethiol to dimethyl disulfide and dimethyl trisulfide in addition to the high volatility of this compound and redundant flavor profile to other sulfur compounds. This compound was not included in the final formulation (Table 5). Methional was characterized as potato-like aroma and previously identified as a high aroma impact compound in Cheddar cheese (Dacremont and Vickers 1994; Christensen and Reineccius 1995; Milo and Reineccius 1997; Drake et al. 2001; Singh et al. 2003; Avsar et al. 2004; Cadwallader et al. 2006).

Furanone compounds (furaneol, homofuraneol and sotolone) were strongly associated with “burnt/brothy” flavor in both cheese models. Homofuraneol and furaneol have been identified as the compounds responsible for “brothy” and “burnt/brothy” flavor in low fat cheeses in the previous studies (Milo and Reineccius 1997; Cadwallader et al. 2006; Drake et al. 2010). In the present study, homofuraneol and furaneol had a higher OAV in low fat cheese compared to full fat cheese, in agreement with a previous study (Milo and Reineccius 1997). Acidic compounds such as acetic and butyric acids were strongly associated with free fatty acid or rancid flavor in both full and reduced fat Cheese models. Different aromas were associated with different free fatty acids, which is also consistent with previous studies

(Whetstine et al. 2003; Dacremont and Vickers 1994). Butyric acid was identified as a high impact compound in Cheddar cheese flavor in many previous studies due to its high OAV and high concentration in the cheese (Dacremont and Vickers 1994; Christensen and Reineccius 1995; Milo and Reineccius 1997; Avsar et al. 2004; Singh et al. 2003; Drake et al. 2010). In the present study, butyric acid was identified as a high impact compound in both low fat and full fat Cheddar cheese flavor, and the absence of this compound greatly reduced the similarity of cheese like flavor, indicating the importance of its role in Cheddar cheese flavor. Butyric acid has a distinct cheesy aroma character. Dacremont and Vickers (1994) reported that butyric acid was one of three compounds with the closest association with Cheddar-like aroma as determined by sixteen untrained panelists.

Based on the results from the individual compound addition to cheese models and calculated OAVs from threshold and instrumental analyses, twelve compounds were selected as key contributing compounds to aged Cheddar cheese flavor (Table 5). The concentration for the selected compounds was adjusted based on descriptive analysis of 3- fold variable concentrations of each compound in each cheese matrix. When comparing full fat and low fat Cheddar cheese, the milk fat descriptor was higher in full fat cheeses compared to 75% reduced fat cheeses. In terms of age related descriptors (sulfur, brothy, and nutty), cheese models with added compounds were significantly higher in these attributes regardless of cheese model type compared to base models, and as a result, young cheese flavor descriptors (cooked and sour aromatic/whey) decreased in models with added compounds (Fig 3).

In order to identify the significance of each compound, a compound subtraction technique (n-1 model subtraction) was applied. The purpose of this method was to determine which compound(s) were most crucial to aged Cheddar cheese flavor (Table 5). A trained panel used a 0 to 10 point similarity scale, where 0= very different, and 10 = identical to reference. Regardless of cheese model type, elimination of butyric acid resulted in the greatest reduction in similarity score, which indicated that butyric acid has a high impact on Cheddar cheese flavor. This result was in agreement with the calculated OAV from this study, previous instrumental studies (Milo and Reineccius 1997; Collins et al. 2003; Singh et al. 2003; Drake et al. 2010) and a previous sensory study (Dacremont and Vickers 1994). 2-methyl butanal, δ-decalactone, furaneol were more influential in full fat cheese compared to low fat cheese. These compounds also had differences in BET values between water and oil (Table 1) suggesting that their impact on flavor would be influenced by fat reduction. Diacetyl, methional, 2-methyl-3- furanthiol, phenyl acetaldehyde, homofuraneol, 1-octene-3-one, DMTS and butyric acid had greater influence on aged Cheddar cheese flavor in 75% reduced fat cheese. It is important to note that these compounds were associated with age-related flavor descriptors from the compound addition study. This optimum formulation was targeted towards low fat Cheddar cheese to mimic the character of aged Cheddar cheese flavor commonly found in commercial aged full fat Cheddar cheeses. Therefore, compounds responsible for age-related attributes played a more critical role in the lower fat cheese matrix, and become more noticeable when subtracted from the current formula. It is important to note that among furanone compounds, furaneol had a greater impact on the full fat matrix, and homofuraneol had a greater impact on the low fat matrix. These two compounds have a similar hydrophobicity and sensory thresholds. Low fat and full fat Cheddar cheese contain different amount of protein, fat, and water and this different ratio of constituents leads to different physical properties. Compounds may be trapped by cheese constituents and ultimately can affect flavor release patterns in the mouth (Yang and Vickers, 2004).

2.5.4. Consumer Acceptance

Eighty-five self-reported low fat Cheddar cheese consumers participated in the consumer acceptance test. Seventy five percent fat Cheddar cheese with the added compounds (Table 5) performed at parity or higher than other commercial aged Cheddar cheese in cheese aroma and aroma similarity. Dacremont and Vickers (1994) previously used concept matching techniques for determining the importance of volatile compounds for Cheddar cheese aroma. Sixteen panelists picked the three most important aroma compounds from an initial screening of 15 Cheddar cheese aroma compounds selected from the literature, and evaluated the similarity to the concept of Cheddar cheese aroma. They used a sniff jar of the chemical mixture and a sniff jar of grated commercial Cheddar cheese for their study. According to their results, 20 ppm of diacetyl, 40 ppm of butyric acid and 0.8 ppm of methional were most similar to the consumer concept of Cheddar cheese aroma. In the current study, these three compounds were included in the final model cheese formulation to mimic aged Cheddar cheese aroma, but their concentrations were different, as this study introduced the matrix effect of cheese constituents and was also focused on aged Cheddar cheese. Cheddar cheese and aged Cheddar cheese aroma mean different things to different consumers (Drake *et al.* 2008; 2009). Aroma evaluation may not be fully representative of consumer liking as consumer acceptance can be influenced by many factors, such as texture and taste (Yang and Vickers 2004). Aroma liking and similarity scores were low for all cheeses, including the full fat cheeses, and this may be because evaluating cheese aroma in place of tasting cheese was a difficult concept for consumers. However, the consumer acceptance part of this study was conducted to determine if specific compound concentrations added to a lower fat Cheddar cheese matrix resulted in a product that matched an "aged" Cheddar concept to consumers, consistent with trained panel results.

2.6. Conclusions

Based on a combination of quantitative analyses including orthonasal threshold analysis, instrumental analysis, calculation of odor activity values, and sensory model studies, the specific role of key volatile compounds that contribute to Cheddar cheese flavor were confirmed: acetic, butyric, hexanoic, octanoic, decanoic and phenyl acetic acids; methional, DMTS, 2-acetyl-2 thioazoline, 2-methyl 3 furanthiol; δ-decalactone, δ-dodecalactone, γ-octalactone; furaneol, sotolone, and homofuraneol; 1-octene-3-one and diacetyl; skatole; phenyl acetaldehyde, 2/3-methyl butanal and 2-methyl propanal. Homofuraneol and phenyl acetaldehyde contributed to off-flavors in 75% reduced fat Cheddar cheese as well as full fat Cheddar cheese. The optimum concentration range of 12 compounds to create aged cheese flavor was determined: butyric acid, furaneol, homofuraneol, δ-decalactone,diacetyl, 1-octene-3-one, methional, DMTS, phenyl acetaldehyde, 2-methyl butanal, 2 –methyl propanal, and 2-methyl 3- furanthiol. Of these compounds, butyric acid, furaneol, methional, and 2-nethyl butanal were most critical to full fat flavor and butyric acid, DMTS, 1-octene-3-one and homofuraneol were most critical to low fat cheese flavor. Young 75% reduced fat Cheddar cheese with the 12 compounds added received acceptance scores that were not different from natural aged low fat Cheddar cheeses. These findings may help the cheese industry and ongoing research on the production of low fat cheese with an acceptable flavor.

2.7. Acknowledgements

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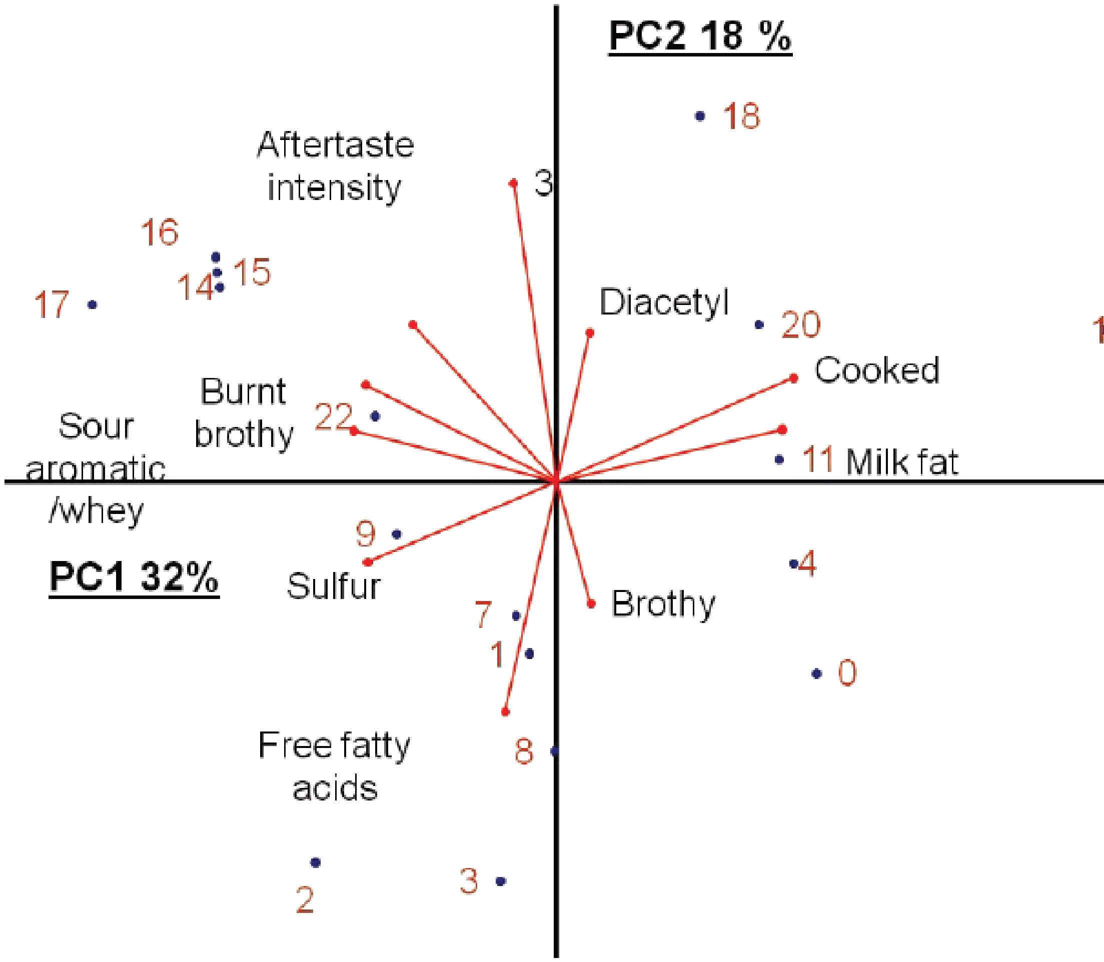

Figure 2-1 PCA Biplot of the Sensory Impact of Individual Compounds Added to the Full Fat Cheese Model

Principal component (1 and 2) biplot of descriptive sensory analysis and individual compound characteristics in full fat Cheddar cheese models; PC 1 and PC 2 explain 51% of variability. Key volatile compounds responsible for Cheddar cheese flavor were represented by numbers found in Table 4. 0 is the control cheese without any added compounds.

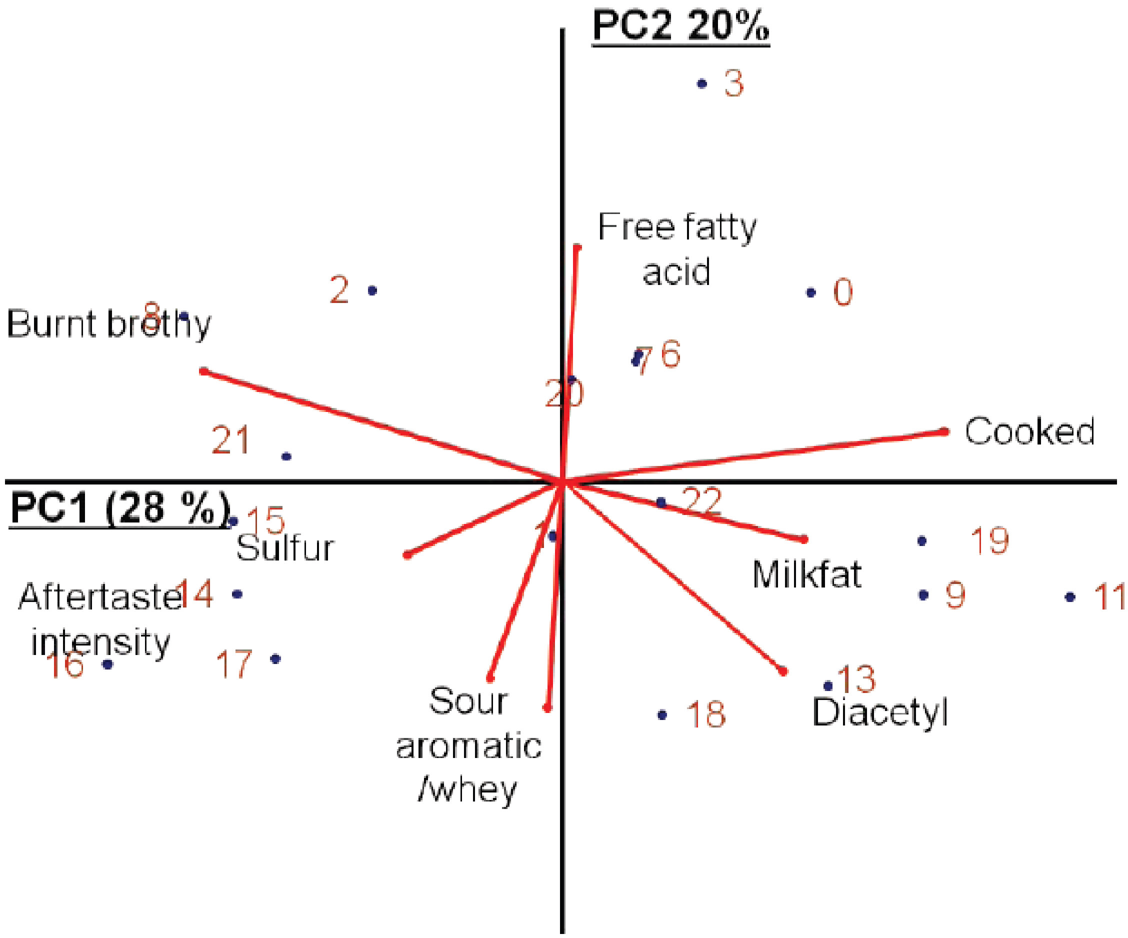

Figure 2-2 Principal Component Biplot of the Sensory Impact of Individual Compounds Added to the Low Fat Cheese Model

Principal component (PC 1 and 2) biplot of descriptive sensory analysis and individual compound characteristics in low fat Cheddar cheese models; PC 1 and PC 2 explain 48% of the variability. Key volatile compounds responsible for Cheddar cheese flavor were represented by numbers found in Table 4. 0 is the control cheese without any added volatile compound

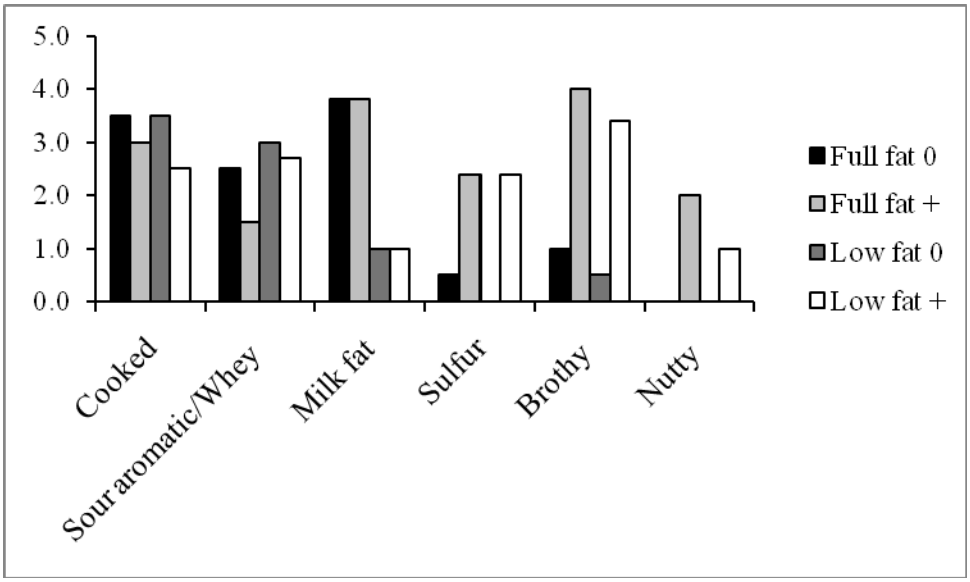

Figure 2-3 Selected Sensory Attributes of Full Fat and Low Fat Cheese Models with and without Added Flavor Compounds

Sensory profiles were conducted using a 0 to 15-point universal intensity scale, where 0 = absence of attribute, 15= very high intensity of attribute (Meilgaard *et al.* 1999; Drake and Civille 2003). y-axis represents aroma intensity from the scale, (partial scale presented for clarity). 0 indicates the model without added volatile compounds, + indicates the model with added volatile compounds (Table 5).

Table 2-1 Best Estimate Threshold (BET) Values for Each Odorant in Water, pH 5.5 Buffer and in Oil

Compounds	BET (µg/kg)			
	Water	pH 5.5 Buffer	Oil	Log P[***]
Acidic				
Acetic [*]	$42.5^{b}\pm0.7$	$169.6^{a}\pm0.6$	$0.27^{c}\pm0.8$	-0.23
Butyric[*]	$0.23^{a}\pm0.8$	$0.19^{a}\pm0.8$	$0.21^{a}\pm0.8$	1.00
Hexanoic[*]	$3.25^{ab}\pm0.4$	$2.61^{a}\pm0.7$	$4.12^{b}\pm0.6$	2.01
Octanoic[*]	$0.70^{b}\pm0.8$	$0.12^{c}\pm1.2$	$221.2^{a}\pm0.5$	3.02
Decanoic[*]	$0.75^{c}\pm0.6$	$1.66^{b}\pm0.6$	$9.69^{a}\pm0.8$	4.03
Phenyl acetic	$464^{a}\pm0.9$	$17^{c}\pm0.8$	$91.63^{b}\pm0.6$	1.36
Sulfur				
Methional	$0.31^{c}\pm0.7$	$1.47^{b}\pm0.8$	$7.41^{a}\pm0.8$	0.93
DMTS	$0.0007^{c}\pm1.3$	$0.82^{b}\pm0.6$	$2.99^{a}\pm0.5$	1.84
2-acetyl 2- thiazoline	$0.15^{b}\pm0.7$	$0.15^{b}\pm0.9$	$1.30^{a}\pm0.7$	0.17
2-methyl 3 furanthiol[**]	$0.08^{b}\pm0.47$	$8.2^{b}\pm0.74$	$2540.0^{a}\pm 0.63$	1.34
Lactones				
δ-decalactone	$2.12^{c}\pm0.6$	$3.34^{b}\pm0.7$	$2510^{a}\pm0.8$	-0.01
δ-dodecalactone[*]	$0.03^{b}\pm0.8$	$0.03^{b}\pm0.7$	$32.6^{a}\pm0.6$	1.01
γ-octalactone	$10.8^{c}\pm0.9$	$17.3^{b}\pm0.6$	$968^{a}\pm0.8$	1.11
Furanones				
Furaneol	$18.6^{b}\pm0.6$	$20.9^{b}\pm0.7$	$148.7^{a}\pm0.9$	0.55
Sotolone	$0.42^{a}\pm0.8$	$0.10^{c}\pm0.7$	$0.27^{b}\pm0.8$	1.13
Homofuraneol	$0.01^{b}\pm0.5$	$0.01^{b}\pm0.7$	$13.2^{a}\pm0.7$	1.26
Ketones				
1-octene-3-one	$0.63^{b}\pm1.0$	$0.18^{c}\pm1.0$	$450.4^{a}\pm0.9$	2.58
Diacetyl	$4.45^{b}\pm0.7$	$6.52^{b}\pm0.8$	$15.1^{a}\pm0.8$	-0.60
Indoles				
Skatole	$0.001^{c}\pm0.8$	$0.01^{b}\pm0.7$	$107.5^{a}\pm0.5$	2.54
Aldehydes				
Phenyl ethanal	$2.00^{b}\pm0.8$	$0.80^{c}\pm0.7$	$1230^{a}\pm1.1$	1.94
2-methyl propanal	$0.32^{b}\pm1.1$	$0.51^{b}\pm1.1$	$7.89^{a}\pm0.9$	1.26
2-methyl butanal	$0.21^{c}\pm1.0$	$0.59^{b}\pm0.8$	$56.9^{a}\pm1.1$	1.76
3-methyl butanal	$160^{b}\pm0.6$	$0.001^{c}\pm0.9$	$6060^{a}\pm1.0$	1.79

[*] units are in mg/kg
[**] units are in ng/kg
[***]Log P value was obtained from Molinspiration Cheminformatics (1986)
Data points are the geometric means of group BET values
[a, b, c] letters above the means indicate significant differences ($p<0.05$) within the same compound in different matrices; the delta method was used for the pair-wise comparison for BET values among different matrices, using the formula $Z=(BET_2 - BET_1) / (\sqrt{(SE_1^2 + SE_2^2)}$ described in Leksrisompong *et al.* 2010

Table 2-2 Odor Activity Values (OAVs) of Key Compounds Found in Full Fat Cheddar Cheese

Compounds	Time 0		9 month	
	Water	Oil	Water	Oil
Acidic				
Acetic	20.6	3238.3	22.0	3457.5
Butyric	6021.7	6595.2	13917.4	15242.9
Hexanoic	598.8	472.3	816.6	644.2
Octanoic	260.5	0.8	957.1	3.0
Phenyl acetic acid	na	na	0.0	0.2
Sulfur				
Methional	683.4	28.6	648.4	27.1
DMTS	5828.6	1.4	9671.4	2.3
2-acetyl thiazoline	36.2	4.2	346.7	40.0
Lactones				
Delta-decalactone	30.8	0.0	16.2	0.0
Delta-dodecalactone	0.2	0.0	0.1	0.0
Gamma-octalactone	0.4	0.0	0.8	0.0
Furanones				
Furaneol	0.4	0.1	0.6	0.1
Sotolone	25.9	40.3	14.5	22.6
Homofuraneol	6911.0	5.2	5092.0	3.9
Ketones				
1-octene-3-one	101.1	0.1	ND	ND
Diacetyl	133.4	39.2	166.5	48.9
Indoles				
Skatole	na	na	ND	ND
Aldehydes				
Phenyl ethanal	13.5	0.0	190.0	0.3
2 methyl propanal	na	na	250.6	10.2
3 methyl butanal	361.0	1.3	1352.4	5.0
2 methyl butanal	0.2	0.0	0.3	0.0

*OAV was calculated by concentration found in cheese divided by BET from orthonasal threshold.
** The OAVs were calculated for each compound using the concentration found in 9 mo. aged full fat Cheddar cheese reported by Drake *et al.* (2010) and the orthonasal threshold BET values from table 1
*** 2-methyl 3 furanthiol was not included because the concentration of this compound was not quantified in Drake *et al*. (2010).
NA not applicable – not detected by instrumental analysis

Table 2-3 Odor Activity Values (OAVs) of Key Compounds Found in Low Fat Cheddar Cheese

Compounds	Time 0		9 month	
	Water	Oil	Water	Oil
Acidic				
Acetic	25.1	3951.9	115.9	18237.0
Butyric	1747.8	1914.3	17700.0	19385.7
Hexanoic	232.6	183.5	492.3	388.3
Octanoic	na	na	ND	ND
Phenyl acetic acid	0.0	0.2	0.0	0.2
Sulfur				
Methional	2250.6	94.2	487.1	20.4
DMTS	10685.7	2.5	9400.0	2.2
2-acetyl thiazoline	0.7	0.1	ND	ND
Lactones				
Delta-decalactone	8.6	0.0	22.2	0.0
Delta-dodecalactone	na	na	ND	ND
Gamma-octalactone	0.2	0.0	0.0	0.0
Furanones				
Furaneol	0.5	0.1	1.0	0.1
Sotolone	42.7	66.4	125.7	195.5
Homofuraneol	5497.0	4.2	30480.0	23.1
Ketones				
1-octene-3-one	318.0	0.4	603.2	0.8
Diacetyl	169.5	49.8	51.7	15.2
Indoles				
Skatole	74.1	0.0	ND	ND
Aldehydes				
Phenyl ethanal	95.0	0.2	297.0	0.5
2 methyl propanal	na	na	104.7	4.2
3 methyl butanal	272.9	1.0	571.4	2.1
2 methyl butanal	na	na	0.1	0.0

*OAV was calculated by concentration found in cheese divided by BET from orthonasal threshold.
** This OAVs were calculated for each compound using the concentration reported by Drake et al. (2010) and the orthonasal BET values from Table 1
*** 2-methyl 3 furanthiol was not included because the concentration of this compound was not quantified in Drake *et al.* (2010).
NA not applicable - not detected by instrumental analysis

Table 2-4 Sensory Detection Concentration of Individual Compounds in Full Fat and Low Fat Cheese Models from < 3 Week Old Cheese Models

No	Compounds	Full fat		Low fat		Aroma and flavor character
		µg/kg				
		Conc. in cheese[1] 9mo.	Sensory Detection Conc.	Conc. in cheese[1] 9mo.	Sensory Detection Conc.	
1	Acetic acid*	933.5	874.0	4924.9	3203.0	Vinegar
2	Butyric acid*	3201.1	461.0	4071.7	402.0	Cheesy/rancid
3	Hexanoic acid*	2654.2	72.0	1600.9	84.0	Sweaty
4	Octanoic acid*	671.0	182.0	ND	NA	Waxy
5	Decanoic acid	ND	NA	ND	NA	Waxy
6	Phenyl acetic acid	19.0	19.0	22.0	1220.0	Floral/rosy
7	Methional	202.0	74.0	151.0	869.0	Potato
8	DMTS	6.77	4.08	6.58	7.48	Sulfur-like/Cabbage
9	2-Acetyl thiazoline	52.00	1.81	ND	0.33	Popcorn/roasted nutty
11	δ-decalactone	34.3	195.0	47.1	18.2	Coconut, milkfat
12	δ-dodecalactone	3.33	6.27	ND	NA	Coconut, milkfat
13	γ-octalactone	8.39	4.07	0.49	5.76	Waxy, coconut
14	Furaneol	11.30	69.00	18.2	869.0	Burnt sugar
15	Sotolone	6.10	1.31	52.8	17.9	Maple/spicy
16	Homofuraneol	50.9	69.1	305.0	164.0	Sweet/burnt sugar
17	1-octene-3-one	ND	63.7	380.1	200.0	Mushroom
18	Diacetyl	742.0	594.0	230.0	754.0	Buttery
19	Skatoles	ND	NA	ND	0.30	Fecal/mothball
20	Phenyl acetaldehyde*	3.80	0.73	5.60	0.19	Rosy/floral
21	2-methyl propanal	80.2	80.2	33.5	33.5	Dark chocolate
22	2-methyl butanal	47.9	56.2	284.1	80.2	Dark chocolate/malty
23	3-methyl butanal	120.6	152.0	11.7	115.0	Dark chocolate/malty

*units are in mg/kg
[1] Concentrations in cheese were obtained from Drake *et al*. (2010)
*** 2-methyl 3 furanthiol was not included, because the concentration of this compound was not quantified in Drake *et al.* (2010).
ND –Not detectable
NA- Not applicable – not detected by instrumental analysis

Table 2-5 The Compound Concentration Combination Added to 2 Week Old Full Fat or Low Fat Cheddar Cheese Models to Mimic Aged Cheddar Cheese Flavor as Determined by Trained Descriptive Panelists

Compound	Concentration in Cheese model (µg/kg)
Butyric acid[1]	153.0[*]
Furaneol	69.0
Homofuraneol	69.0
Delta-decalactone	195.0
Diacetyl	593.0
1-octene-3-one[1]	1.0
Methional	74.0
DMTS	4.0
Phenyl acetaldehyde[1]	7.3
2-Methyl butanal	56.0
2-Methyl propanal[1]	240.0
2- Methyl 3- furanthiol	4.0

[*] units are in mg/kg
[1] The concentration was adjusted from the concentration found in full-fat Cheddar cheese

Table 2-6 Descriptive Analysis of Full Fat Cheddar Cheese Models with Single Compounds Removed (n-1 Subtraction)

Compounds	Similarity[a]	cooked[b]	sour aromatic /whey[b]	milk fat[b]	sulfur[b]	brothy[b]	nutty[b]
Complete model	9.5a	3.0a	2.0a	3.8a	2.4a	4.0a	2.0a
Minus butyric acid	3.5cd	3.0a	2.5a	3.8a	2.0a	2.8bcde	0.5b
Minus furaneol	5.3bc	3.5a	2.5a	3.8a	1.8a	3.0abcd	ND
Minus homofuraneol	8.7ab	3.5a	2.5a	3.8a	1.8a	1.5e	ND
Minus δ-decalactone	6.5abc	3.0a	2.0a	3.8a	1.9a	3.0abcd	1.0ab
Minus diacetyl	8.3ab	2.8a	1.8a	3.4b	2.5a	2.7bcd	1.5ab
Minus 1-octene-3-one	6.8abc	3.0a	2.5a	3.8a	2.0a	2.8bcde	0.8b
Minus methional	6.0abc	3.0a	2.0a	3.8a	1.8a	1.8de	ND
Minus DMTS	6.3abc	3.0a	2.0a	3.8a	2.0a	2.3bcde	0.5b
Minus phenyl acetaldehyde	8.0ab	3.5a	2.5a	3.8a	2.4a	3.3abc	ND
Minus 2-methyl butanal	6.0abc	3.0a	2.5a	3.8a	1.8a	2.8bcde	0.5b
Minus 2-methyl propanal	7.8ab	3.0a	2.5a	3.8a	2.0a	3.0abcd	ND
Minus 2 methyl 3 furanthiol	5.8bc	3.5a	2.5a	3.8a	2.2a	3.5ab	1.0ab
Nothing added (control)	1.0d	3.5a	2.5a	3.8a	1.8a	2.0cde	ND

Tukey's HSD was used for multiple pair-wise comparison on each attribute
Means in a column followed by different letters denote differences among samples ($p<0.05$)
[a] similarity were evaluated using a 10-point scale, where 0 - different to reference, 10- identical to reference; reference was model with all compounds added (Table 5).
[b] descriptive analysis were conducted using 0 to 15-point universal Spectrum™ intensity scale, where 0 = absence of attribute, 15= very high intensity of attribute (Meilgaard *et al.* 1999; Drake and Civille 2003).

Table 2-7 Descriptive Analysis of Low Fat Cheddar Cheese Models with Single Compounds Removed (n-1 Subtraction)

Compounds	Similarity[a]	cooked[b]	sour aromatic /whey[b]	milk fat[b]	sulfur[b]	low fat broth[b]	brothy[b]	nutty[b]
Complete model	10.0a	2.5a	2.8ab	1.0a	2.4a	0.5a	2.9a	1.0a
Minus butyric acid	2.3d	3.3a	2.0ab	0.5b	0.5	0.5a	0.5c	ND
Minus furaneol	7.3abc	2.5a	2.5ab	1.0a	1.4abc	1.0a	0.5c	ND
Minus homofuraneol	3.5cd	2.8a	1.5b	1.3a	1.5abc	0.5a	1.8abc	1.0a
Minus δ-decalactone	7.5ab	2.5a	3.0ab	1.0a	1.8ab	0.3a	1.8abc	ND
Minus diacetyl	5.8bcd	2.5a	3.0ab	1.0a	1.7ab	0.3a	1.9ab	0.5a
Minus 1-octene-3-one	3.5cd	3.0a	3.5a	1.0a	1.4abc	0.5a	1.8abc	0.5a
Minus methional	4.8bcd	2.8a	3.4a	1.0a	0.5bc	1.0a	0.5c	ND
Minus DMTS	3.5cd	3.0a	3.4a	1.0a	0.8bc	1.3a	1.0bc	ND
Minus phenyl acetaldehyde	4.3bcd	3.3a	3.0ab	1.0a	1.0abc	0.8a	1.3bc	0.8a
Minus 2-methyl butanal	7.5ab	2.5a	2.8ab	1.0a	1.3abc	0.3a	1.3bc	ND
Minus 2-methyl propanal	7.3abc	2.5a	2.8ab	1.0a	1.8ab	0.5a	1.9ab	ND
Minus 2 methyl 3 furnathiol	4.0bcd	2.5a	2.5ab	1.0a	0.9abc	1.0a	1.0bc	0.8a
Nothing added (control)	2.3d	3.5a	3.5a	1.0a	0.3c	1.0a	ND	ND

Tukey's HSD was used for multiple pair-wise comparison on each attribute
Means in a column followed by different letters denote differences among samples ($p<0.05$)
[a] similarity were evaluated using a 10-point scale, where 0 - different to reference, 10- identical to reference; reference was model with all compounds added (Table 5).
[b] descriptive analysis were conducted using 0 to 15-point universal Spectrum^{TM} intensity scale, where 0 = absence of attribute, 15= very high intensity of attribute (Meilgaard *et al.* 1999; Drake and Civille 2003).

Table 2-8 Consumer Acceptance of Cheddar Cheese Aroma (n=85)

Sample description	Cheddar cheese aroma liking[1]	Aged Cheddar cheese aroma liking[1]	Cheddar cheese aroma similarity[2]	Aged Cheddar cheese similarity[2]
Low Fat control (no compounds added)	3.7 c	2.8 d	3.4 b	2.4 b
Low fat complete model*	5.3 ab	4.6 bc	3.6 b	4.0 b
Low fat commercial 75% reduced fat cheese aged 9 mo.	4.5 c	3.6 cd	4.4 ab	3.4 b
Experimental 80% reduced fat cheese aged 9 mo.	4.0 c	3.5 cd	3.6 b	3.0 b
Full fat control (no compounds added)	3.8 c	3.2 d	4.5 ab	3.1 b
Full fat commercial sharp Cheddar cheese aged 2yrs	5.4 ab	4.9 ab	5.1 a	4.8 a
Full fat commercial extra sharp Cheddar cheese aged 3yrs	5.6 a	5.5 a	5.3 a	5.8 a

[1] Liking attributes are scored on a 9-point hedonic scale, where 1=dislike extremely and 9=like extremely
[2] Similarity attributes are scored on a 10-point scale, where 1= not similar at all and 10= extremely similar
* Low fat Test is low fat cheese (~ 2 weeks old) with added 12 compounds from Table 5
Tukey's HSD was used for multiple pair-wise comparison on each attribute; means in a column followed by different letters denote differences among samples ($p<0.05$)

CHAPTER 3

CONSUMER AWARENESS OF SALT AND SODIUM REDUCTION

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Running head: Consumer awareness of salt…

3.1. Abstract

Reduction of dietary sodium by reduction of sodium in foods is a current industry target. Quantitative information on consumer knowledge of sodium and sodium reduction is limited. The objectives of this study were to characterize consumer knowledge and awareness of sodium and salt reduction in foods. Consumers (n=489) participated in a quantitative internet survey designed to gather knowledge and attitudes towards dietary sodium, sodium in foods, and health. Eating habits and food consumption characteristics, knowledge of salt and sodium, and interest in health and wellness were probed. Salt and sodium knowledge indices were calculated based on correct responses to salt levels in food products. Kano analysis was conducted to determine the role of nutrition labels and satisfaction /dissatisfaction of foods. Consumers were aware of the presence of sodium in "salty" foods, and that sodium was part of salt. People who had a family history of certain diseases associated with a higher intake of dietary sodium did not necessarily have more knowledge of the relationship between sodium intake and a specific disease compared to consumers with no family history. Sodium content on the food label panel did not influence consumer dissatisfaction; however sodium content did not necessarily increase consumer product satisfaction either. The addition of a healthy nutrient (i.e. whole grain, fiber) into a current food product was appealing to consumers. For nutrient labeling, a "reduced" claim was more appealing to consumers than a "free" claim for "unhealthy" nutrients such as fat, sodium, and sugar.

Keywords: Sodium reduction, Kano analysis, nutrition labeling

3.2. Practical Application

This study demonstrated the current state of consumer knowledge on sodium and salt reduction, and consumer perception of the relationship between diets high in sodium and many chronic diseases. Information that may contribute to consumer satisfaction on nutrition panel labeling was also determined.

3.3. Introduction

A current trend in the US food industry is health and wellness of consumers. Consumers believe that limiting processed foods are important for healthy eating (Sloan 2011). Processed foods are known to have higher amounts of sodium, preservatives, flavor enhancers, and artificial ingredients than home-cooked, unprocessed food sources (Mattes and Donnelly 1991). Unfortunately, US consumers have heavily relied on processed foods rather than home cooked meals. One of the drawbacks from eating processed foods is excessive sodium intake. Only 11% of sodium in US diets came from a table salt shaker, nearly 89% of dietary sodium was from packaged food items (New York City Department of Health and Mental Hygiene 2010). Excessive sodium intake has been associated with many chronic diseases such as hypertension, bone disease, and higher risk of stomach cancer (Leshem 2009; USDA 2005).

The US government has set the maximum daily intake of sodium as 2.4 g sodium/day, which equates to 6.05 g salt per day (approximately 1 tsp of salt) (USHHA and USDA 2005). The FDA Food Labeling Guide requires indicating “free” “low” or “reduced/less” on the food label based on the sodium level rather than salt level. Sodium free and low sodium claims are based on the actual amount of sodium added to food (< 5mg per 100g, and 140 mg or less per 100 g reference amount), whereas reduced/less and light in sodium claims can be made based on proportional reduction (greater than 25% reduction and 50% reduction, respectively) when compared to reference foods (FDA/CFSAN 2008). Webster and others (2010) conducted a systematic survey on the sodium content of Australian processed food products. They documented the sodium content of many commercially available processed foods including pasta sauces, meat products, cheese, canned vegetables and canned soups, and snack foods. According to their results, most commercial products have sodium levels above the current government standard. Recently, the National Salt Reduction initiative, led by New York City, states and national health organizations, proposed a voluntary 25% sodium reduction on packaged and restaurant foods in the next 5 years (NYC-DHMH 2010). This initiative has influenced the food industry to reduce the amount of sodium in processed foods. In addition, a recent report from Health Focus International showed that 43% of consumers checked product labels for “low sodium” claims (HFI 2009).

While government and food industry have focused on reduced sodium food items, consumer perception of reduced sodium and/or reduced salt products is still largely unknown. Fifty- percent of consumers responded that they would like to decrease their sodium intake but would not want to sacrifice taste (NMI 2008). Flavor and texture remain the driving force for purchase intent and liking of many food products (Childs and Drake 2009; Chambers 1996; Young and others 2004; Yates and Drake 2007). Sodium chloride (salt) plays a crucial role in microbial stability, flavor development and texture formation of food including cheese, meat, snacks and cereals, and bakery goods (Schroeder and others 1988; Guinee and Fox 2004; Desmond 2006). Two main strategies to reduce sodium are reducing the amount of sodium or partial replacement of sodium chloride with other salt substitutes such as potassium chloride. At this stage, both strategies have not been successful, as consumer acceptance for reduced sodium products is still poor i.e. popcorn (Vickers and Roberts 1993), processed meat products (Desmond 2006; Guardia and others 2006), broiler breast fillets (Saha and others 2009), cottage cheese (Drake and others 2011), and Cheddar cheese (Reddy 2004).

Nutrition labeling is mandated by the Office of Nutritional products, Labeling, and Dietary Supplements in the Center for Food Safety and Applied Nutrition at the U.S Food and Drug Administration and applies to all packaged products sold in the US (FDA 2009). Mandatory nutrition labeling was established to support and/or encourage consumers to make healthier choices when grocery shopping (Grunert and others 2010). However, whether consumers truly understand the facts of nutrition labeling, and whether they make use of this information for their purchase decisions are still unknown. Recently, interest has focused on measuring consumer satisfaction rather than acceptance. Satisfied customers are most likely to re-purchase products on a long term basis. Kano and others (1984) suggested that the attributes driving acceptance were not necessarily associated with consumer satisfaction. They concluded that the relationship between fulfillment of a need and satisfaction/dissatisfaction of a product were not linear, and proposed a model to establish the importance of product attributes in terms of consumer satisfaction. There were four categories of this model: must-have, one-dimensional, attractive, and indifferent (Xu and others 2008). Must-be attributes are the ones that lead to consumer extreme dissatisfaction if absent, however these attributes do not increase the satisfaction if met. One-dimensional attributes are the ones that show linear increment of customer satisfaction with fulfillment of them. One dimensional attributes are particularly of interest, because these attributes are considered drivers of consumer satisfaction. Attractive attributes are the unexpected attributes but can lead to greater satisfaction if present; therefore they are also called "exciters" as they surprise consumers unexpectedly. Indifferent attributes are those that do not influence consumer expectation of products. Kano analysis can be done by consumer surveys with a carefully designed questionnaire. By identifying the attributes that are strongly associated with consumer satisfaction, product developers as well as food marketers can incorporate this information more efficiently.

The goal of this study was to quantitatively assess the consumer perception of sodium and sodium reduction in food. To achieve this goal, we investigated the following five questions: 1. Does consumer knowledge of sodium level affect the perception of salty taste? 2. Do consumers link sodium containing food items to sodium related health conditions? 3. What information drives consumer satisfaction on the nutrition label, and can we identify the impact of the ingredients listed on the nutrition label. 4. What is the impact of adding an adjective on the nutrition information (i.e. reduced-, low- and high in-) on the purchase intent of a food product? 5. What are the recommendations for consumers and food marketers based on these results?

3.4. Materials and Methods

Surveys were created using SSI Web (Sawtooth Software version 7.12, Sequim, WA). Respondents were recruited through e-mail list-serves and internet postings on campus and in an online consumer database of 3,500 individuals in the Raleigh, NC area maintained by the North Carolina State University Sensory Service Center. Target consumers consisted of US consumers ages 18- 65 y, with an even distribution of each age bracket. Prior to asking questions on consumer knowledge of sodium and salt in food products, respondents were first asked for their background and food consumption habits including age, gender, weight, and eating habits. Then, the respondents were asked to answer a series of knowledge and awareness questions regarding sodium content and saltiness. These questions were aimed at understanding how aware consumers were of terminology used in describing foods with high sodium/ salt contents in 23 selected food commodities. These 23 food items were chosen to represent foods with different amounts of sodium. The sodium content per serving size was obtained from published data from the USDA National Nutrient Database for Standard Reference. The basic format of these questions was to have respondents answer their opinion about food items using a 5 –point category scale, anchored with 1- not salty at all and 5- extremely salty for awareness of saltiness, and anchored with 1= contains no sodium, and 5 = extremely high amount of sodium for the awareness of sodium content. These questions were designed to compare how consumers linked sodium as a source of salty taste. To understand the perceived risk of certain diseases associated with consuming high amounts of sodium, consumers were asked about given health conditions and then asked to select their opinion, from has nothing to do with salty foods; will increase the risk significantly; or will decrease the risk significantly. Similar questions were asked for sodium to compare the responses collected from salt against those from sodium. By asking the same questions with slightly different changes in the wording of scales, direct comparisons can be made to observe the current status of consumer awareness.

A carefully designed Kano-related questionnaire was included to determine how the nutrients on the current nutrition panel influenced customer satisfaction/dissatisfaction. Kano questions were asked by providing nutrients in the current nutrition panel and then satisfaction and dissatisfaction questions. The satisfaction question was worded, if the nutrition label in your food contained the following items, how would you feel? The dissatisfaction question was worded, if the nutrition label in your food does not contain the following items, how would you feel? The answer choices for satisfaction/dissatisfaction question were: like, must have, do not care, can live with it, and dislike (Xu and others 2008). After Kano questions, consumers were asked to answer questions that were designed to measure purchase intent of foods with specific food claims. Consumers were asked about given food claims, and then asked to select their opinion using a 5-point category scale anchored with 1-not at all appealing, will negatively impact my purchase intent, 3-will not influence my purchase intent, and 5-highly appealing, will positively influence my purchase intent. A drawing for three $20 gift cards was held after all participants had gone through the survey as an incentive for participation.

3.4.1. Statistical analysis

Frequency analysis was applied to collected data using XLSTAT (Version 2010. 2.02; Addinsoft, Paris, France). To measure consumer knowledge on sodium and salty taste, a sodium and salty knowledge index was created. Based on the sodium content per given serving size from USDA published data, the 23 food items were divided into 2 groups: high sodium containing foods and low sodium containing foods. The cut-off for the two groups was made based on the FDA rules for labeling sodium on food products. According to the FDA, "low sodium" foods should have 140 mg or less sodium per reference serving size. Therefore, if foods contained less than 140 mg sodium per serving size, they were classified as low sodium in this study. According to this categorization, the low sodium containing food included apples, fresh green beans, cookies, chocolate, microwave popcorn, jell-o, yogurt, and steamed fish. Once the foods were classified into two different groups, consumer scores based on 5-point scales were converted to an index. The conversion was made as following: consumers who responded < 3 for food items that had lower sodium content, 1 was assigned, consumers who responded ≥ 3 on food items that had lower sodium content, 0 was assigned. This can be viewed as a grading system by assigning 1 for correct answers and 0 for incorrect answers. After the conversion, a sodium index was calculated by summing up the values, such that the maximum value for the sodium index would be 489 if all consumers correctly identified the sodium content of each food. Sodium and salty indices were created separately for each food item.

In order to answer the second question in the objective: Do consumers link sodium containing food items to sodium related health conditions? Consumers were divided into 2 groups based on their responses on disease history: group 1 consisted of people with no family history of diseases; group 2 consisted of people with a family history of diseases. The diseases that qualified for this classification were diseases that were known to be associated with high sodium intakes: high blood pressure, stroke, bone health, kidney disease, and stomach cancer (Wardlaw and Kessel 2002). This group was assigned after the collection of the dataset; therefore the number of consumers in each group was different. The percentage of people who correctly linked consumption of sodium containing food items to a risk factor of getting sodium related health conditions including hypertension, stroke, bone health, kidney disease and stomach cancer were reported. The responses were compared between salt and sodium indices and between the two groups previously described. The purpose was to determine if there was a difference between the two different groups regarding knowledge of sodium/salt on increased risk of getting diseases and eventually to determine if getting exposed to those diseases (e.g. family history) resulted in increased awareness of the possible dietary cause(s) of the disease. In addition, by comparing the result of sodium and salt within a group, consumer awareness of sodium and salt as a risk factor of these diseases was determined. Kano index and satisfaction/dissatisfaction coefficients were calculated based on previously described methods (Walden 1993; Xu and others 2008).

3.5. Results and Discussion

3.5.1. Respondent Demographics

A total of 489 consumers qualified and participated. Briefly, respondents were 75% female, 25% male, ages 18-65y, and each age group increment of 10 years was evenly distributed (n= ca. 100 in each age group). A Body Mass Index (BMI) was calculated for each consumer based on their self-reported height and weight information: body mass (kg) divide by (height (m))^2. The obesity education initiative published from the National Heart, Lung and Blood Institute (NHLBI) indicated that a BMI above 30 is considered obese, and a BMI above 25, below 30 is considered overweight (Chobanian and Hill 2000). Fifty-seven percent of participants from the current survey were classified as overweight (28.2%) and/or obese (29.1%) (Table 1). Obesity is correlated with many chronic diseases, including high blood pressure, type 2 diabetes, high blood cholesterol level, coronary heart disease, and gallbladder diseases (Must and others 2011). The BMI values from this study were based on self-reported weight and therefore may not represent the actual value, but provide an estimate, as Villanueva (2001) reported the differences between self-reported and actual height and weight information and reported some discrepancies. Women were more concerned about their weight and body shape (data not shown) and a higher percentage of women considered their weight higher ($p<0.05$) than normal than that of men in the corresponding BMI group. Narchi and others (2008) also reported that self awareness of appearance and weight was higher in women than men. In this study, nearly 70% of respondents answered that their weight was higher than normal, but only 2.2% of consumers considered their eating habits as unhealthy (Table 1).

When asked about frequency of reading food labels while shopping for groceries, 92% of consumers responded that they read food labels (Table 1). This is a significant increase from reports in previous years. Wyatt (1980) surveyed 40 consumers on sodium restricted diets to determine the adequacy of current food labeling for sodium content in processed foods. Seventy percent of those consumers responded that they read food labels on a regular basis. In this survey, a similar result was observed. Seventy-six percent of consumers responded that they were conscious about sodium intake, however only 7% of consumers amongst these 76% consumers were on a low sodium diet. Consistent with previous studies, only a small percentage of consumers are on sodium restricted diets, even though current US public awareness toward sodium reduction has increased.

3.5.2. Do consumers knowledge of sodium level affect the perception of salty taste?

To answer this question, sodium and salty indices were calculated (Tables 2a, 2b). Sodium index was defined in this study as the numbers of consumers who correctly identified the sodium content of given food items, and salt index was defined as the number of consumers who correctly identified the salty intensity of given food items. To investigate the first question, a direct comparison between sodium index and salt index was conducted. Overall, the sodium index and salt index followed a similar trend (Tables 2a, 2b). Over 95% of consumers correctly identified low sodium containing foods as foods that contained less sodium (sodium index) and foods that were less salty (salty index), except for microwave popcorn. Fewer respondents correctly acknowledged the lower sodium content of microwave popcorn: 132 correct responses out of 489 on sodium index, and 261 correct responses out of 489 on salty index. The published standard serving size for microwave popcorn was 1 cup; however the serving per package is typically 2-3 servings per one package. Cowburn and Stockley (2005) mentioned that poor nutrition knowledge among US consumers, especially on serving size, could limit the interpretation of the information on the package by consumers. The lower sodium and salt index value on microwave popcorn in this study was a good example of the discrepancy between recommended serving size from the nutrition label and the actual serving size for consumers. When directly asked how they think about foods with high sodium content, 93% responded that these foods were salty (data not shown), confirming that consumers were aware of the salty taste associated with the presence of sodium in the food, and were able to correctly recognize the amount of sodium in various food items.

3.5.3. Do consumers link sodium containing food items to sodium related health conditions?

A large proportion of the US population suffers from chronic diseases that are associated with high sodium intake such as bone diseases, cancer risk, hypertension, heart disease and stroke (Leshem 2009). Several studies have demonstrated that the process of eliminating excess sodium from the kidneys, skin and GI tract results in calcium loss, therefore long term high intake of sodium can be a risk factor for bone disease (i.e. osteoporosis) (Devine 1995; Greeley 1997; Teucher and others 2008). A recent report from

WHO (World Health Organization) in 2003, concluded that a high intake of salt-preserved foods and salt probably increased the risk of gastric cancer, one of the leading causes of cancer death worldwide (WHO 2003). High blood pressure (hypertension) is defined as the condition where blood pressure is chronically elevated above 140/90mmHg (Wardlaw and Kessel 2002) and is commonly regarded as a major risk factor for cardiovascular disease, stroke, heart failure, kidney failure, coronary heart diseases and premature death (Chobanian and Hill 2000). Overall, respondents in the current survey were familiar with the concept that a diet high in sodium and/or salt could lead to increased risk of getting high blood pressure and stroke (Table 3). Heart disease is considered a secondary disease of sodium intake, as heart disease is caused by high blood pressure. Hence, consumer knowledge on the relationship between increased risk for heart disease and high salt/sodium diet was poor: only 12% of 489 consumers correctly linked excess salt as a possible cause of heart disease, and only10% of respondents indicated excess sodium intake as a possible cause of heart disease. In contrast, 68% of respondents were able to link sodium and salt intake and kidney disease. Knowledge of bone disease risk was poor: only 31 % and 37% of consumers (n=489) were aware that a diet high in salt/sodium could negatively impact bone health.

Respondents were divided into 2 groups: group 1 for those who had no history of disease among their family and direct relatives, and group 2 for those who had a history of disease amongst their family and direct relatives. We hypothesized that the knowledge of the cause of certain diseases may be influenced by the health conditions of family members and relatives. The total number of respondents classified in group 1 or group 2 was different for each disease group. Family history of disease had no impact on association of salt or sodium intake with disease knowledge/ dietary association ($p>0.05$). Having a disease history did not increase the level of belief of excess sodium and salt intake as increased risk of getting diseases.

In addition to current knowledge level, this study investigated if there was a better way to position low sodium products in the US food market. In order to achieve this goal, we investigated consumer perception of package nutrition information. Specifically, what drives consumer satisfaction for the information on the nutrition label and the impact of adding adjectives to nutrition labels were investigated.

3.5.4. What drives consumer satisfaction among the information (i.e. fat content, sodium content) on the nutrition label, and can we identify the impact of the ingredients listed on the nutrition label?

It is important to know the attributes that are directly associated with customer satisfaction in current competitive food markets. Nutrition labeling on the package has served as a communication tool for food companies and consumers (Jacoby and others 1977). Public policy makers and food marketers often made decisions under the assumption that the information on the nutrition label impacts consumer purchase decisions (Jacoby and others 1977). This study investigated the impact of nutrient information on consumer satisfaction, specifically to answer this question: which of the nutrients played a role in customer satisfaction/dissatisfaction. Table 4 shows the Kano classification for each feature of the nutrition panel of the package, first for all respondents (n=489) then segmentation by frequency of reading nutrition label while making purchase decisions.

All nutrients were classified as “must-have” attributes by all respondents except for vitamin and mineral content (Table 4). Walden (1993) and Kano (1984) reported that must-be quality are attributes that are taken for granted when fulfilled, but lead to great dissatisfaction if not fulfilled. As all nutrients were considered must-have attributes, it is important to pay attention to the satisfaction/dissatisfaction coefficient. Positive satisfaction coefficients are an indication that customer satisfaction increases as the consumer need is fulfilled; negative dissatisfaction coefficients are an indication that customer dissatisfaction increases as the consumer need is not fulfilled (Walden 1993). Among “must-have” attributes, for total calories, the absolute value of dissatisfaction coefficient (0.74) was greater than the absolute value of satisfaction coefficient (0.36), which indicates that customers are dissatisfied greatly if this information is not present on the nutrition panel, however the total calories did not increase satisfaction as much if it is present. In contrast, vitamin content was considered an “attractor” attribute in this study. Attractor attributes are items that provide satisfaction if fully achieved, however they do not cause dissatisfaction if not fulfilled (Kano and others 1984; Walden 1993; Xu and others 2009). The vitamin content had similar satisfaction (0.54) and dissatisfaction coefficients (-0.46). Attractor attributes are usually attributes that are not normally expected (Walden 1993). The vitamin content is not required in the nutritional panel, however it is included in many food products (Code of Federal Regulation 2011). Mineral content was identified as an “indifferent” attribute, which means that it does not impact customer satisfaction. Again, mineral content is not mandated to be present on the nutritional panel. According to 21 CFR 101.9, the following nutrients should be listed on the nutrition panel: total fat, sodium, carbohydrates, and proteins (Code of

Federal Regulations 2011). This study revealed the important information on the nutrition panel for consumer satisfaction.

Consumers were segmented into two groups: consumers who frequently read labels (n=324), and consumers who do not/or rarely read labels (n=165). We hypothesized that difference in Kano classification would be noticeable based on the label reader status. For consumers who read labels frequently (n=324), the protein and fiber content information were one-dimensional attributes. One dimensional attributes are attributes that marketers need to pay more attention to as customer satisfaction increases as more of these attributes are present. This result indicated that frequent label readers were more satisfied when they saw protein and fiber content on the nutrition panel. Cowburn and Stockley (2005) reported that the consumers with a special interest or positive attitude to diet and health were more likely to read nutrition labels frequently. Interestingly, frequent label readers were more satisfied by the presence of information on healthy ingredients (protein and fiber).

For consumers that rarely read labels (n=165), nutrition label information had no impact on consumer satisfaction except for total calorie, fat content and sodium content. In other words, the satisfaction toward products amongst non-label readers typically would not be affected by the information on the package because they do not read labels; however the information on total calories, fat and sodium content are one of the few things that could potentially affect the satisfaction of the product for those who rarely read labels. Interestingly, non-label readers were more satisfied with the presence of information on unhealthy ingredients such as total calorie, fat, and sodium content compared to frequent label readers. Also, these respondents responded that carbohydrate and salt content should be on the package as well (Must-have). Kano analysis showed the level of importance of the information on the package, but not necessarily the level that is satisfying. To further investigate this question, the impact of adding an adjective to nutrition information was investigated.

3.5.5. What is the impact of adding an adjective on nutrition information (i.e. reduced-, low- and/or high in-) on the purchase intent of a food product?

Adjectives such as reduced-, low-, free of-, and/or good source of -, which represented allowable claims consistent with US government regulations, were added and evaluated by participants. Reduced-, low-, and free- adjectives were added to see if these adjectives impacted purchase intent. Consumers preferred reduced- and/or low- claim more so than the free of- claim (Table 5). More than 75% of consumers answered that reduced and low fat claim would positively influence purchase intent, while only 56% of consumers answered that a fat free claim would positively influence the purchase intent. Childs and Drake (2009) also reported that reduced and low fat claims were more appealing than fat free claims with cheeses. A similar trend was observed for salt and sodium claims. Sodium and salt was classified as must-have attributes from Kano analysis. More than 75% of consumers answered that reduced- and low- claim would positively influence purchase intent, but only 52% of consumers responded that salt free would positively influence purchase intent ($p<0.0001$). For unhealthy ingredients (i.e. fat, salt, sodium, and sugar), the purchase intent decreased when a "free-" adjective was added to the nutrition panel. Consumers responded that "good source of" protein and calcium, whole grain, and "high in" fiber claim would positively influence the purchase intent of a food product. In conjunction with Kano analysis results: frequent label readers desired protein and fiber content on the nutrition panel from Kano analysis, and they would like to see the “more of” and “high in” claim on those healthy items to increase their satisfaction. Natural and organic claims positively influenced purchase intent, however the degree of positive influence was lower for the organic claim than the natural claim: only 54% of respondent said an organic label would positively impact purchase decision whereas 70% of respondents said a natural label would positively impact purchase decision ($p<0.0001$). A recent survey also reported that US consumers believed “natural” label claims were better indicators of an eco-friendly product than a product with “organic” claims (Scott-Thomas 2009).

3.5.6. What are the recommendations for consumers and food marketers based on these results?

For practical application, the information on the food package plays a large role in purchase decisions. From this study, most information on the nutrition panel was identified as must-have attributes. Consumers want reduced amounts of negative food components (fat and sodium) rather than completely out of the food system, as free- adjective had negative connotations. Protein content was an important satisfier for those who read labels for purchase decisions, but did not make a difference on those who did not read labels. Adding an appropriate adjective on the labeling can give positive feedback to consumers, and in turn affect the positive communication that can influence purchase intent.

3.6. Conclusions

Most consumers were able to consistently identify that foods with high sodium were the same as foods with high salt. People with a family history of sodium-related diseases did not have more knowledge on the relationship between sodium consumption and risk of getting diseases than those with no history. Sodium content on the food label panel did not influence dissatisfaction; however sodium content did not necessarily increase consumer product satisfaction.

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Table 3-1 Demographic information and consumer consumption characteristics

n = 489		%
Gender	Male	25.4%
	Female	74.6%
Age (y)	19-25	9.6%
	26 – 35	22.9%
	36 – 45	20.9%
	46 – 55	23.5%
	Over 55	23.1%
BMI	<16.5 (severely underweight)	0.6%
	16.5 – 18.4 (underweight)	1.4%
	18.5 – 24.9 (normal)	40.7%
	25 – 30 (overweight)	28.2%
	30.1 – 34.9 (Obese class I)	13.7%
	35 – 40 (Obese class II)	7.0%
	40 < (Obese class III)	8.4%
Self-consciousness of eating habits	Definitely very healthy	2.2%
	Healthy	14.9%
	Moderately healthy	49.5%
	Somewhat healthy	31.1%
	Not healthy at all	2.2%
Self-consciousness of their weight	Too high	10.8%
	High	24.9%
	A bit higher than normal	33.9%
	Normal	27.8%
	Lower than normal	2.2%
	Too low	0.2%
Eating habit – sodium diet	On a low sodium diet, follow diet plan strictly	3.5%
	On a low sodium diet, don't follow diet plan strictly	3.5%
	Not on a low sodium diet, but conscious about sodium intake	69.3%
	Not on a low sodium diet, not conscious about sodium intake	21.7%
	Not sure	2.0%
Reading food label	Always read food label	17.6%
	Frequently read food label	48.7%
	Sometimes read food label	26.0%
	Rarely read food label	6.7%
	Never read food label	1.0%

Percentage of respondents (n=489) with each criteria total sums up to 100%

Table 3-2 Consumer Knowledge Index on the Amount of Sodium/Salt: Low Sodium Foods

Food items	Serving Size	Sodium (mg)	Sodium index	Salty index
Apples	1 apple	1	480	482
Fresh green beans	1 cup	1	479	486
Cookies	1 cookie	18	445	479
Chocolate	1 bar	35	468	481
Microwave popcorn	1 cup	97	132	261
Jello-O	1/2 cup	101	473	485
Yogurt	8 oz container	104	475	484
Steamed fish	1 fillet	133	472	473

Sodium index was calculated based on number of respondents who correctly identified low sodium food as low sodium food. Low sodium foods were defined as foods that contained 140mg or less sodium per reference amount. Salty index was calculated based on number of respondents who correctly identified low sodium food as low in salty taste. The minimum value in this index system was 0, and maximum value was 489.

Table 3-3 Consumer Knowledge Index on the Amount of Sodium/Salt: High Sodium Foods

Food items	Serving Size	Sodium (mg)	Sodium index	Salty index
Cheddar cheese	1 oz	176	324	214
Potato chips	1 oz	186	426	459
Pepperoni pizza	1 slice	267	466	416
Milkshakes	11 fl oz	297	471	468
Canned green beans	1 cup	339	388	314
Processed cheese slices	1 oz	422	403	277
Prepared frozen pasta meal	1 package	473	450	398
Chicken nuggets	6 piece	608	442	354
Tomato Soup	1 cup	695	450	366
Lunch meat	2 slices	739	465	418
Pickles	1 pickle	833	427	384
Canned chicken noodle soup	1 cup	850	472	444
Cottage Cheese	1 cup	851	212	130
Ham	3 oz	908	470	444
Pretzels in a bag	10 pretzels	1029	472	464

Sodium index was calculated based on number of respondents who correctly identified low sodium food as low sodium food. Low sodium foods were defined as foods that contained 140mg or less sodium per reference amount. Salty index was calculated based on number of respondents who correctly identified low sodium food as low in salty taste. The minimum value in this index system was 0, and maximum value was 489.

Table 3-4 Knowledge of Sodium and Risk of Disease (n=489)

	Total		No family Disease (Group 1)		Family history of Disease (Group 2)	
	Salt	Sodium	Salt	Sodium	Salt	Sodium
High blood pressure (n_1=144 n_2=345)	96.1%	97.1%	96.5%	96.5%	95.9%	97.4%
Heart disease (n_1=318 n_2=171)	12.3%	9.8%	12.9%	11.3%	11.1%	7.0%
High cholesterol (n_1=186 n_2=303)	39.1%	30.7%	35.5%	30.6%	41.3%	30.7%
Stroke (n_1=402 n_2=87)	82.2%	86.3%	81.8%	85.3%	83.9%	90.8%
Bone health (n_1=384 n_2=105)	30.9%	36.6%	31.0%	35.7%	30.5%	40.0%
Kidney disease (n_1=455 n_2=34)	67.9%	68.5%	67.0%	67.7%	79.4%	79.4%
Cancer (n_1=474 n_2=15)	28.6%	33.1%	28.9%	32.9%	20.0%	40.0%
Stomach disease (n_1=474 n_2=15)	39.3%	39.5%	38.8%	39.0%	53.3%	53.3%
Diarrhea (n_1=474 n_2=15)	69.7%	64.4%	69.6%	64.8%	73.3%	53.3%
Acid Reflux (n_1=474 n_2=15)	52.6%	53.0%	52.7%	53.2%	46.7%	46.7%

Consumers were grouped based on their specific disease history, and the numbers of respondents in each group were different for different diseases. Group 1 was defined as people who do not have any family history of having each disease, and group 2 was defined as people who had a family history of having each disease. No statistical differences were observed in each disease, within and between groups ($p>0.05$).

Table 3-5 Kano Classification of Nutrition Information on the Nutrition Label

Feature	Kano Classification		
	Total (n=489)	Consumer segments by their purchase habit	
		Frequent label readers (n=324)	Non-label readers (n=165)
Total Calorie	Must Have	Must Have	One dimensional
Fat content	Must Have	Must Have	One dimensional
Sodium content	Must Have	Must Have	One dimensional
Vitamin content	Attractor	Attractor	Indifferent
Mineral content	Indifferent	Indifferent	Indifferent
Protein content	Must Have	One Dimensional	Indifferent
Sugar content	Must Have	Must Have	Indifferent
Cholesterol	Must Have	Must Have	Indifferent
Ingredient	Must Have	Must Have	Indifferent
Carbohydrate	Must Have	Must Have	Must have
Salt content	Must Have	Must Have	Must have
Fiber content	Must Have	One Dimensional	Indifferent

Kano classification was calculated by previously described methods (Kano 1984). The satisfaction and dissatisfaction questions were asked to consumers, and the contingency table of satisfaction and dissatisfaction answers were created on each feature. The number of consumers who were assigned on each cell of contingency table was accounted for by Kano classification. The Kano classification was conducted with total n=489 respondents, followed by consumer segmentation based on label reader status. Frequent label readers were consumers who frequently read labels when making purchase decisions (n=324) and non-label readers were consumers who rarely and/or never read labels when making purchase decisions (n=165).

Table 3-6 Consumer Interest in Foods Based on Label Adjective (n=489)

Category	will negatively impact my purchase intent	Will not influence my purchase intent	will positively influence my purchase intent
Reduced fat	10.6% b	11.5% b	77.9% a
Low fat	10.4% b	11.5% b	78.1% a
Fat free	27.0% b	16.2% b	56.9% a
Trans fat free	4.5% c	19.4% b	76.1% a
Reduced salt	8.2% c	15.1% b	76.7% a
Reduced sodium	7.2% c	16.2% b	76.7% a
low salt	8.4% c	19.4% b	72.2% a
Low sodium	7.8% c	19.0% b	73.2% a
Salt free	28.2% c	19.4% b	52.4% a
Sodium free	17.2% b	22.3% b	60.5% a
Cholesterol free	7.6% c	26.4% b	66.1% a
Reduced calorie	9.4% c	14.7% b	75.9% a
Sugar free	26.2% b	24.1% b	49.7% a
Low carbohydrate	8.2% c	31.1% b	60.7% a
High in fiber	4.7% c	15.7% b	79.6% a
Whole grain	4.9% c	11.0% b	84.0% a
Good source of protein	2.0% c	18.4% b	79.6% a
Good source of calcium	2.0% c	16.2% b	81.8% a
Natural	4.5% c	25.4% b	70.1% a
Organic	11.9% c	33.9% b	54.2% a

Percentage of respondents (n=489) with each claim total sums up to 100%
Different letters in a row following percentage signify significant differences ($p < 0.0001$)

CHAPTER 4

INFLUENCE OF BRAND AND PACKAGE ON CONSUMER LIKING OF CHOCOLATE MILK

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4.1. Abstract

The flavored dairy beverage market is increasing due to its special benefits such as unique flavor and nutrition. Chocolate milk varies widely in flavor, color and viscosity, and liking is influenced by these properties. Additionally, package and brand name may influence consumers. The objective of this study was to evaluate the effects of packaging and brand name on consumer liking and purchase intent of chocolate milk. A consumer acceptance test, emotion measurements, and subsequent conjoint survey and Kano analysis were conducted. One hundred and eight consumers evaluated seven chocolate milks with and without brand information in a two day crossover design. Results were evaluated by two way analysis of variance and multivariate analyses. A conjoint analysis survey and Kano analysis were conducted after the consumer acceptance test. Package and brand influenced overall liking and purchase intent for chocolate milks to differing degrees ($p<0.05$). Chocolate milks made with whole milk were positively influenced, and those with lower fat content (1% or fat free) were negatively influenced by brand and packaging information ($p<0.05$). Positive emotions were positively correlated with high purchase intent of products and overall liking ($p<0.05$). A subsequent conjoint analysis (n=250) revealed that fat content was a driver of choice for purchasing chocolate milk followed by sugar content and brand. Brand name was less important for purchase intent of chocolate milk than fat or sugar content. Among fat content of chocolate milk, 2% and 1% fat level were most appealing to consumers, and reduced sugar and regular sugar were equally important for purchase intent. Kano analysis confirmed that fat content (whole milk, 1/2% fat chocolate milk) was an attractive attribute for consumer

satisfaction more so than brand of chocolate milk. Organic labeling did not impact the purchase decision of chocolate milk, however Kano results revealed that having an organic label on a package positively influenced consumer satisfaction of chocolate milk. Findings from this study can help chocolate milk producers as well as food marketers better target their product labels with attributes that drive consumer choice of chocolate milk.

4.2. Introduction

Flavored milk is gaining popularity among children as well as adults due to its special taste along with its ability to meet the dietary requirements for dairy foods in the United States (U.S.). In 2010, about 1.8 million metric tons of flavored milks were produced in the U.S. (International Dairy Foods Association, 2010). The American Dairy Council and the American School Food Service Association revealed that offering flavored milk could be one way to increase milk consumption among children and adolescents (Anonymous, 2003; Murphy et al., 2008) as well as provide nutrients, such as essential macronutrients (Ca, Mg, P, K, Z., and vitamins A, B12, D, and riboflavin (Murphy et al., 2008). Of the flavorings in these milks, chocolate is the most popular flavor in the U.S. (Thompson et al., 2004; Bermudez-Aguirre et al., 2010). Based on that finding, Garey et al. (1990) and Yon et al. (2012) concluded that school children are more likely to drink milk if they are offered chocolate-flavored milk at school. Despite having similar nutritional benefits as regular fluid milk, chocolate milk has been criticized for its high sugar content and higher calorie and fat content compared to regular milk (Johnson et al., 2002; Murphy et al., 2008). In 2005, the

New York City (NYC) Department of Education recommended replacing whole milk with low-fat and/or fat-free chocolate milk to reduce fat intake (Centers for Disease Control (CDC), 2010), and the following year, NYC implemented a ban of whole milk and reduced the availability of sweetened flavored milk in the school lunch system (Golub et al., 2011). Most recently, flavored milk was banned in the LA school system, as part of a child obesity prevention program (Hoag, 2011). However, experts in the Milk Industry Foundation (MIF) raised concern for limiting milk options available to school children, by highlighting the continuous decline of milk consumption and simultaneous increase of competing beverages at schools. They suggested adding sugar or calorie restrictions rather than the exclusion of low fat flavored milk in school meal systems (CMN. 2012).

Several varieties of commercial chocolate milk are available in the market, and these vary in flavor, color and viscosity. Previous research has demonstrated that cocoa aroma/flavor, cooked/eggy and malty flavors were the positive drivers for commercial chocolate milk (Thompson et al., 2004). Later, Thompson et al. (2007) reported ethnic differences in chocolate milk preferences: 71% of Hispanic adults consumed milk with 2% or higher milk fat content, and rarely drank chocolate milk that was less than 2% milk fat while 67% of Caucasians tended to choose low-fat milk and skim milk when drinking chocolate milk. The same study found that the level of fat in chocolate milk was not a differentiating factor among children: children tended to like chocolate milk with high intensities of cocoa aroma and cocoa flavor and dark color (Thompson et al., 2007). Children in general scored flavored milks higher in liking than adults.

Consumer behavior in purchasing food products in the grocery store is a complex psychological, sensory and marketing-related process. Although the sensory perception (especially with regard to flavor) of products has been regarded as the main determinant for consumer choices, other factors such as price, consumer attitudes, and product information also play a role in purchase decisions (Deliza and MacFie, 1996; Guerrero et al., 2000). Among the various types of information on the product package, one of the most ubiquitous and influential pieces of information is the brand name (Guerrero, 1995). Brand and food labels serve as an important communication tool to reach consumers (Dam and Trijp, 2006). Therefore, many studies have been conducted to investigate the effects of brand name in food choices. These studies include investigations with strawberry yogurt (Vickers, 1993), lager beer (Guinard et al., 2001), wine consumption in Ireland (Keown and Casey, 1995), yogurt and yogurt-like products (Bayarri et al., 2010), and crisp snack foods (Bower and Turner, 2001). Taken as a whole, the effect of brand on purchase decision is product-dependent. However, to our knowledge, no study has been published to evaluate the effect of brand name and packaging on purchase intentions with regard to chocolate milk.

Measuring emotions has been researched extensively in many fields, including clinical psychiatry (POMS; McNaire, 1989), social sciences (Russell, 1991), health and nutrition (Gibson, 2006), and consumer research (Desmet, 2004; Laros and Steenkamp, 2005; Desmet and Hekkert 2007; King and Meiselman, 2010). Recently, product developers in food science have started to pay more attention to emotional changes and responses of consumers, because higher liking scores in consumer testing do not necessarily reflect the success of the product in the market (Kempt et al., 2009). Porcherot et al. (2010) reported that information about acceptability was not the same as the information derived from emotion testing. In short, emotion measurements can be used as another tool, in addition to traditional hedonic testing, to understand consumer behavior during the product development process.

Conjoint analysis has been used in market research for years to measure the factors that affect consumer choice (Green and Srinivasan, 1978; Orme, 2006). Conjoint analysis first measures consumer overall judgments about a set of complex alternatives, then individual attributes are evaluated (Green and Wind, 1975). By separating overall concepts into smaller components, conjoint analysis provides valuable information about the relative importance of the attributes of a product. Adaptive choice-based conjoint (ACBC) analysis has been recently introduced. Cunningham et al. (2010) reported that ACBC analysis was more engaging than conventional choice-based conjoint (CBC) analysis to improve utility estimation and to better predict real-world preferences, as the survey itself adapts the choice tasks based on previous responses (Cunningham et al., 2010).

Kano analysis is another tool to model consumer satisfaction and/or dissatisfaction with a product. Must-have attributes are the ones that lead to extreme consumer dissatisfaction if absent; however; must-have attributes do not necessarily increase satisfaction if they are present. One-dimensional attributes are those that show linear increments of customer satisfaction with the fulfillment of those attributes. Attractive attributes are unexpected attributes that can lead to greater satisfaction if present; therefore, attractive attributes are also called exciters, as they surprise consumers unexpectedly. Indifferent attributes are those that do not affect consumer expectations of the product.

Among the attributes in the Kano model, one-dimensional attributes are the most important because these attributes are considered to be the drivers of consumer satisfaction. Ullah and Tamaki (2011) suggested Kano analysis as a solution for identifying hidden customer needs. Moreover, the results from Kano analysis can provide valuable guidance along with conjoint analysis (a trade-off situation) during the product development process (Conklin et al., 2004; Chen and Chuang, 2008).

To our knowledge, no study had been conducted to investigate the effects of packaging and brand name on consumer liking and the purchase intent of chocolate milk. Therefore, the objective of this study was to evaluate the effects of packaging and brand name on consumer liking and the purchase intent of chocolate milk. A consumer acceptance test, emotion measurements, and subsequent conjoint survey and Kano questionnaire were conducted.

4.3. Materials and Methods

4.3.1. Experimental overview

Consumer acceptance testing was conducted using a two-day cross-over design (Figure 1). Briefly, participants for the acceptance test (n = 108) were recruited from an internet survey. All participants were informed prior to the test that they were required to participate both days. On a given day, 50% of participants evaluated 7 unbranded samples, and 50% of participants evaluated 7 branded samples. For the unbranded sample evaluation set, the participants evaluated coded samples that did not show any packaging information, such as brand name, fat content, sugar content, or organic labels. For the branded samples evaluation set, the participants evaluated samples with a picture of the package that provided the brand name, fat content, sugar content and whether the samples were organic/conventional. For example, a picture of the commercial package of the chocolate milk was provided while consumers evaluated the samples. In addition to the tasting component of the evaluation, a picture of each commercial labeled package/container was evaluated separately for purchase intent after the unbranded sample evaluation to gather information about brand equity. That is, the order of presentation for the unbranded samples focused on the unbranded sample evaluation set: i.e., blind tasting, and then evaluation of the commercial package label. The participants were not able to match the commercial package with the chocolate milks tasted, because the order of presentation within the unbranded tasting set and the order of presentation within a commercial package picture evaluation set were balanced and randomized.

One week later, acceptance testing was conducted with the same group of participants for the second day of testing. Those participants who received the branded evaluation set to taste on day 1 received the unbranded sample set to taste (unbranded sample evaluation and brand-only picture evaluation), and those participants who received the unbranded sample set on day 1 to taste evaluated 7 branded samples on day 2. Emotion measurements were conducted at the screener stage for all consumers, which was prior to the consumer acceptance testing and immediately after the branded sample tasting, after the blind sample tasting, and after the picture evaluation. A conjoint analysis survey was subsequently performed in order to confirm which attribute(s) on the container, such as fat content, brand name, sugar content, and organic vs. conventional were the most influential in consumer purchase intent of chocolate milk. Along with the conjoint analysis survey, a Kano functional/dysfunctional questionnaire (Berger et al., 1995) was included to gather further information about the attributes that drive consumer satisfaction of chocolate milk.

4.3.2. Sample Selection for Consumer Acceptance Test

Various types of chocolate milk were selected based on market share and availability: one national brand (Nesquik® — low fat, fat free), one regional brand (PET — whole milk, low fat), one store brand (Food Lion – whole milk, low fat) and one organic brand (Organic Valley – 2% fat). If whole milk and fat-free versions were not available for one of these brands, then others were selected. For each brand, a low-fat and a whole fat version were selected, except for the organic brand, which was available only as a 2% fat version. A total of 7 types of chocolate milk were evaluated. All of the types were purchased locally and were at a minimum within two weeks of their pull date. After purchase, the chocolate milk containers were kept at 4˚C until the day of the test.

4.3.3. Consumer Acceptance Testing

Consumer acceptance testing was performed in compliance with the North Carolina State University (NCSU) Institutional Review Board. Consumers were recruited through e-mail list-servs and internet postings on-campus and from an online consumer database of 4,000 individuals in the Raleigh, North Carolina area maintained by the NCSU Sensory Service Center. A screening survey was created using SSI Web (Sawtooth Software Version

7.12, Sequim WA). One hundred and twenty consumers were recruited, and 108 consumers participated in the consumer acceptance test. Target consumers consisted of U.S. consumers aged 19 to 65 with an even distribution of each age bracket (10 years). All participants were chocolate milk acceptors and at least occasional chocolate milk consumers (drink chocolate milk at least once every two months). A two-day cross-over design (Schantz and Pontius, 1994; Cloephas and Zwinderman, 2002) was used for presentation format (brand versus no brand) with a one-week interval to avoid any carry-over effects due to memory.

Chocolate milk was served at 4˚C. Overhead lights in the kitchen were turned off to minimize light exposure to the samples. Prior to serving, each container of chocolate milk was screened for atypical flavor by two highly experienced (> 1000 h) judges. Chocolate milk (30 ml) was poured into 3-digit coded 207 ml clear plastic tumblers (Waddington North America Inc., Chelmsford, MA). Compusense® Five version 5.2 (Compusense, Guelph, ON, Canada) was used for data collection. All participants were compensated with a $20 grocery gift card on their second day of participation.

On the first day of the test, all participants were asked to answer a brief questionnaire containing 11 demographic questions that included consumption characteristics. For the chocolate milk evaluation, the participants first looked at samples and evaluated the visual appearance and color on a 9-point hedonic scale. Then, participants were instructed to taste the sample and to evaluate it for overall liking, chocolate flavor liking, sweetness liking, texture/mouthfeel liking, and aftertaste liking. Specifically, "just about right" (JAR) questions were asked along with liking questions for chocolate flavor, sweetness, and texture/mouthfeel. Participants used a 9-point category scale anchored on 1 = dislike extremely to 9 = like extremely for the liking attributes, and a 5-point JAR scale anchored on 1 = not at all, 3 = just about right and 5 = too much. In the case of the branded tasting, the picture of the corresponding chocolate milk container (that showed brand name and label information) was presented prior to tasting, and consumers were able to recall the picture while evaluating the corresponding sample. Purchase intent questions also were asked to consumers before and after tasting the product as well as at the picture-only stage after the unbranded sample evaluation set to evaluate the changes in purchase intent with and without tasting the product. Purchase intent was scaled using a 5-point category scale anchored with 1 = definitely would not purchase, 3 = may and/or may not purchase and 5 = would definitely purchase. The order of presentation for the chocolate milk samples was balanced and randomized within each session, and the order of presentation for the brand-only evaluation for the unbranded sets was balanced and randomized within each session.

4.3.4. Emotion Measurements

During consumer acceptance testing, 16 emotions also were measured at four different stages (Table 1). These 16 emotions were selected based on the appraisal theory derived from Johnson and Stewart (2005). Their appraisal theory states that emotions emerge when the experience is compared to a goal, and individuals appraise the experience by comparing the experience to the goal in his/her mind. Appraisal theory emphasizes that a situation based on the individual's unique experience, expectations and goals ultimately becomes a determinant of the individual's emotional responses. The eight positive emotions (happy, hope, admire, satisfied/pleased, joyous, excited, love, delighted) and eight negative emotions (shame/guilt, anxiety, contempt/anger, disappointed, disgusted, afraid/uncertain, frustrated, miserable) that were employed in this study were taken directly from the Johnson and Stewart (2005) study. Statements that matched the 16 selected emotion terms were written to be more applicable to each stage of emotion measurement (Johnson and Stewart, 2005). At the screener stage, the emotion questionnaires were aimed at measuring the participants' ideas about chocolate milk. At the unbranded sample stage, the questionnaires were intended to measure the participants' experience of tasting blind samples. At the branded sample tasting stage, the questionnaire was aimed towards the participants' experience of tasting samples when the brand name was known. At the brand-only stage (after the unbranded sample tasting), the statements were aimed toward the evaluation of the idea about the brand name itself without tasting the product. The participants were asked to answer each emotion-based statement on a 5-point category scale anchored with 1 = do not agree at all to 5 = definitely agree.

4.3.5. Conjoint Analysis

A conjoint analysis survey was conducted after consumer acceptance testing to define more clearly the attributes that drive consumer purchase behavior of chocolate milk. An online survey was created using SSI web (Sawtooth Software version 7.0.22, Sequim, WA). Four attributes (brand name, fat content, sugar content and organic claim) were chosen based on the availability of the products in the current market and the types of product that were used in the consumer acceptance test (Table 4). Levels (contents) of product attributes that were not available in the current market were also included to determine the extent to which consumers would assign utility to those products if they were available to them. The survey was designed as an ACBC analysis model using one build-your-own (BYO) sequence (SSI web version 7.0.22). The BYO sequence was followed by six screening tasks with four product concepts per task, with the possible responses of a possibility or won't work for me for each product concept (Cunningham et al., 2010). A minimum of one and a maximum of two attributes varied from the BYO selections for each product concept. Three unacceptable questions and two must-have questions also were built into the survey. The screening task selection was followed by 14 choice task tournament sections with a minimum of 3 concepts per choice task. Root likelihood (RLH) values were analyzed to remove any respondents that showed an RLH value of 0.25 or lower.

Once the survey was completely constructed, the survey was uploaded to an internet server, and consumers (n=250) were recruited through e-mail list-servs and internet postings on campus and from an online consumer database of 4,000 individuals in the Raleigh, NC area maintained by the NCSU Sensory Service Center. Once the respondents passed the demographic screener, participants who were under 18 and never had consumed chocolate milk were eliminated from the survey. After the demographic questions, consumers began to answer a series of trade-off scenarios containing the predefined attributes and levels presented in Table 4. Respondents then answered a series of Kano-related questions (described in the Kano analysis section of this paper).

Respondents who completed the entire conjoint analysis survey were entered into a drawing to receive a $20 gift card to a local shopping store. Once the target number of participants completed the survey (n = 250), utility scores were extracted and rescaled using a zero-centered difference method (Orme, 2010; Jervis et al., 2012).

4.3.6. Kano Analysis

A carefully designed Kano-related questionnaire was given to the participants after the conjoint survey to determine the ways the attributes of chocolate milk affected customer satisfaction/dissatisfaction. The attribute levels were presented in a balanced and randomized order within a satisfaction questionnaire and dissatisfaction questionnaire series. That is, the Kano-related attributes were balanced and randomized in both satisfaction and dissatisfaction questions (Berger et al., 1993). The satisfaction question was: If you have the following choices for chocolate milk, how would you feel? The choices for the attribute levels were: Your chocolate milk is made by xyz, where xyz represents the attribute level; for example, your chocolate milk is made by Nesquik. The dissatisfaction question was: If you have the following choices for chocolate milk, how would you feel? The choices for the attribute levels were: Your chocolate milk is not made by xyz, where xyz represent the attribute levels: for example, your chocolate milk is not made by Nesquik. Attribute levels were presented in a balanced and randomized order within satisfaction questionnaire and dissatisfaction questionnaire series. The answer choices for the satisfaction/dissatisfaction questions were: like, must have, do not care, can live with it, and dislike (Xu et al., 2008).

4.3.7. Statistical analysis

Data analysis was performed in XLSTAT (Version 2010. 5.02; Addinsoft, Paris, France). Two-way analysis of variance (ANOVA) was conducted using a general linear model. The fixed effects were brand name (branded vs. unbranded) and treatment (7 types of chocolate milk) and their interactions. Day effects also were measured as random effects; however, there was no day effect between the two days of testing ($p > 0.001$). For the consumer tests, ANOVA followed by Tukey's Honestly Significant Difference (HSD) were used for all liking scores, and penalty analysis was conducted for all JAR scores. The demographic and behavior questions were analyzed for frequency of choice. Individual utility scores were extracted by hierarchical Bayesian (HB) estimation and rescaled using a zero-centered difference method (Childs and Drake 2009; Orme, 2010). Principal component analysis (PCA) of clusters was performed on individual utility scores. All statistical analyses were carried out at a 95% significance level.

4.4. Results and Discussion

4.4.1. Cross-over design

A cross-over design is an experimental design that minimizes the variability among subjects when evaluating several treatments (Schantz and Pontius, 1994). However, the statistical power and model may be compromised if the responses in the first period carry over into the second period (Schantz and Pontius, 1994; Cloephas and Zwinderman, 2002).

In this study, the carry-over effects between day 1 and day 2 were investigated prior to further analysis. No significant day effects on the presentation order ($p > 0.001$) were evident.

4.4.2. Consumer Acceptance Test

A total of 108 consumers participated in the study. Table 2 presents the consumption characteristics and demographics of the participants of the consumer acceptance test. The participant primary choice of fat content in chocolate milk varied: 29% of participants chose whole fat chocolate milk; 45% of participants drank low/reduced fat chocolate milk; and 27% participants chose fat-free chocolate milk. When asked about the factors that affected their purchase intent of chocolate milk, flavor was the most influential factor on the purchase intent (90%), followed by price, brand name and nutrition. The following brands were selected as the most frequently purchased: Nesquik® (71%), PET (44%), Organic Valley (24%), and store brand (57%).

Internal preference mapping was used to model the consumer perceptions of chocolate milk (Figure 2). Overall liking and other liking attributes (chocolate milk liking, sweetness liking and texture liking) were positively correlated to PC1 (75% variability). Chocolate flavor and overall liking were highly correlated ($p < 0.05$; $r = 0.86$), and thickness/viscosity and sweet taste liking and overall liking were highly correlated ($p < 0.05$, $r = 0.87$ and 0.80, respectively). From penalty analysis (data not shown), milks 2 and 4 were too weak in chocolate flavor ($p < 0.05$). Milk 2 was penalized for being too sweet, and milk 4 was penalized for not nearly sweet enough ($p < 0.05$). These results suggest that high chocolate flavor, typical thickness and sweet taste drive consumer liking of chocolate milk, consistent with previous studies (Thompson et al., 2004). Appearance liking was the dominant attribute of PC2, which explained 19% of the consumer responses. No differences were noted in the appearance liking scores (Table 3). Thompson et al. (2007) demonstrated that the color of chocolate milk was less influential than chocolate flavor and sweetness. In the current study, appearance liking was not a differentiating attribute among the chocolate milks (Table 3). Chocolate milks 3 and 6 were made with whole milk, and were highly associated with overall acceptance regardless of branding (Figure 2). Chocolate milks 1, 2, 4 and 5 were not liked, regardless of branded or blind tasting (Figure 2). These chocolate milks were made with fat-free milk (Milk 2), 1% milk (Milk 4), and 2% milk (Milks 1 and 5). Breweret et al. (1999) revealed that consumer preferences for 2% and/or whole fat chocolate milk were higher than 1% or lower fat milk, and that liking scores increased with increasing fat content. Whole milk chocolate milk was preferred regardless of brand information in the current study.

Two-way ANOVA was conducted to determine the effect of brand/package label on overall acceptance of chocolate milks. There was a significant treatment and brand/package label interaction for overall acceptance ($p < 0.001$; Figure 3). Overall acceptance of milks 2 and 4 decreased when tasted with knowledge of brand and package label ($p<0.05$). Milk 2 was the national brand of fat-free chocolate milk and milk 4 was the regional brand 1% fat chocolate milk. The higher fat versions of milks 2 and 4 (milks 1 and 3) did not show any difference in overall acceptance with and without brand/package label, suggesting that fat content played a larger role on changes in overall acceptance scores than brand recognition. Milks 6 and 7 were store brand chocolate milks, and no differences were observed for overall liking scores with and without the presence of brand/packaging information (Figure 3). Besides overall acceptance of chocolate milks, there was a significant treatment and brand/package label interaction for flavor liking and sweet taste liking of chocolate milk ($p<0.05$; data not shown). Brand and package label positively influenced chocolate flavor liking as well as sweetness liking of chocolate milk 3, the regional brand full fat milk. Other milks were not influenced by brand/packaging label for chocolate flavor liking and sweetness liking ($p>0.05$; data not shown). There were no treatment and brand/package label interactions for appearance and texture/mouthfeel liking ($p>0.05$). Previous studies reported that national brands were viewed as superior to store brands in terms of taste, appearance, labeling and variety of choice of 5 different products, such as cheese, chips, dip, cookies, and jelly (Richardson et al., 1994). Interestingly, the current study did not find an overall positive effect of national brand over store brand or brand in general, and were not in agreement with Richardson et al. (1994). Rather, this study found the influence of fat content on the overall likings of chocolate milks.

Two-way ANOVA w as also conducted to determine the effect of brand/package label on overall purchase intent of chocolate milks. There were significant treatment and brand/package label interactions ($p < 0.001$; Figure 4). Brand influence on consumer purchase intent was similar to that observed with overall liking (Figure 3). Overall, the purchase intent of lower fat chocolate milks (Milks 1, 2, 4, and 5) decreased regardless of brand ($p<0.05$). The purchase intent of whole fat chocolate milk (Milks 3 and 6) increased ($p<0.05$) after tasting (Figure 4). The purchase intent of Milks 1, 2, 4 and 5 decreased ($p < 0.05$) after the participants knew the brand/package label of the chocolate milk that they tasted (branded tasting). Milk 2 was the fat-free version of chocolate Milk 1 and Milk 4 was the lower fat version (1%) of chocolate milk 3, and 5 was a low fat organic brand. Once again, this result suggested that low fat and/or fat free chocolate milks decreased purchase intent after participants linked the brand/package label of the milks that they tasted (Figure 4).

The brand did not appear to play as large of a role as fat level. Milks 1 and 2 were the same brand, and Milks 3 and 4 were same brand but different fat level chocolate milks. Different effects of brand/packaging label on purchase intent were observed between two fat levels within one brand. Purchase intent of milks before tasting and brand only evaluation were not different ($p > 0.05$), as expected (figure 4). The purchase intent before tasting and purchase intent of brand only evaluation measured consumer expectations of brand, therefore this result (Figure 4) confirmed the brand equity of each brand: national, regional, store and organic brand. Brand equity is often known as an image of brand, and/or a brand beyond the physical assets associated with its manufacture or provision (Biel, 1992). Torres-Moreno et al. (2012) showed that expected purchase intent of dark chocolates was mainly affected by the chocolate brand: the proportion of consumers who would probably or definitely purchase the sample was significantly higher for premium brand samples than for the store brand samples, when evaluating just packaging of dark chocolate products. The regional brand may have been perceived as a more premium brand than the store brand in this study, however the same brand but different fat content (Milk 3 and 4; Milk 6 and 7) showed different trends (Figure 4). Therefore the factors influencing purchase intent of chocolate milk were not solely dependent on brand, but more dependent on fat content. Interestingly, the purchase intent of national brand chocolate milks (Milks 1 and 2) decreased after consumers tasted products ($p < 0.05$) regardless of fat level. This result suggests that the consumers recognized the national brand and viewed the national brand as superior to the store brand initially, which is in agreement with Richardson et al. (1994). However disappointment occurred after tasting the national brand chocolate milk, which negatively impacted purchase intent. However, both milks 1 and 2 were 2% fat and fat free versions of chocolate milk, therefore the fat content may also have influenced this trend.

The organic brand chocolate milk (Trt. 5) did not show any difference in overall liking scores between the branded and non-branded taste scenarios (Figure 3). However, the purchase intent decreased after consumers tasted the product when consumers were aware of what brand they were to taste (Figure 4). These differences could be due to the high intensity of aftertaste in this product, which was revealed from penalty analysis (data not shown), or due to the organic brand itself. Bower and Turner (2001) reported that the purchase intent for a product with high liking scores decreased when high price information was displayed. Organic milk typically has a higher price than conventional milks (Smith et al., 2009), which may have influenced the decrease in purchase intent after consumers linked the organic brand chocolate milk to the sample they tasted. The overall liking and purchase intent of chocolate milks were affected by fat content as well as brand information. Since brand and label information were confounded, individual effects could not be discerned. Therefore, a follow-up conjoint analysis was conducted to clarify the drivers of consumer choice of chocolate milks.

4.4.3. Emotion measurements

Consumers also evaluated emotion measurements when chocolate milks were evaluated. Sixteen selected emotion terms, as suggested from the appraisal theory (Johnson and Stewart, 2005), were used in this study. First-person emotions (happy, hope, shame, anxiety, joy, delighted, afraid, and depressed) were used to measure the personal experience of drinking chocolate milk. Objective emotions (satisfied, hope, disappointed, uncertain, irrelevant, delighted, excited, miserable, and afraid) were used in this study to measure the emotion directed towards chocolate milk itself. The eight positive and eight negative emotions from the Johnson and Stewart (2005) study were employed for this study, and within these 16 emotion terms, emotions related to personal experience and emotions towards an object (chocolate milk) were measured to determine the emotions that differentiated chocolate milks (Johnson and Stewart, 2005).

Principal component analysis was conducted to characterize the 16 emotions as well as overall liking and purchase intent scores and chocolate milks (Figure 5). PC1 explained 76% of the emotion measurements, and indicated significant differentiation of the positive and negative emotions; the positive emotion terms were located on the positive axis, and the negative emotion terms were on the negative axis. Along this axis, milks 3 and 6 (regardless of the presence of brand information) showed high correlation with positive emotions, such as happy, satisfied, hope, joy and delighted. Overall liking and purchase intent also were highly associated with these positive emotions ($p < 0.05$; Table 4 and Figure 5). First-person-anxiety and object-uncertain were explained primarily on PC2, which explained 11% of the emotion measurements, and object-irrelevant was correlated with PC3 (6% variability; data not shown). Milks 3 and 6 were further differentiated on PC2, which was differentiated by first person-anxiety and object-uncertain emotion terms (Figure 5). Milks 6 and 7 were store brand chocolate milks, and they were highly associated with first person-anxiety and object-uncertain (Figure 5) regardless of fat level. Varela et al. (2010) revealed that the brand and package information had a large impact on consumer liking score only for well-recognized brands. The store brand selected in this study may have been an unfamiliar brand to consumers. Fifty-seven percentages of participants were primary store brand users for chocolate milk consumption (Table 2), but not necessarily Food Lion, the store brand used in this study. Also, object-uncertain and first person-anxiety were highly correlated (R=0.69; Table 4). The unfamiliar brand may have given a person anxiety due to uncertainty of milk quality.

Overall liking was highly associated with positive emotion terms (happy, hope, satisfied, joy, delighted, and excited) and negatively associated with negative emotion terms (shamed, disappointed, afraid, and miserable; Table 4). Desmet and Schifferstein (2008) concluded that positive emotions were reported more frequently than negative emotions in terms of food products, because food products are designed to be satisfying. In other words, consumers chose food products because they want to consume, which is a concept referred to as hedonic asymmetry (Desmet and Schiffersten, 2008). In this study, positive emotions were highly associated with overall liking and the purchase intent of chocolate milk, thereby confirming hedonic asymmetry found from Desmet and Schiffersten (2008). Interestingly, first-person-anxiety and object-irrelevant did not correlate to other emotion terms nor to overall liking and purchase intent, which suggested that these emotion terms were not high impact emotions to overall liking and purchase intent of chocolate milks ($p > 0.05$; Table 4).

4.4.4. Conjoint analysis

To separate intrinsic cues (fat level and associated taste and flavor) and extrinsic cues (brand name and nutrition information), conjoint analysis was conducted. From consumer acceptance testing, overall liking and purchase intent of chocolate milks were affected by fat content as well as brand information, however it was not clear which attribute was more important to consumers to make purchase decisions for chocolate milk.

A total of 250 respondents completed the survey. No respondents had RLH values 0.333 or below, so no responses were removed from the data analysis. A utility score explains how attractive each attribute/level used in the conjoint analysis is; therefore, higher utility scores indicate more appealing attributes. Negative utility values do not necessarily indicate an attribute is unappealing/non-driver, but less appealing than positive utility values (Orme, 2006). Utility values cannot be compared between attributes; therefore, utility values within one attribute were compared in this study (Figure 6). Zero-centered utility scores for consumer responses ($n = 250$) show that PET (regional brand) had the highest utility as a brand for purchasing chocolate milk, followed by Nesquik® (national brand), Store brand, Organic Valley (organic brand) and Darigold (an unfamiliar brand). The Darigold brand did not have a market share in North Carolina and this brand was added to determine how an unknown brand performed in comparison to known brands. Hoyer and Brown (1990) reported that brand awareness had a considerable effect on consumer choice. Darigold received the lowest utility score among the brand attributes, which confirms the findings from Hoyer and Brown (1990). Varela et al. (2010) also showed a large impact on consumer liking scores for well-recognized brands of orange-flavored powdered drinks. In this study, a regional brand as well as a national brand received the highest utility scores among the brand attribute (Figure 6). Guerrero et al. (2000) investigated consumer attitudes towards store brands and found that women showed a more positive attitude towards a store brand than men (Guerrero et al., 2000). Seventy-six percent of the participants in the conjoint analysis survey were women. Olsen et al. (2011) also revealed that the consumers with a positive attitude towards private label/store brand were more likely to choose private labels instead of national brand (Olsen et al., 2011). The participant demographic may have influenced this result.

In terms of the fat content of chocolate milk, 2% milk received the highest utility value, followed by 1% milk, fat-free milk and whole milk. The proportion of consumers who primarily chose 2% fat chocolate milk were 40% and 39% for whole milk (Table 6, total population n=250). The label 2% fat milk is appealing to consumers. Studies with Cheddar cheese (2% reduced fat cheese was most appealing; Childs and Drake, 2009) and latte-style beverages (Jervis et al., 2012) have demonstrated its appeal. A previous study (Kim et al., in press) also revealed that consumers preferred to see a "reduced" claim over a "free" claim for unhealthy nutrients such as fat, sodium and sugar. As such, the conjoint analysis results from the current study are in agreement with previous studies except for the utility score of whole milk chocolate milk. Whole milk chocolate milk received the lowest utility score by conjoint analysis, while 24% of participants chose whole milk chocolate milk as their primary choice of chocolate milk. From the current study of consumer acceptance testing, whole milk chocolate milks (milks 3 and 6; Table 3) were also highly accepted compared to lower fat chocolate milk. Jaeger (2006) concluded that consumers typically trade several sensory and non-sensory factors when making every day food choices. Childs and Drake (2009) reported that the consumers still do not want to sacrifice flavor while seeking lower fat alternatives. The current study may be a good example of consumer language discrepancy, where consumers are conscious about purchase of lower fat products, but actually purchase higher fat products.

Among sugar levels of chocolate milk, a reduced sugar option was at parity with regular sugar (no sugar reduction) in chocolate milk ($p > 0.05$), but a sugar-free label was less appealing ($p < 0.05$). From the current study as well as previous studies (Thompson et al., 2004, 2007), the sweetness of chocolate milk is one of the drivers of liking, therefore consumers may not find sugar-free chocolate milk as appealing as milk with sugar. Sixty percent of the conjoint analysis participants responded that they were moderately or more interested in reduced sugar chocolate milk. There was no difference in utility scores between conventional and organic labels ($p > 0.05$). Only 22% of participants in the tasting part of this study responded that the organic seal influenced the purchase intent of chocolate milk (Table 2). Shepherd et al. (2005) showed a discrepancy between attitudes and behavior for organic products. People were positive about organic foods but often did not purchase them. Kiesel and Villas-Boas (2007) demonstrated that the USDA organic seal on the food label increased the probability of purchasing organic milk. However, an organic label does not seem to provide more appeal than conventional chocolate milk.

Another measure that can be generated by conjoint analysis is relative importance, which indicates how important each attribute is to the whole product (Orme, 2006). Figure 7 presents the attribute importance (%) scores for the total population and three identified clusters. Among the four attributes (fat, brand name, sugar and organic), the attribute that was the most important in the purchase intent of chocolate milk was fat content, followed by sugar content, brand name and organic label for the total population (n = 250). This finding clarified the uncertainty surrounding the branding/packaging effects in the acceptance test (Milks 3 and 6). Milks 2 and 4 decreased in overall liking and purchase intent after the participants knew the brand name of the chocolate milk. Based on the consumer acceptance test results alone, it was not clear if these effects were due solely to fat content or to the brand name of the chocolate milk. However, conjoint analysis of the total population (n = 250) confirmed that fat content drove the purchase intent of chocolate milk, and that the brand name was less appealing to consumers than fat content, when they purchase chocolate milk.

Segmentation of the respondents was conducted based on patterns found in the reported utility scores, and three distinct clusters were identified (Figure 7 and Table 6 and 7). Clusters 1 and 2 were similar: fat was their driver of choice (Figure 7). Cluster 1 consumers responded that fat was the driver of choice, followed by brand and sugar and an organic claim had the lowest contribution to purchase of chocolate milk. Among fat levels, whole milk and 2 % fat chocolate milk had the highest utilities, and fat free had the lowest utility score (Table 7). Nesquik and PET showed the highest utility scores followed by store brand. Cluster 1 members gave reduced sugar a high utility for sugar claim of chocolate milk (Table

7). This trend is shown in the principal component biplot in Figure 8. Cluster 1 has a higher correlation with Nesquik, a regular sugar level chocolate milk than other clusters. Cluster 1 consisted of 79% females, 60% of cluster 1 consumers were between 25 to 44 y, and 53% of cluster 1 consumers responded that brand was one of the factors influencing purchase of chocolate milk. Forty-eight percent of Cluster 2 respondents (n = 110) indicated that fat content was their driver of choice, followed by sugar (27%), brand (14%) and organic claim labeling (11%; Figure 7). Table 7 showed that 1% chocolate milk and/or fat- free chocolate milk had the highest utility values in cluster 2 participants, which differed from the results for Clusters 1 and 3. Figure 8 demonstrated the distinct differentiation of Cluster 1 and Cluster 2 characteristics. PC1 was differentiated by whole fat (positive) and fat free (negative; Figure 8). The whole milk and 2% fat chocolate milk received high utility values among cluster 1 consumers, and were shown positively correlated to these two fat levels in Figure 8. Fat free and 1% fat chocolate milk received high utility values from the Cluster 2 members (Table 7), and it is also shown in Figure 8. Brand name was not a differentiating attribute for Cluster 2 participants. Reduced sugar option received the highest utility score for the sugar attribute, and an organic option received a higher utility values than a conventional label for Cluster 2 consumers (Table 7). The main difference between Cluster 1 and Cluster 2 consumers was found on how consumers perceived brand as a important driver of choice. Cluster 1 consumers perceived brand as equally important as sugar content, while Cluster 2 members chose sugar as more important attribute than brand name for chocolate milk. Fat was the leading driver of choice for both clusters. It is important to note that whole milk and 2% fat milk received high utility scores from Cluster 1 respondents, but fat free and 1% fat milk received high utility scores from Cluster 2 respondents (Table 7). The respondents in Cluster 2 had relatively large families: 11% live with 5 or more people in the household, which was a higher percentage than for the other clusters. Sixty-two percent of the respondents in Cluster 2 responded that their eating habits were healthy. They did not necessarily read labels often, nor were they interested in reduced fat/sugar in food. However, the conjoint analysis revealed that Cluster 2 respondents were more health-conscious than the respondents for the other clusters, as fat and sugar received higher importance scores and fat-free and/or 1% fat in fat attribute, and reduced sugar in sugar attribute were identified as the drivers of choice for Cluster 2 participants.

Cluster 3 (n = 93) respondents were different than clusters 1 and 2. Figure 7 shows that their driver of choice in choosing chocolate milk was sugar (the highest), followed by fat content. When looking at zero-centered utility values for attributes and levels in Cluster 3 (n = 93), Darigold had the lowest utility value of all the brands (Table 7); however, brand name was not a differentiating attribute for the Cluster 3 participants (Figure 7). Chocolate milk with 2% fat had the highest utility value, followed by whole milk, 1% fat and fat-free chocolate milk. Thirty-six percent of consumers in Cluster 3 chose 2% fat chocolate milk as their primary choice followed by fat-free milk. Regular chocolate milk with sugar (i.e., non-reduced sugar) had the highest utility value followed by reduced sugar, and sugar-free chocolate milk. Interestingly, Cluster 3 was the only group to have a higher utility score for the regular sugar option for chocolate milk, as shown in Figure 7. From the demographics of cluster 3 (Table 6), 70% of respondents in this group reported their weight as higher than normal, and 48% of respondents reported their eating habits were non-healthy (Table 6).

When comparing organic milk to conventional milk, organic chocolate milk received higher utility values than conventionally made chocolate milk for Cluster 3 participants. Overall, sugar reduction was not a driver for Cluster 3 participants (Figure 8); rather regular sugar level was a strong driver of choice in Cluster 3 members.

In summary, fat was the most important driver of choice in Cluster 1 (n=47) and Cluster 2 (n=110) members. The difference between Cluster 1 and Cluster 2 was found in how the members viewed brand. Cluster 1 members perceived brand as equally important as sugar content, however Cluster 2 members chose sugar as more important attribute than brand name for chocolate milk. Sugar was a driver of choice in Cluster 3 (n=93) members. Organic received the lowest important scores from all three clusters, suggesting that organic chocolate milk is not an important driver of choice in chocolate milk.

4.4.5. Kano analysis

Conjoint analysis helped to determine the drivers of choice of a product, and Kano analysis helped to confirm the drivers of consumer satisfaction of a product. This study investigated the impact of each attribute and level of attribute on consumer satisfaction, specifically to determine: 1) the information that played a role in customer satisfaction and/or dissatisfaction, and 2) whether the findings from the Kano analysis agreed with the findings from the conjoint analysis. The Kano classifications for each attribute and level of attribute used in the conjoint analysis: first for all respondents (n = 250), then segmented from the cluster analysis derived from the conjoint analysis are shown in Table 6 and 7. As identified in the conjoint analysis, fat content-related attributes, such as whole fat, 2% fat, and 1% fat, were identified as attractive attributes, whereas the other attributes were indifferent attributes except for conventional ingredients among the total population (n = 250). Attractor attributes are items that provide satisfaction if they are fully achieved; however, they do not cause dissatisfaction if they are not fulfilled (Kano et al., 1984; Xu et al., 2009). Attractor attributes were also known as exciters, as they surprise consumers unexpectedly. Interestingly, the conjoint analysis results showed that fat content was one of the drivers of choice in chocolate milk; however, the Kano analysis results suggest that fat content was an unexpected attribute that contributes to consumer satisfaction (attractive). It is important to note that other attributes were considered to be indifferent attributes, which meant that these other attributes do not contribute to either consumer satisfaction or dissatisfaction with regard to choice of chocolate milk, while fat content contributed to consumer satisfaction.

The conjoint analysis results indicated that Cluster 1 respondents considered fat content to be the most important attribute, followed by sugar and brand name. In terms of the fat content, whole chocolate milk and 2% fat chocolate milk received the highest utility values, and reduced sugar received the highest utility value as a sugar content attribute from conjoint analysis. A similar trend was found in the Kano analysis in that whole fat, 2% fat and 1% fat content were classified as attractors while the fat-free option was an indifferent attribute for Cluster 1 participants. In terms of the sugar attribute, Cluster 1 participants gave the reduced sugar option a high utility score (Table 7) from conjoint analysis and the Kano analysis revealed that reduced sugar as well as regular sugar were classified as attractors for Cluster 1 participants. Among the different brands, PET, the regional brand in North Carolina, was an attractor for Cluster 1 participants. Fat content, and to a lesser extent, sugar and brand name, were identified as drivers of choice for chocolate milk from the conjoint analysis of Cluster 1. Cluster 2 members from conjoint analysis indicated that fat content was the most important attribute, followed by sugar content. The Kano analysis showed that 2% fat and fat-free chocolate milk were more attractive for these consumers than the other fat contents. It is important to note that 41% of Cluster 2 participants ($N_{cluster2}$=110) chose 2% chocolate milk, and 20% chose fat-free chocolate milk as their primary choice, and fat free and/or 1% fat chocolate milk received high utility scores in fat attribute from conjoint analysis. These Kano analysis results were in line with the conjoint analysis results and consumer consumption characteristics. Similar to the findings for Cluster 1, reduced sugar and non-reduced sugar options were attractor qualities for Cluster 2 participants, whereas sugar-free was classified as an indifferent attribute, which means it did not make a difference to consumer satisfaction. The reduced sugar option received high utility scores from conjoint analysis. Unlike Cluster 1, brand received the lowest utility score from conjoint analysis from Cluster 2 consumers, and Kano analysis also showed that all five brands were classified as indifferent attributes for Cluster 2. It is worth noting that organic ingredients were classified as attractors for Cluster 2 and Cluster 1 consumers. However, an organic label was not an important driver of choice for chocolate milk from conjoint analysis, therefore the result from conjoint analysis and Kano analysis on organic ingredients for Cluster 1 and 2 consumers were not in agreement. Again, the objective of Kano analysis is to find the driver of consumer satisfaction of a product, where as conjoint analysis is performed to determine the driver of choice. Based on these results, it can be concluded that an organic label is important to increase satisfaction of chocolate milk, however it does not drive the choice of chocolate milk.

Cluster 3 consumers from conjoint analysis were different than the Cluster 1 and 2 consumers: sugar content was the driver for Cluster 3 participants. The Kano analysis revealed that regular sugar (i.e., the non-reduced option) was an attractor attribute among the sugar content attributes, which indicated that the non-sugar reduced option (regular sugar level) could contribute to consumer satisfaction of chocolate milk. This result is in agreement with the conjoint analysis results that regular sugar levels received the highest utility value for sugar content attributes from cluster 3 consumers. The Kano analysis showed that whole fat, 2% fat and 1% fat content also were classified as attractor attributes, whereas fat-free was an indifferent attribute in terms of consumer satisfaction of chocolate milk for Cluster 3 participants. From conjoint analysis, 2% fat level received the highest utility score of fat attributes from Cluster 3 consumers.

Kano analysis and conjoint analysis results were generally in agreement. Analyzing the data from different perspectives allowed a confirmation of which of the attributes were important for consumer choice of chocolate milk

4.5. Conclusions

This study investigated the effects of packaging and brand name on consumer choices of chocolate milk. Overall, consumer acceptance of chocolate milk was influenced by the presence of brand and package label information. Chocolate milks made with whole milk were positively influenced, and those with lower fat content (1% or fat free) were negatively influenced by brand and packaging information ($p<0.05$). Among the information shown on the package of chocolate milk, fat content was the driver of choice for purchasing chocolate milk, followed by sugar content, and brand. Brand name had a lesser impact on purchase intent for chocolate milk than fat and sugar content. Organic labeling did not impact the purchase decision of chocolate milk; however Kano results revealed that having an organic label on a package had a positive influence on consumer satisfaction of chocolate milk. Overall, intrinsic cues (sensory attributes including fat and sugar), rather than extrinsic cues (brand name, packaging labels) drive the chocolate milk choice. Findings from this study can help chocolate milk producers as well as food marketers better target their product labels with attributes that drive consumer choice of chocolate milk.

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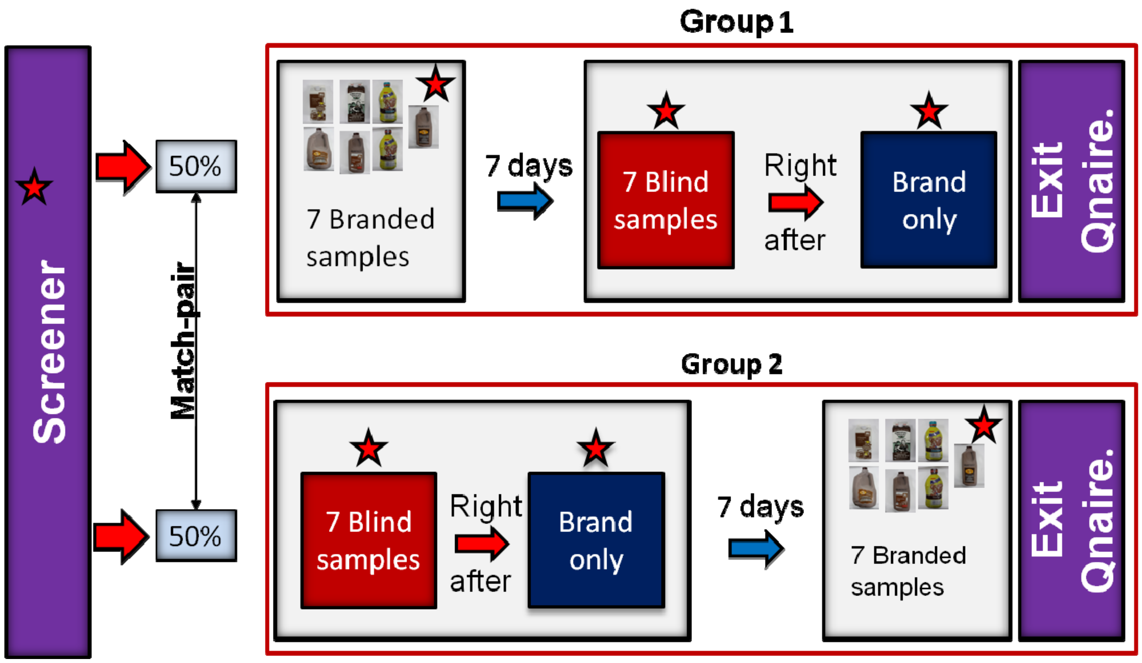

Figure 4-1 Design of Experiment for 2-day Cross-over Consumer Acceptance Test of Chocolate Milks

Note: Stars represent the points at which the emotion measurements were taken.

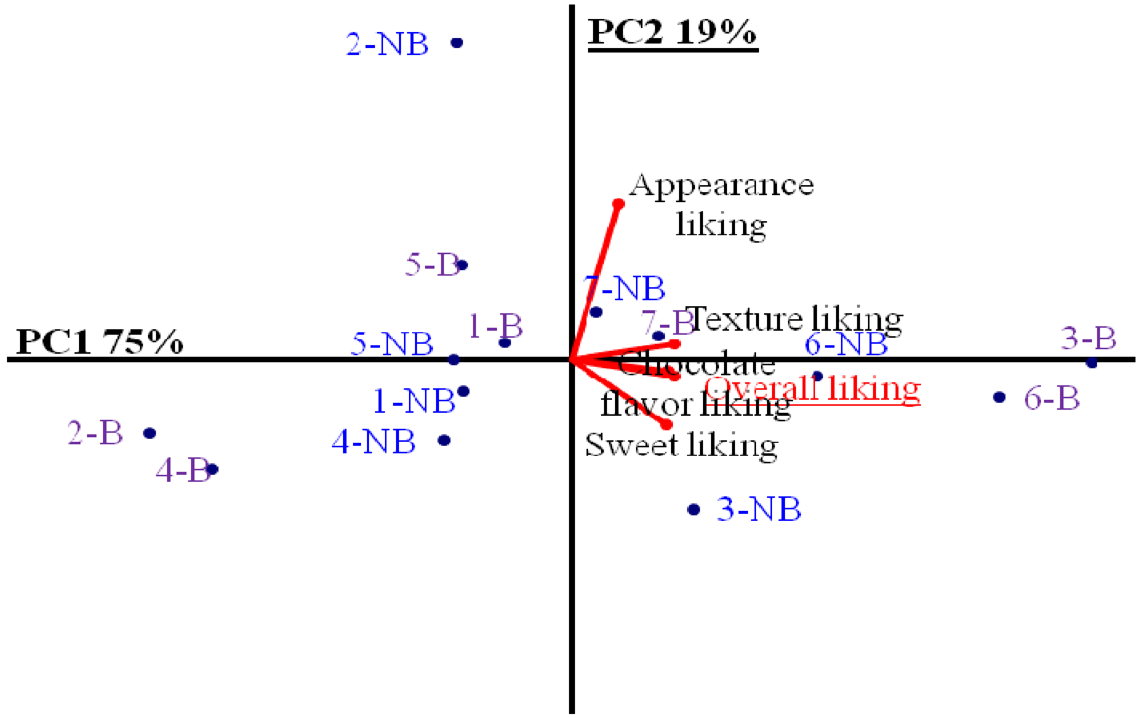

Figure 4-2 Internal Preference Map of Consumer Perception of Chocolate Milks with and without Branding

Note: Numbers represent the type of chocolate milk. NB = Non-Branded; B = Branded; PC1 and PC2 explain 94% of data variability.

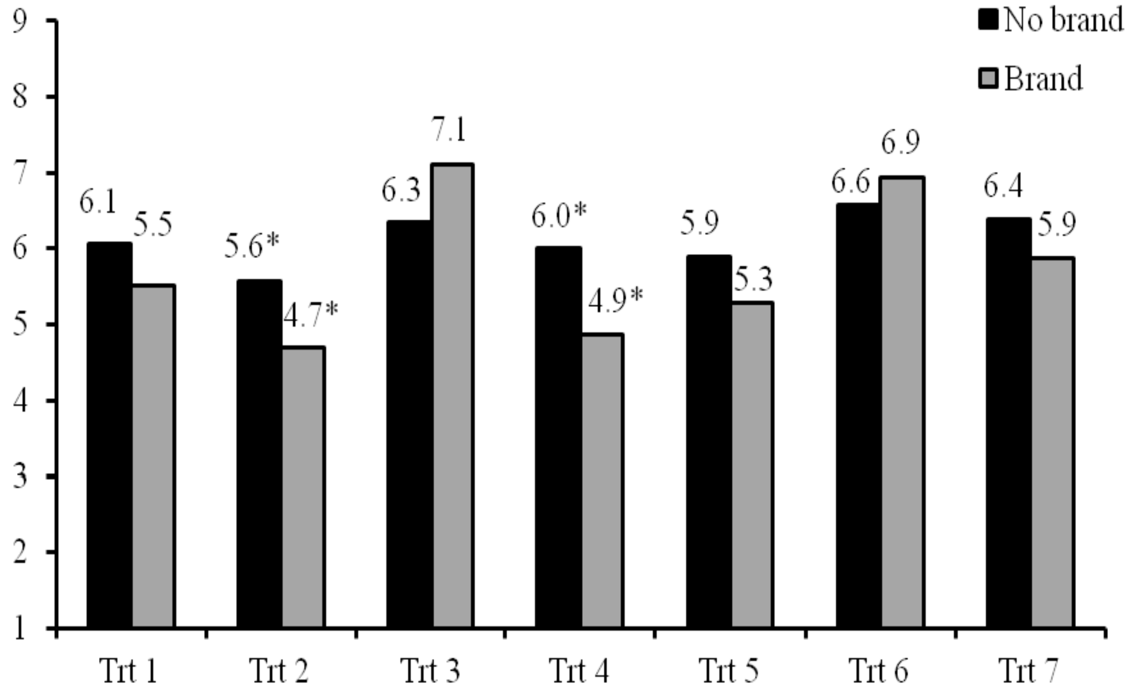

Figure 4-3 Effect of Brand/Package Label on Overall Acceptance of Chocolate Milk

Note: Numbers on top of the bars represent the means of the overall liking scores for each treatment. Statistical analysis was conducted to find the significant difference between no brand and brand within treatments. * next to a number represents the significant difference between no brand and brand within treatments (Trt. 2 and Trt.4).

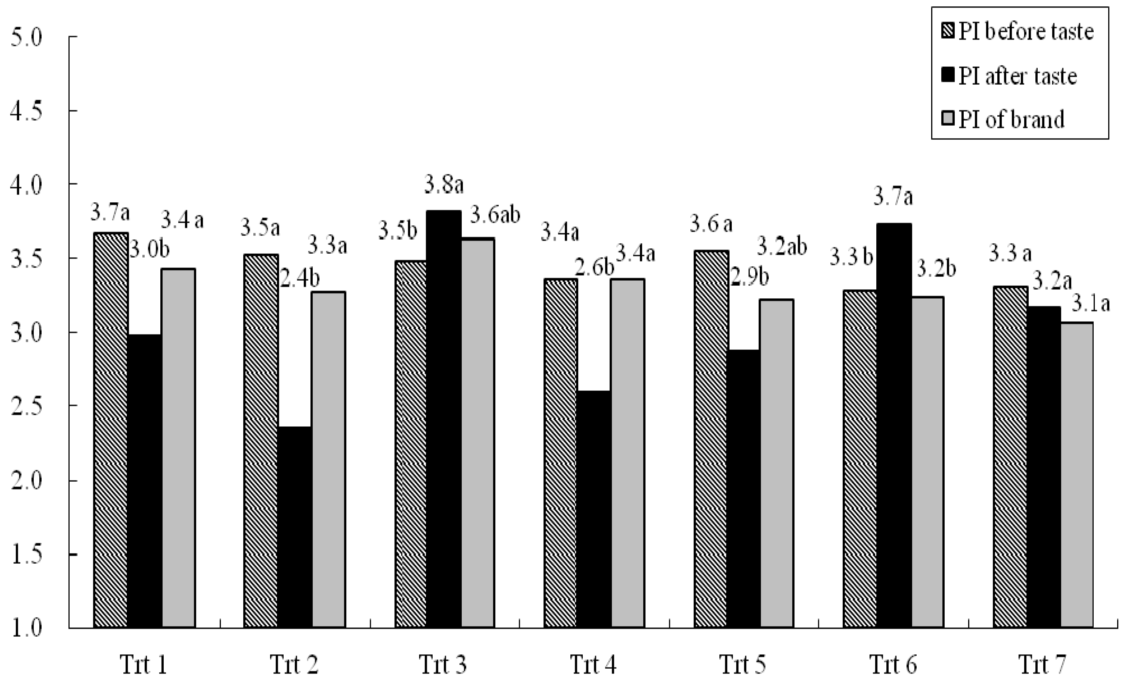

Figure 4-4 Effect of Brand/Package Label on Purchase Intent of Chocolate Milk

Note: statistical analysis was conducted to find a significant difference for the purchase intent from the unbranded (before) to branded (after) and brand only evaluation. Numbers on top of the bars represent the means of the purchase intent scores for each treatment. Letters next to the number represent the significant difference between the unbranded (before) and branded (after) evaluation within treatments. Statistical analysis was conducted within treatment.

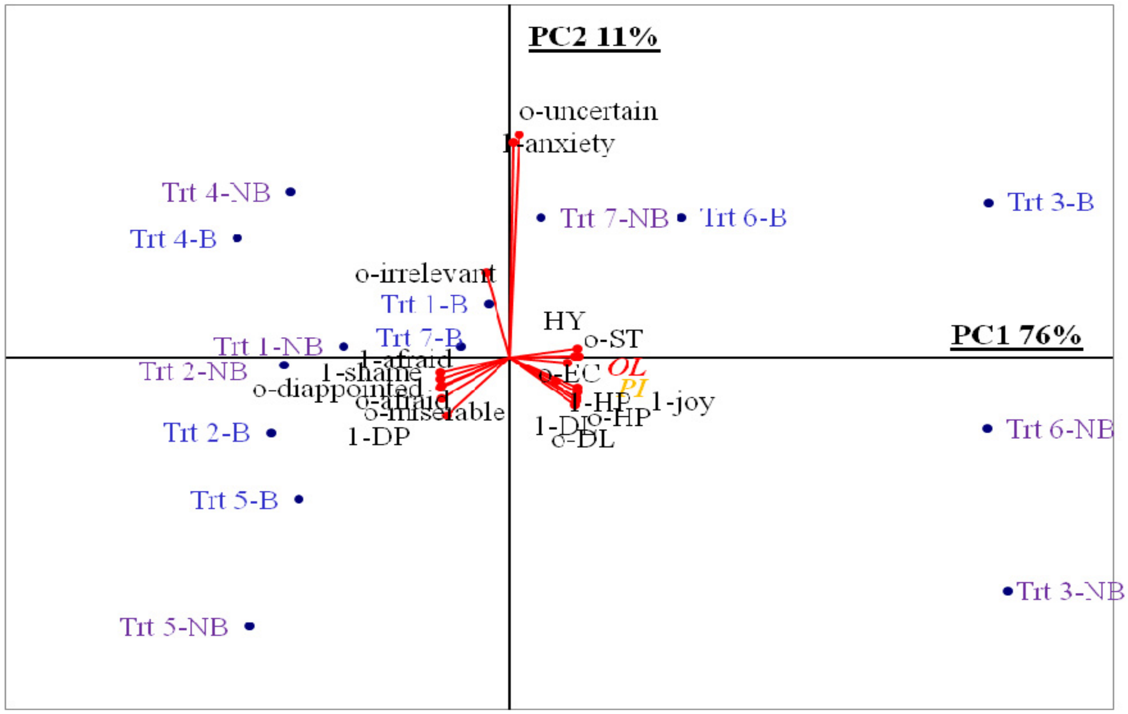

Figure 4-5 Principal Component Biplot of Emotions, Overall Acceptance and Purchase Intent of Chocolate Milks

Note: OL: overall liking; PI: purchase intent; HY: happy; HP: hope; SH: shamed; AX: anxiety; ST: satisfied; DA: disappointed; UC: uncertain; IR: irrelevant; DL: delight; AF: afraid; DP: depressed; EC: excited; MS: miserable.

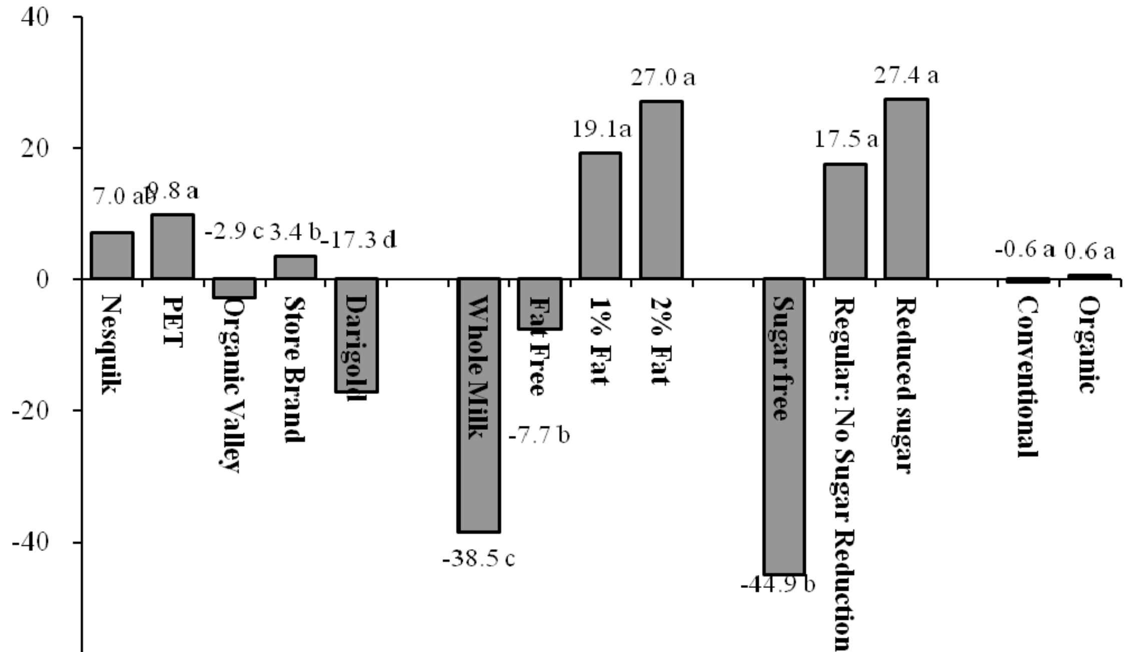

Figure 4-6 Zero-Centered Utility Values for Attributes and Levels

Note: Letters indicate significant differences ($p < 0.05$) within each attribute for the total population ($n = 250$).

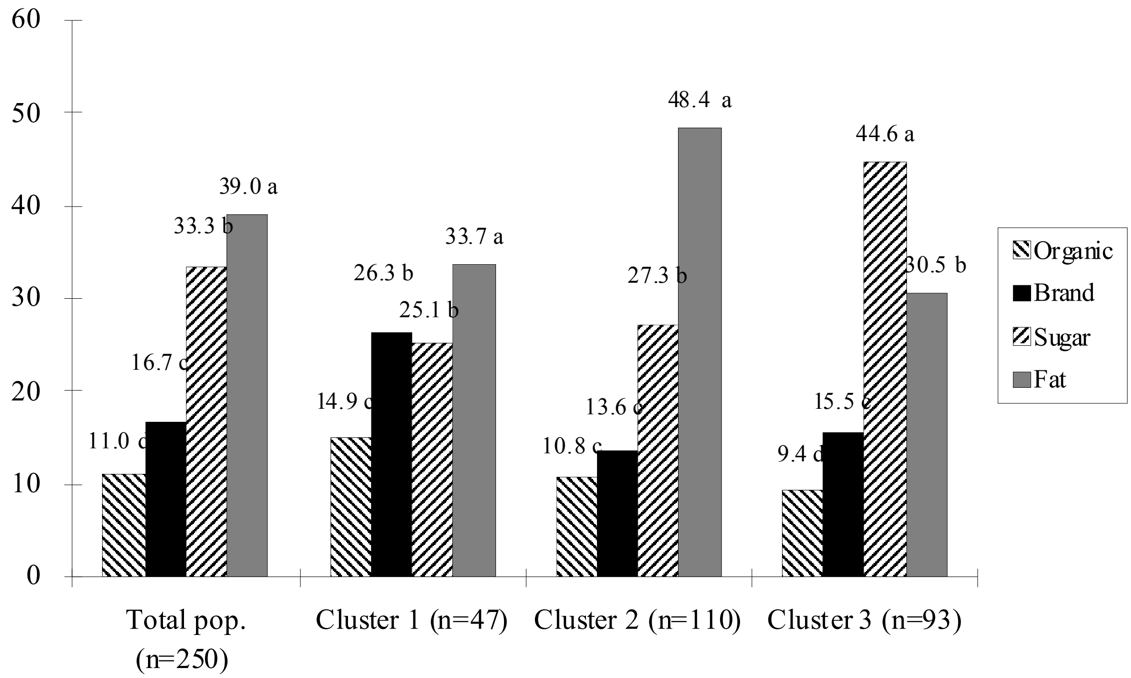

Figure 4-7 Attribute Importance (%) Scores for the Total Population and Segmented Groups

Note: Numbers on top of the bars represent the attribute importance (%) scores. Letters indicate significant differences ($p < 0.05$) within each attribute for the total population (n = 250), Cluster 1 (n = 47), Cluster 2 (n = 110), and Cluster 3 (n = 93).

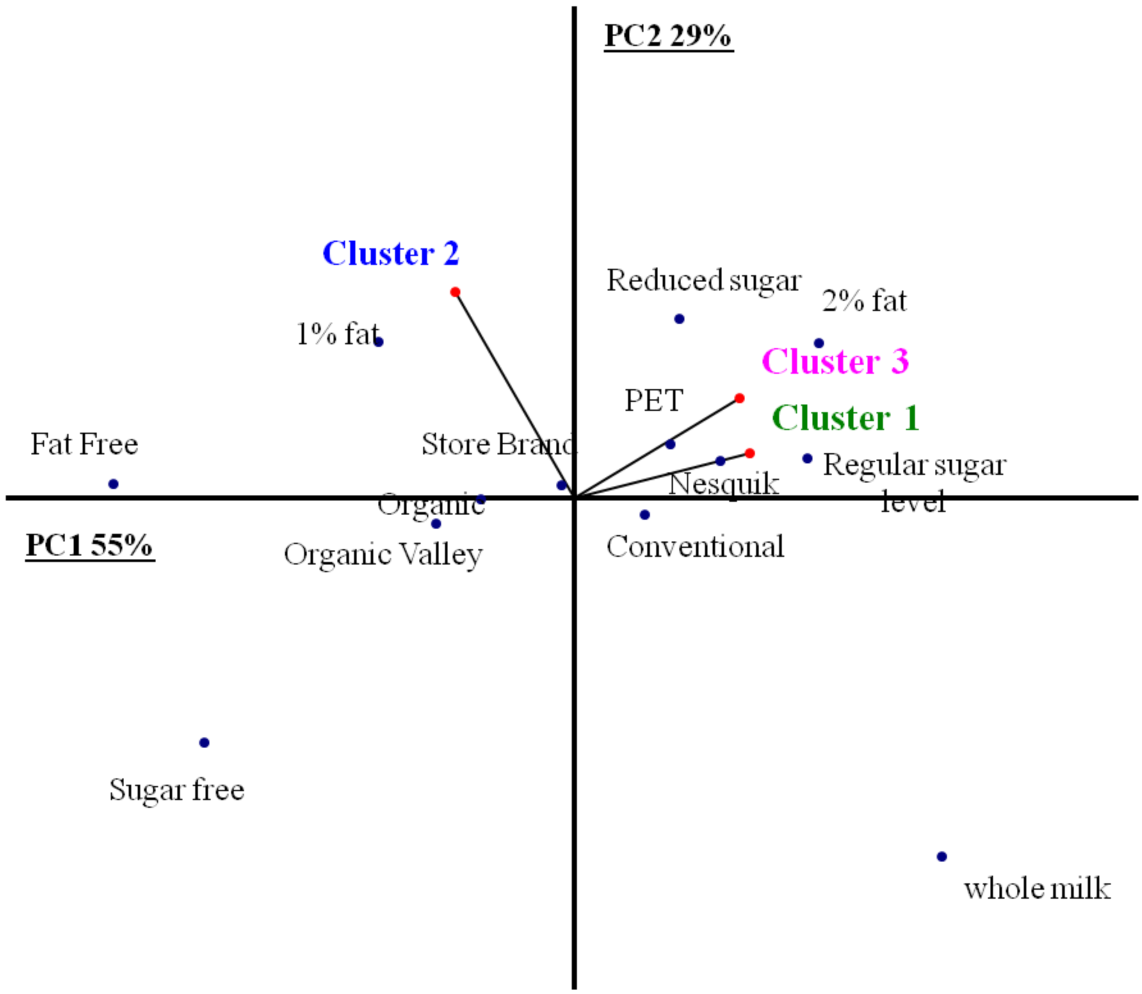

Figure 4-8 Principal Component Biplot of Clusters from Conjoint Analysis Survey with Attributes and Levels

Table 4-1 Appraisal Combinations of Emotion Terms (from Johnson and Stewart, 2005)

Agency	Goal Congruence				Normative/Moral Compatibility
	Positive		Negative		
	Certainty				
	Certain	Uncertain	Certain	Uncertain	
Moderate intensity[1]					
Self	Proud	Hope*	Guilt, shame	Anxiety*	Relevant
	Happy*	Hope*	Distress	Anxiety	Irrelevant
Other person	Admiration	Hope	Contempt	Anxiety	Relevant
	Grateful	Hope	Anger*	Anxiety	Irrelevant
Object or circumstances	Satisfied*	Hope*	Disappointed*	Anxiety*	Relevant
	Pleased*	Hope*	Sad	Anxiety	Irrelevant*
Indeterminate or irrelevant	Glad	Hope	Pity	Anxiety	Relevant
	Happy	Hope	Sad	Anxiety	Irrelevant
High intensity[2]					
Self	Proud	Anticipatory	Humiliated	Afraid	Relevant
	Joyous*	Excited*	Depressed*	Afraid*	Irrelevant
Other person	Love	Anticipatory	Disgust	Afraid	Relevant
	Love	Excited	Enraged	Afraid	Irrelevant
Object or circumstances	Delighted*	Anticipatory	Frustrated	Afraid	Relevant
	Delighted	Excited*	Miserable*	Afraid*	Irrelevant
Indeterminate or irrelevant	Delighted	Anticipatory	Commiserate	Afraid	Relevant
	Joyous	Excited	Miserable	Afraid	Irrelevant

Note:
[1]Moderate intensity of emotion suggests that goal importance is moderate, and situation is appraised as relatively close to the degree of goal congruence expected.
[2] High intensity of emotion suggests that goal importance is high and the expected situation far exceeds or falls short of the goal.
* indicates the emotions measured in this study.

Table 4-2 Consumer Consumption Characteristics and Demographics of Participants in Consumer Acceptance Test (n=108)

		%
Gender	Male	30.6
	Female	69.4
Age	19 – 24 years old	22.2
	25 – 34 years old	31.5
	35 – 44 years old	18.5
	45 – 54 years old	14.8
	55 – 64 years old	13
Marital status	Married	43.5
	Engaged	4.6
	Living with a significant other	7.4
	Single	35.2
	Separated/widowed/divorced	9.3
Number of people in the household	1	17.6
	2	40.7
	3	33.3
	4	8.3
Primary shopper	Yes	92.6
	No	7.4
Income	Under $24,999 per year	19.4
	$25,000 to $49,999 per year	33.3
	$50,000 to $74,999 per year	19.4
	$75,000 to $99,999 per year	10.2
	Prefer not to answer	1.9
Education	High school degree	12
	2 years of college	17.6
	4 years of college	42.6
	5 or more years of college	25.9
	Professional school	1.9
Frequency of consuming chocolate milk	At least once in last 6 months	17.6
	At least once a month	13.9
	At least 2- 3 times per month	27.8
	At least once a week	16.7
	2 or more times per week	24.1

Table 4-2 Continued

		%
Factors that affect purchase intent *	Brand	52.8
	Nutrition	50.9
	Availability	45.4
	Flavor	89.8
	Price	70.4
	Shelf life	30.6
	Package	25
	Organic	22.2
	Calories	47.2
	Fat content	42.6
Primary brand of choice	Hershey's	59.3
	Nestle (Nesquick)	71.3
	PET	43.5
	Promised Land	14.8
	Horizon Organic	31.5
	Organic Valley	24.1
	Maple View Farm	9.3
	Howling Cow	17.6
	Store brands	57.4
	Other brands	14.8

* The 'factors influencing purchase intent' question is a 'check all that apply' type of question. Therefore, the total percentage is greater than 100%.

Table 4-3 Consumer Attribute Means for Chocolate Milk

Trt	Appearance liking	Overall liking	Chocolate flavor liking	Sweet liking	Mouthfeel/ thickness liking
1-B	6.6 a	5.5 defg	5.5 bcd	5.1 def	6.0 abcde
2-B	5.8 a	4.7 g	4.7 d	4.3 f	5.2 e
3-B	7.2 a	7.1 a	7.1 a	7.0 a	6.9 a
4-B	5.8 a	4.9 fg	4.6 d	5.0 def	5.2 e
5-B	7.1 a	5.3 efg	5.3 bcd	5.2 cdef	5.7 cde
6-B	6.9 a	6.9 ab	7.0 a	6.7 ab	6.7 ab
7-B	6.9 a	5.9 cde	5.9 bc	5.8 bcde	6.1 abcd
1-NB	6.3 a	6.1 bcde	5.2 cd	4.9 ef	5.7 cde
2-NB	8.0 a	5.6 def	5.0 cd	4.0 f	6.0 abcde
3-NB	5.9 a	6.4 abcd	5.9 bc	5.9 bcd	6.4 abc
4-NB	6.1 a	6.0 cde	5.1 cd	5.2 cdef	5.6 cde
5-NB	6.5 a	5.9 cde	5.1 cd	5.0 def	5.7 cde
6-NB	6.8 a	6.6 abc	6.3 ab	6.1 abc	6.4 abc
7-NB	6.9 a	6.4 abcd	5.4 bcd	5.3 cde	5.9 abcd

Note: Means in a column followed by different letters represent significant differences ($p < 0.05$).

Liking attributes were scored on a 9-point hedonic scale in which 1 = dislike extremely, 9 = like extremely.

Table 4-4 Correlations among Consumer Emotion Terms, Overall Likings and Purchase Intent

Variables	OL	PI	1-HY	1-HP	1-SH	1-AX	o-ST	o-HP	o-DA	o-UC	o-IR	1-joy	1-DL	1-AF	1-DP	o-DL	o-EC	o-MS	o-AF
OL	**1.00**	**0.85**	**0.82**	**0.76**	**-0.83**	0.04	**0.83**	**0.79**	**-0.81**	0.14	-0.37	**0.79**	**0.78**	**-0.76**	**-0.63**	**0.75**	**0.80**	**-0.84**	**-0.84**
PI		**1.00**	**0.94**	**0.88**	**-0.91**	-0.02	**0.94**	**0.71**	**-0.93**	0.20	-0.31	**0.91**	**0.93**	**-0.92**	**-0.82**	**0.87**	**0.88**	**-0.96**	**-0.93**
1-HY			**1.00**	**0.96**	**-0.99**	0.09	**0.98**	**0.62**	**-0.99**	0.15	-0.32	**0.96**	**0.97**	**-0.98**	**-0.92**	**0.93**	**0.94**	**-0.96**	**-0.98**
1-HP				**1.00**	**-0.94**	-0.09	**0.96**	**0.58**	**-0.93**	-0.07	-0.33	**0.98**	**0.98**	**-0.95**	**-0.88**	**0.96**	**0.97**	**-0.89**	**-0.93**
1-SH					**1.00**	-0.15	**-0.97**	**-0.59**	**0.99**	-0.20	0.35	**-0.96**	**-0.95**	**0.98**	**0.93**	**-0.92**	**-0.94**	**0.95**	**0.98**
1-AX						**1.00**	0.04	-0.02	-0.17	**0.69**	0.14	-0.07	-0.08	-0.11	-0.24	-0.13	-0.11	-0.16	-0.19
o-ST							**1.00**	**0.68**	**-0.97**	0.14	-0.27	**0.98**	**0.98**	**-0.98**	**-0.90**	**0.95**	**0.96**	**-0.97**	**-0.97**
o-hope								**1.00**	**-0.58**	-0.04	-0.01	**0.61**	**0.64**	**-0.58**	-0.37	**0.63**	**0.62**	**-0.69**	**-0.63**
o-DA									**1.00**	-0.25	0.33	**-0.95**	**-0.95**	**0.99**	**0.94**	**-0.91**	**-0.93**	**0.97**	**0.98**
o-UC										**1.00**	0.23	-0.01	0.02	-0.17	-0.33	-0.07	-0.02	-0.31	-0.22
o-IR											**1.00**	-0.36	-0.30	0.29	0.22	-0.26	-0.30	0.22	0.35
1-joy												**1.00**	**0.99**	**-0.97**	**-0.89**	**0.98**	**0.99**	**-0.92**	**-0.94**
1-DL													**1.00**	**-0.97**	**-0.89**	**0.98**	**0.97**	**-0.93**	**-0.93**
1-AF														**1.00**	**0.95**	**-0.94**	**-0.95**	**0.96**	**0.97**
1-DP															**1.00**	**-0.85**	**-0.86**	**0.91**	**0.92**
o-DL																**1.00**	**0.99**	**-0.88**	**-0.89**
o-EC																	**1.00**	**-0.89**	**-0.92**
o-MS																		**1.00**	**0.97**
o-AF																			**1.00**

Note: Numbers in bold represent significant correlations ($p < 0.001$). Bon Ferroni adjustment were made to reduce the type I error associated with multiple comparison
OL: overall liking; PI: purchase intent; HY: happy; HP: hope; SH: shamed; AX: anxiety; ST: satisfied; DA: disappointed; UC: uncertain; IR: irrelevant; DL: delight; AF: afraid; DP: depressed; EC: excited; MS: miserable.

Table 4-5 Attributes and Levels for Conjoint Analysis

Attribute	Level
Brand name	Nesquik (National brand)
	PET (Regional brand)
	My Essential (Store brand)
	Organic Valley (Organic brand)
	Darigold (Unfamiliar brand)
Fat content	Whole milk
	2% fat milk
	1% fat milk
	Fat free milk
Sugar content	Regular sugar
	Reduced sugar
	Sugar free
Organic claim	Organic
	Conventional

Table 4-6 Consumer Consumption Characteristics and Demographics of Conjoint Analysis Participants

		Total (N=250)	Cluster 1 (N=47)	Cluster 2 (N=110)	Cluster 3 (N=93)
Gender	Male	23.20%	21.30%	21.80%	25.80%
	Female	76.40%	78.70%	78.20%	74.20%
Age	19 - 24 years old	18.40%	14.90%	20.00%	18.30%
	25 – 34 years old	32.80%	36.20%	32.70%	31.20%
	35 -44 years old	18.00%	21.30%	16.40%	18.30%
	45 – 54 years old	18.00%	14.90%	18.20%	19.40%
	55 – 64 years old	10.40%	10.60%	10.90%	9.70%
	Above 65 years old	2.40%	2.10%	0.00%	3.20%
Marital status	Single	28.40%	25.50%	26.40%	32.30%
	Engaged	2.40%	4.30%	2.70%	1.10%
	Living with significant other	10.40%	12.80%	10.00%	9.70%
	Married	50.00%	51.10%	52.70%	46.20%
	Separated/Widowed /Divorced	8.80%	6.40%	8.20%	10.80%
Number of people living in the household	1	15.20%	19.10%	13.60%	15.10%
	2	40.80%	40.40%	39.10%	43.00%
	3 – 4	36.80%	36.20%	36.40%	37.60%
	5 or more	7.20%	4.30%	10.90%	4.30%
Primary shopper	Yes	93.20%	95.70%	93.60%	91.40%
	No	6.80%	4.30%	6.40%	8.60%
Household income	Under $25,000 per year	13.60%	10.60%	14.50%	14.00%
	$25,000 - $49,999 per year	28.40%	38.30%	25.50%	26.90%
	$50,000 - $74,999 per year	21.20%	14.90%	22.70%	22.60%
	$75,000 - $ 100,000 per year	21.60%	27.70%	16.40%	24.70%
	More than $100,000 per year	10.40%	8.50%	12.70%	8.60%
	Prefer not to answer	4.80%	0.00%	8.20%	3.20%

Table 4-6 Continued

		Total (N=250)	Cluster 1 (N=47)	Cluster 2 (N=110)	Cluster 3 (N=93)
Education	Some high school	0.00%	0.00%	0.00%	0.00%
	High school degree	16.40%	14.90%	18.20%	15.10%
	2 years of college (i.e. Associate's degree)	15.60%	12.80%	16.40%	16.10%
	4 years of college (i.e. Bachelor's degree)	38.80%	38.30%	36.40%	41.90%
	5 or more years of college (i.e. Master's or Ph.D.)	27.20%	34.00%	28.20%	22.60%
	Professional school	2.00%	0.00%	0.90%	4.30%
Ethnicity	African American	17.20%	12.80%	20.90%	15.10%
	American Indian or Alaska Native	0.40%	0.00%	0.90%	0.00%
	Asian	4.00%	4.30%	3.60%	4.30%
	Caucasian	72.00%	78.70%	69.10%	72.00%
	Hispanic	4.00%	2.10%	2.70%	6.50%
	Native Hawaiian or other pacific islander	0.40%	0.00%	0.90%	0.00%
	Other	2.00%	0.00%	1.80%	2.20%
Weight	Too high, I think I am obese	7.20%	4.30%	5.50%	10.80%
	High, I think I am overweight	24.80%	21.30%	22.70%	29.00%
	A bit higher than normal	33.20%	40.40%	32.70%	30.10%
	Normal	30.80%	34.00%	33.60%	25.80%
	A bit lower than normal	4.00%	0.00%	5.50%	4.30%
	Too low	0.00%	0.00%	0.00%	0.00%
Eating habits	Definitely very healthy, I am very strict about my diet	1.20%	0.00%	0.90%	2.20%
	Healthy, I follow my diet plan regularly	11.20%	6.40%	14.50%	9.70%
	Moderately healthy, I prefer to eat everything in moderation	45.20%	51.10%	47.30%	39.80%
	Somewhat healthy, I try to eat healthy, but sometimes I cannot resist	35.20%	38.30%	28.20%	41.90%
	Not healthy at all, I eat what I want when I want	7.20%	4.30%	9.10%	6.50%

Table 4-6 Continued

		Total (N=250)	Cluster 1 (N=47)	Cluster 2 (N=110)	Cluster 3 (N=93)
Frequency of consuming chocolate milk	Never	0.00%	0.00%	0.00%	0.00%
	At least once in last 6 months	19.20%	23.40%	19.10%	17.20%
	At least once a month	18.00%	19.10%	33.60%	25.80%
	At least 2 – 3 times per month	24.80%	36.20%	20.00%	24.70%
	At least once a week	18.80%	12.80%	18.20%	22.60%
	2 or more times per week	9.20%	8.50%	9.10%	9.70%
Primary choice of chocolate milk	Whole milk chocolate milk	24.00%	25.50%	27.30%	19.40%
	2% fat chocolate milk	39.60%	44.70%	40.90%	35.50%
	1% fat chocolate milk	12.40%	8.50%	10.90%	16.10%
	Fat free chocolate milk	23.60%	21.30%	20.00%	29.00%
Primary choice of regular milk	Whole milk	14.00%	12.80%	16.40%	11.80%
	2% fat milk	38.40%	46.80%	40.90%	31.20%
	1% fat milk	13.60%	12.80%	9.10%	19.40%
	Fat free milk	33.60%	27.70%	32.70%	37.60%
Factors that affect purchase of chocolate milk*	Availability	47.60%	40.40%	48.20%	50.50%
	Brand	49.20%	53.20%	50.90%	45.20%
	Calories	28.80%	27.70%	25.50%	33.30%
	Flavor	75.20%	74.50%	74.50%	76.30%
	Nutrition	28.80%	25.50%	24.50%	35.50%
	Organic	16.40%	17.00%	11.80%	21.50%
	Package	13.60%	17.00%	13.60%	11.80%
	Price	74.40%	68.10%	69.10%	83.90%
	Others	4.00%	2.10%	3.60%	5.40%

Table 4-6 Continued

		Total (N=250)	Cluster 1 (N=47)	Cluster 2 (N=110)	Cluster 3 (N=93)
Frequency of reading labels	Always read food labels	29.20%	38.30%	25.50%	29.00%
	Frequently read food labels	42.80%	38.30%	41.80%	46.20%
	Sometimes read food labels	21.20%	19.10%	23.60%	19.40%
	Rarely read food labels	6.00%	4.30%	8.20%	4.30%
	Never read food labels	0.80%	0.00%	0.90%	1.10%
Interest in fat-reduced foods	Not at all interested	7.60%	8.50%	7.30%	7.50%
	Slightly interested	23.60%	27.70%	32.70%	10.80%
	Moderately interested	32.00%	36.20%	26.40%	36.60%
	Very interested	23.60%	17.00%	22.70%	28.00%
	Extremely interested	13.20%	10.60%	10.90%	17.20%
Interest in fat-reduced chocolate milk	Not at all interested	7.60%	12.80%	4.50%	8.60%
	Slightly interested	20.40%	17.00%	28.20%	12.90%
	Moderately interested	24.00%	27.70%	22.70%	23.70%
	Very interested	29.60%	29.80%	26.40%	33.30%
	Extremely interested	18.40%	12.80%	18.20%	21.50%
Interest in sugar-reduced foods	Not at all interested	13.60%	10.60%	13.60%	15.10%
	Slightly interested	22.00%	29.80%	27.30%	11.80%
	Moderately interested	26.40%	19.10%	24.50%	32.30%
	Very interested	23.60%	25.50%	19.10%	28.00%
	Extremely interested	14.40%	14.90%	15.50%	12.90%
Interest in reduced sugar in chocolate milk	Not at all interested	14.80%	14.90%	12.70%	17.20%
	Slightly interested	25.20%	25.50%	29.10%	20.40%
	Moderately interested	22.80%	23.40%	24.50%	20.40%
	Very interested	27.20%	27.70%	24.50%	30.10%
	Extremely interested	10.00%	8.50%	9.10%	11.80%

* The ‘Factors that affect purchase of chocolate milk’ question was a ‘check all that apply’ type of question. Therefore, the total percentage is greater than 100%.

Table 4-7 Zero-Centered Utility Values for Attributes and Levels for each Segment from the Conjoint Analysis

	Cluster 1	Cluster 2	Cluster3
	n = 47	n = 110	n = 93
Nesquik	35.4 a	1.58 a	-0.99 a
PET	21.0 a	6.36 a	8.23 a
Organic Valley	-28.7 c	2.53 a	3.81 a
Store brand	-1.75 b	4.00 a	5.29 a
Darigold	-25.9 c	-14.5 b	-16.3 b
Whole milk	20.5 a	-111.0 c	17.6 b
2% fat	41.4 a	15.5 b	33.3 a
1% fat	-17.3 b	50.6 a	0.36 c
Fat free	-44.6 c	45.0 a	-51.3 d
Regular sugar level	-3.40 b	-21.1 b	73.8 a
Reduced sugar	25.9 a	32.5 a	22.0 b
Sugar free	-22.5 b	-11.4 b	-95.8 c
Organic	-16.4 b	6.24 a	2.37 a
Conventional	16.4 a	-6.24 b	-2.37 b

Note: Different letters within a column within an attribute are different ($p < 0.05$).

Table 4-8 Kano Classifications of Attributes and Levels set for Conjoint Analysis of Chocolate Milk

	Kano Classification			
	Total (n=250)	Cluster 1 (n=46)	Cluster 2 (n=111)	Cluster 3 (n=93)
Nesquik	Indifferent	Indifferent	Indifferent	Attractor
Organic valley	Indifferent	Indifferent	Indifferent	Indifferent
PET	Indifferent	Attractor	Indifferent	Indifferent
Store brand	Indifferent	Indifferent	Indifferent	Indifferent
Darigold	Indifferent	Indifferent	Indifferent	Indifferent
Organic ingredient	Indifferent	Attractor	Attractor	Indifferent
Conventional ingredient	attractive	Attractor	Indifferent	Indifferent
Whole fat	attractive	Attractor	Indifferent	Attractor
2% fat	attractive	Attractor	attractor	Attractor
1% fat	attractive	Attractor	Indifferent	Attractor
Fat free	Indifferent	Indifferent	Attractor	Indifferent
Regular sugar	Indifferent	Attractor	Attractor	Attractor
Reduced sugar	Indifferent	Attractor	Attractor	Indifferent
Sugar free	Indifferent	Indifferent	Indifferent	Indifferent

Note: Kano classification was calculated by previously described methods (Kano 1984). The satisfaction and dissatisfaction questions were asked to consumers, and the contingency table of satisfaction and dissatisfaction answers were created for each feature. The type of consumer that is assigned to each cell of the contingency table is labeled according to Kano classification. The Kano classification was conducted with total n = 250 respondents, followed by consumer segmentation of three clusters segmented from the conjoint analysis.