ABSTRACT

JERVIS, SUZANNE. Identification and Investigation of Key Consumer Liking Attributes of Whole Wheat Bread and Sour Cream. (Under the direction of Dr. MaryAnne Drake).

Understanding the drivers of liking of a food or beverage product is the most important information related to product success. If a sensory attribute has not met consumer expectations, the product will not be acceptable and will ultimately fail due to lack of purchase. The purpose of this research was to investigate the process of identifying and investigating drivers of liking through the application of studies with whole wheat sliced sandwich bread and sour cream.

A study was conducted to determine if pictures of individual product attributes of sliced bread products could be used to determine the utility of sliced bread in adaptive choice based conjoint (ACBC) analysis. Commercial sliced sandwich bread were photographed, formatted, sized, and composed for visual evaluation. All possible crust/crumb combinations (n=36) were first presented to pre-screened bread consumers in an online survey to determine their overall appearance liking using the 9-pt hedonic scale followed by a conjoint survey with crust and crumb pictured attributes. Subsequently, consumers (n=100) evaluated commercial bread representing select levels of crust and crumb for appearance liking using the 9-point hedonic scale. Both composite and ACBC surveys revealed crumb with seeds/flakes to be more appealing than a uniform crumb, and crust with flakes/oats was more appealing than crust with no topping. The utility scores estimated from the attribute pictures were representative of choice behavior in a consumer test.

Traditional preference mapping methods can suffer where attributes with large variances dominate the analysis thus detracting attention from attributes of potential

importance as drivers of liking. A comparison of two traditional methods, Partial Least Squares Regression (PLS) and PREFMAP, were compared against a new method (PrefHMFA) designed to control dominance of high variance attributes. Whole wheat sliced sandwich bread was the subject (n=25). Traditional methods showed similar drivers of traditional white bread attributes and whole wheat bread attributes with broad ideal points. PrefHMFA showed additional drivers not evident by traditional methods based on appearance and hand-perceived texture attributes. PrefHMFA offers potentially a wider identification of key drivers of liking for food and beverage products.

Creaminess has been identified as a key driver of liking for dairy products and is a consumer attribute that is difficult to define or describe because the mechanism or modality (s) for its perception remain uncertain. Understanding the modality (s) responsible for creaminess perception will aid the food industry in formulating dairy products that are optimal for creaminess. The objective of this study was to determine the sensory modality, or combination thereof, responsible for creaminess perception in sour cream. Consumers evaluated creaminess of 12 representative sour creams. Subsequently, in separate sessions, the effect of each modality was evaluated: visual only, stirring, blindfolded stirring, blindfolded tasting, blindfolded tasting with nose clips, and tasting with nose clips. Creaminess was evaluated on an eleven point rating scale. Flavor had the greatest impact on creaminess perception followed by visual assessment of the sour cream while stirring. A combination of flavor and visual assessment of flow characteristics was important for creaminess perception in sour cream.

Identification and Investigation of Key Consumer Liking Attributes of Whole Wheat Bread and Sour Cream

by
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DEDICATION

My dissertation is dedicated to my loving and supportive husband. Without his leap of faith to let me attempt graduate school, I wouldn't be where I am today.

BIOGRAPHY

Suzanne Marie Jervis was born on August 26th, 1980 to Robert Joseph Gavula and Barbara Marie Gavula. Suzanne attended the University of Pittsburgh in the fall of 1998 and earned a Bachelor's of Science degree in Chemistry with a minor in Education. Suzanne went on for an additional year to earn her Secondary Education Teaching Certificate from the University of Pittsburgh. During that same year Suzanne married Matthew Gabriel Jervis on June 14th, 2003.

Suzanne and Matthew both began working as teachers for Caesar Rodney School District in Wyoming DE. Suzanne taught high school Chemistry, Physical Science, and started the AP Chemistry program. Suzanne taught at Caesar Rodney for three years before accepting a position as a Chemistry Teacher at Upper Darby High School in Upper Darby Pennsylvania. After completion of one year at Upper Darby Suzanne left that position for family reasons, and moved to Pittsburgh where she began working as a Research Scientist for H.J. Heinz Company. After completion of one year with the company Suzanne and family relocated to Raleigh North Carolina for a job opportunity for Matthew. Shortly thereafter, Suzanne began working for Nomacorc LLC as a Sensory Analyst. During that time, the 2007 recession hit and Suzanne was let go from her position. Suzanne took that opportunity to go back to school and earn a Masters in Food Science degree which had been a goal of hers since her experience at Heinz.

Upon completion of her Masters in Food Science in 2011, Suzanne continued on in her education through the doctoral food science program at North Carolina State University under Dr. MaryAnne Drake focused in sensory and consumer science. Upon completion of

the degree, Suzanne with her husband and twin boys will relocate to suburban Chicago Illinois where Suzanne will work for PepsiCo as a R&D Senior Scientist.

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CHAPTER 1:

The importance of brand label, perceived satiety, and price in determining the drivers of liking: A review

The content of this chapter has been submitted to the Journal of Food Science 2014

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RUNNING TITLE: Drivers of Purchase Intent

ABSTRACT

Drivers of liking studies (DOL) are useful for product development to formulate acceptable products, however, this alone is insufficient for understanding why a product is purchased and repurchased, which is ultimately the indication of a successful product. Ultimately intrinsic product attributes drive product success, (i.e. repeat and continued purchase), however ignoring the importance of extrinsic factors when determining drivers of liking, neglects the vital product attributes responsible for the initial purchase which may in turn, affect repeat purchase especially if product expectations are not met by the sensory attributes. The perception of sensory attributes, as assessed by DOL, is mitigated by perceptions of perceived satiety, brand label, and perceived value based upon price. If the sensory attributes do not deliver based upon the quality perceptions of the extrinsic factors, the product will not be acceptable. Three key extrinsic factors that affect purchase intent are the perceived satiety, brand label, and price. Therefore, it is of vital importance to assess sensory attributes in the presence and absence of key important extrinsic attributes, perceived satiety, brand, and price, in order to understand the ultimate success or failure of a product.

PRACTICAL IMPLICATIONS

Drivers of liking studies gain insight into the sensory attribute responsible for liking. These attributes are often only assessed after the initial purchase has taken place. It is important to understand the extrinsic attributes responsible for initial purchase and the magnitude of that influence on repeat purchase. Three extrinsic factors that influence purchase intent are perceived satiety, brand label, and price. DOL studies should account for the effect each of these factors has on product purchase as each factor provides quality cues for the consumer which influences their perceived liking of the sensory attributes.

KEY WORDS

Drivers of Liking, Purchase, Brand, Perceived Satiety, Willingness-to-pay

INTRODUCTION

The success of a product is marked by repeat sales from consumers. Products may be initially successful in securing purchase from consumers, but if repeat purchases are not conducted, the product is ultimately doomed to fail. When assessing the success of a product, it is important to understand why a consumer initially purchases a product, and what factors influence their drivers of purchase intent (DPI). An understanding of the overall drivers of liking, taking into account important extrinsic and intrinsic factors can be modeled to understand the DPI. A DPI study accounts for the perceptions of the product in packaging, (perceived satiety, brand, price, etc), and the sensory attributes apparent during the tasting condition. Understanding the DPI is to understand the overall attributes responsible for a product's success. To understand DPI, three things need to be understood.

1- The importance of extrinsic factors to product liking
2- The importance of intrinsic factors to product liking
3- The relationship of extrinsic and intrinsic factors to product liking

A basic DOL study determines the sensory attributes of a food or beverage product through descriptive analysis profiling, and models those attributes with consumer overall liking scores to conclude the degree of importance of each sensory attribute on liking. Ultimately when assessing DPI, other factors not involving the sensory attributes, known as extrinsic factors, drive the initial purchase. Extrinsic factors can include brand image, package attributes, labeling information, and price. It is important to understand both the

intrinsic and extrinsic product factors to determine what is responsible for product's repeat purchase and ultimately product success. The purpose of this paper is to explore the influence of perceived satiety, brand labeling, and price on the perceived quality of a product and how it may influence the drivers of liking. For the remainder of this paper, the authors will refer to a 'traditional DOL study' as one that involves descriptive analysis followed by a consumer acceptance test and a multivariate statistical technique to model the sensory attributes with consumer overall liking. Multivariate analysis techniques for DOL studies were recently reviewed by Bi 2012.

Drivers of Liking

Drivers of liking are defined as those attributes responsible for product acceptance (Moskowitz 2001). Based upon published literature DOL studies, most are focused on sensory related attributes of taste, texture, and appearance of the product and generally in the absence of packaging or price information. DOL studies can be very useful for product developers for new product development before extrinsic factors are a concern. Utilizing DOL techniques, researchers have identified key ingredients, ingredient levels, and sensory attributes from key ingredients to target in product optimization of various product categories (Table 1) (Tomaschunas *et al.* 2013; Kreger *et al.* 2012; Cruz *et al.* 2011; Allgeyer *et al.* 2010; Cardello et al. 2003).

Understanding the target consumer population for a specific product is fundamental for understanding pertinent DOL for PI. Intrinsic and extrinsic cues influence food choice and these cues are often influenced by culture (Kim *et al.* 2013). Several studies have been conducted to determine the DOL of a product category with a specific cultural group and

have identified key DOL for products specific for the cultural group studied (Table 1) (Kim *et al.* 2013; Kim *et al.* 2010; Williamson *et al.* 2010; Chung 2009; Herrera-Corredor *et al.* 2007; Thompson *et al.* 2007). Not only is the target purchasing population important to know when evaluating DPI for a product category, but previous history of product exposure and demographics (gender, age, etc) will also influence DPI (Cardello and Sawyer 1992; Deliza and Macfie 1996; Solheim and Lawless 1996; Bayarri *et al.* 2010). Intrinsic and extrinsic cues can also be affected by age, gender, and consumption habits. The eating habits of men and women, or the young versus the elderly can be quite different. Several studies have reported different DOL for various product categories by demographic breakdown and product familiarity (Table 1) (Morais *et al.* 2014; Bayarri *et al.* 2012; Childs *et al.* 2009; Michon *et al.* 2010; Drake *et al.* 2008, 2009; Liggett *et al.* 2007; Cardello et al. 2003)

There is no set of sensory attributes that will be important across all products. The importance of flavor and texture attributes in DOL is product dependent (Table 1) (Morais *et al.* 2014; Delgado *et al*. 2013; Lee *et al*. 2012; Leksrisompong *et al.* 2013; Piombino et al. 2013; Bayarri *et al.* 2012, Kim *et al.* 2010; Krause *et al.* 2007; Liggett *et al.* 2007; Herrera-Corredor *et al.* 2007). This concept was explored in a seminal study conducted by Moskowitz and Krieger (1995) which investigated the DOL of six different food categories, bologna, hot dog, carbonated fruit beverages, blueberry pie filling, peanut butter, and salad dressing. The authors attempted to demonstrate how the complexity of the food system may prevent researchers from obtaining the DOL for a particular food system. On average across all food systems, the DOL categories were in order of importance taste/flavor, texture, and appearance. The authors also reported that no one pattern applied to all individuals however

they did report that the ranking between products within a product category was the same. This is consistent with other DOL studies which show distinct consumer segmentation based upon DOL (Leksrisompong *et al.* 2013, Shepard *et al.* 2013; Kreger *et al.* 2012, Lee *et al*. 2012; Kim *et al.* 2010, Michon *et al.* 2010; Childs *et al.* 2009; Drake *et al.* 2009, 2008; Cardello *et al*. 2003). Appearance was reported to be irrelevant to some consumers for blueberry pie filling which is an important result for companies that make products with an internal taste component such as cakes, pies, or pocket savory meals.

Shepard *et al.* (2013) conducted an exhaustive study of sour creams available across the U.S. market. Consumers who participated in a DOL study were surveyed prior to participation and reported flavor to be the top factor for influencing PI followed by price, availability, and brand. Although Shepard *et al.* (2013) gained some extrinsic factor information by way of a survey; the importance of the extrinsic factors was not assessed in conjunction with a taste evaluation. Leksrisompong *et al.* (2012) investigated the DOL of different sweet potato cultivars with varying flesh colors. In agreement with Moskowitz and Kreiger (1995), the authors reported flavor and texture attributes to be the stronger drivers of liking followed by appearance. Leksrisompong confirmed the importance of appearance by having consumers evaluate products in blinded and unblinded condition. This is an important step in determining the importance of extrinsic factors. Regardless of condition, smooth texture, brown sugar, dried apricot flavor, and sweet taste were the major DOL with bitter, umami, astringent mouthfeel, vanilla aroma, and residual fiber texture negative attributes of sweet potatoes.

Expectation plays an important role in product purchase because it may improve or degrade the perception of the product even before it is tasted (Deliza and MacFie 1996). Expectation is strongly related to consumer satisfaction (Anderson 1973). Expectation is strongly driven by extrinsic factors because products are rarely tasted prior to purchase. A thorough understanding of consumer expectations of a product from extrinsic factors is important as extrinsic factors can be an indication of product quality and perceived product quality can impact product performance and therefore repeat purchase (Stefani *et al.* 2005; Rao 2005). According to the Total Food Quality Model (TFQM) developed by Grunert (2005), consumers utilize cues from cost, extrinsic properties, expected intrinsic quality cues of sensory, health, and convenience, when assessing their perceived quality of a product before it is purchased. The difference between expected intrinsic quality cues and actual product performance is assessed in DOL studies. Understanding the expectations of consumers from cues due to perceived satiety, brand label, and price, is paramount for understanding initial purchase. The important categories of extrinsic properties for discussion in this review will be grouped into three categories; perceived satiety/portion size, properties associated with packaging and label (brand image), and cost/price.

Perceived Satiety and Portion Size

Perceived satiety of a food or beverage is the expectation of the degree of fullness (satiety) after consuming that product. Perceived satiety and portion size go hand-in-hand as the portion size is already dictated by the packaging of that food/beverage. Brunstrom *et al.* (2008) define this concept as ‘expected satiety’ where consumers consider if a particular food/beverage portion is large enough to stave off hunger until the next meal. The

importance of perceived satiety and portion size on purchase intent was investigated by Brunstrom and Shakeshaft (2009) where participants were asked to indicate the amount of money they would spend for particular portion sizes of eight different snack foods. The authors used pictures of the different snack foods of specific food amounts that were correlated to specific fat, carbohydrate, and protein contents. Participants then conducted a trade-off between two images as to which food would prevent them from feeling hungry for the longest period of time, and indicated their liking of each food with size of food portion also being decided. The authors reported that foods with high expected satiety were regarded as more rewarding and were also chosen in smaller portions (Brunstrom and Rogers 2009; Brunstrom and Shakeshaft 2009). The study concluded that reasonably familiar and palatable foods are not selected in equal portion sizes. The authors also reported that individuals with a higher body mass index (BMI) were more likely to rely on expected satiety when making their portion size decisions. The authors also reported that expected satiety was a better predictor of purchase intent over food liking. No tasting was conducted in this experiment. It is possible that sensory influences, cognitive factors, and post-ingestive consequences all interact to affect the amount of food that is consumed (Kral 2006). The availability of foods/beverages in specific packaged portion sizes may not be the ideal portion size for each consumer and would affect purchase intent and would therefore be a potential DPI (Brunstrom and Rogers 2009).

Sensory specific satiety (SSS) is defined as the decrease in pleasantness of a product after eating the product to satiety (Rolls 1986). Weenen *et al.* (2004) reported that daily exposure to cheese biscuits and pears resulted in decreased liking of both products with a

longer effect of food aversion from repeat exposure observed with cheese biscuits. The authors speculated that the eating of cheese biscuits lead to a larger degree of boredom than pears. The decrease of liking after consuming a food/beverage product to satiety may affect the frequency of repeat purchase. Havermans *et al.* (2008) investigated the degree to which participants would work for either chocolate milk or crisps to acquire more of either item to consume when hungry. The "work" was determined by way of a computer game where participants could click on a computer screen to earn points that would allow them to earn more of either item. The amount of work that went into the task was then equated to purchase intent. The authors reported participants were more motivated to obtain points for crisps than for chocolate milk. Chocolate milk hedonic ratings decreased more so than crisps with continued consumption. The authors concluded that, SSS is food/beverage product dependent and will affect PI differently based upon that food product.

Yeomans *et al.* (2008) demonstrated with a flavored and unflavored porridge sweetened with either sucrose, or aspartame, that participants demonstrated learned satiety by associating the flavor of the porridge with post-ingestive effects of increased satiety from a higher energy dense porridge sweetened with sucrose. Learned satiety would not be an extrinsic factor as the food would have to be consumed in order for learned satiety to affect repeat purchase intent. However, the concept of learned satiety is very important in understanding how consumer expectation of satiety affects their repeat purchase. Sweetness is usually a reliable predictor of energy intake since sugars are caloric, (Yeomans *et al.* 2008), however, this relay mechanism for satiety is not predictive of satiety from foods sweetened with non-caloric artificial sweeteners (Swither and Davidson 2008). Swither

and Davidson (2008) reported rats fed food sweetened with artificial sweeteners, consumed more food than when sweetened with sucrose and therefore gained more weight and became less sensitive to satiety tests. If the consumer perceives an artificially sweetened food to be less satiating than the same food sweetened with sucrose or another caloric sweetener, it is possible that the consumer will consume more of the artificially sweetened food in order to become sated. If a consumer perceives a lower calorie food to be less satiating, the packaging size, (portion size), may affect their frequency of purchase. In other words, a low calorie food may be consumed to completion at a faster rate and be repurchased possibly more often if all other sensory quality cues are met. There may be confounding effects due to boredom discussed previously, but an interesting direction for the research to go into. Yeomans *et al.* (2005) in a precursor study to the 2008 study, reported participants ate a greater mass of low energy dense porridge sweetened with aspartame than a high energy dense porridge sweetened with sucrose. The increased consumption of the low calorie food will affect the frequency of repeat purchase and the perceived satiety will be mitigated by the portion size offered. If the food is to be consumed in larger portions because the perceived satiety is low, the portion size offered at the time of purchase will be important. Yeomans *et al.* (2005) also reported than when the porridge was flavored similarly in the high energy and low energy conditions, there was no response in consumption amount and energy density suggesting palatability, (flavor), was a more important predictor of the quantity consumed than perceived satiety. This is not to suggest that satiety does not play a role in consumption amount, but flavor may be the more important factor. In a follow-up study, Yeomans *et al.* (2009) reported that respondents adjusted the amount of intake of a flavored high energy

porridge but this adjustment in quantity consumption was not observed when the porridge was not flavored, suggesting the importance of flavor in providing a cue towards satiety. This type of learned satiety could affect repeat purchase intent frequency, specifically a high energy dense food may be purchased with less frequency than the corresponding low energy density food because self-regulated smaller portion sizes of the high energy dense food will result in the food lasting longer between purchases.

Perceived satiety of a food may be dependent upon food type. Flood-Obbagy and Rolls (2008) investigated the perceived satiety of different forms of apples adjusted for energy density. Whole apple, applesauce, and juice with and without additional fiber of similar weight and calorie density, (except for the juice without additional fiber), were evaluated by participants for perceived satiety after a timed consumption period. Perceived hunger was lowest after consuming solid apple, followed by applesauce, and both juices. Fullness was greatest for whole apples, followed by applesauce and both juices. The results of this study suggest that food form can affect perceived satiety. Purchase decisions based upon perceived satiety will be different depending on perceived calorie density and food form.

Emotional state or mood at time of purchase may also affect the quantity and type of food purchased, although this is not a factor under the control of food scientists or marketers. Yeomans and Coughlan (2009) reported a higher frequency of consumption of popcorn and raisins from a test population with a reported negative mood after watching video clips intended to elicit a negative emotional affect. This study only involved women and also reported that women with a higher body mass index (BMI) consumed more snacks than

women with a lower BMI. Negative moods may decrease inhibitions and allow for overeating (Herman and Polivy 1980). We eat because of cues that tell us sufficient time has passed since our last meal, or to experience the sensory pleasure of foods, or because of boredom (Prescott 2012). Consumer mood prior to purchase will affect the type of food purchased and the quantity. Consumer mood at time of purchase is not an extrinsic factor that can be controlled however it is an important driver of purchase intent. This is why understanding the emotional effect food has on consumers has been a popular research topic (Brown et al. 2013; Cardello et al. 2012; Ferrarini et al. 2010; King and Meiselman 2010; King et al. 2010; Wallis and Hetherington 2009; Desmet and Schifferstein 2008; Macht 2008; Canetti et al. 2002; Oliver and Wardle 1999)

Product Features – Brand and Labeling

Brand Name

It is well known that branding affects consumer perceptions of a product (Rubio *et al.* 2014, Wyma *et al.* 2012, Vranesevic and Stancec 2003, Deliza and MacFie 1996, Vickers 1993). The degree and direction of which is of vital importance to measure in DOL studies because the brand sets up expected quality cues. Brand name is an important piece of information when consumers are deciding between competing products (Deliza and MacFie 1996). Private brands are often perceived as lower in quality than national brands (Rubio *et al.* 2014, Wyma *et al.* 2012; Jervis *et al.* 2012). Private brands include store brands, private labels, distributor's brands, reseller brands, middleman brands, own brands, dealer brands, and 'generic' products that are brand-free, no-name, house brands and unbranded products (Wyma *et al.* 2012). However, consumers' brand preferences may be a reflection of their

perceptions rather than from the actual product performance (Bronnenber *et al.* 2007). Consumers who are quality conscious place more trust in the performance of recognized brands and associate store brands as having an increased risk of not performing up to expectations of that product (Rubio *et al.* 2014, Paasovaara *et al.* 2012). Rubio *et al.* (2014) conducted a store intercept interview study with Spanish consumers to understand consumer perception of branded and store branded products. According to the authors, the more aware consumers are of a brand, the more the awareness will affect their perception of the product quality which in turn, increases the perceived risk of purchasing a store brand product in that product category. Wyma *et al.* (2012), investigated consumer perceptions and preferences for private vs. national brand across a variety of food products, (cooking oil, dry pasta, jam, ice cream, rice, fruit juice, etc., n=25 food products) in a grocery store intercept questionnaire with South American consumers. According to the authors, consumers surveyed showed significantly higher preferences for brand label products in all product categories surveyed with the exception of cooking oil and dry pasta. The authors reported, with the exception of cooking oil and dry pasta, the likelihood of a consumer purchasing a private label product over a national label product was less than 30% (Wyma *et al.* 2012). Jervis *et al.* (2012) evaluated consumer perception of brand label sour creams in a conjoint comparative study. Store brands and unfamiliar regional brands had a lower utility than national brands. Mueller and Szolnoki (2010) reported informed liking, defined as the relationship between blind liking and acceptance of extrinsic attributes of packaging, brand, and grape variety, to be the strongest driver of purchase intent. Meaning extrinsic and intrinsic factors in conjunction with each other were the highest predictors of liking for branded wines. This

was followed by price as the next highest driver of purchase intent. For wine, extrinsic factors appear to be more important for RPI than for crisp snack foods. Paasovaara *et al.* (2012) investigated the perception of a national brand and a regionally unfamiliar brand of drinkable yogurt. The authors investigated the branding affect on liking as well as the effect of a recognizable national brand vs. a regionally unknown brand. According to the authors, the national brand liking increased significantly between a blind and unblinded tasting, however the regional unfamiliar brand liking did not increase significantly. This result highlights the increased quality perception consumers place on foods with recognizable branding. Vranesevic and Stancec (2003) investigated this effect with tin can pate', a commonly consumed food in Croatia where the study was conducted with two high quality brands where only one of the brands was well known to the consumers surveyed. According to the authors, the lesser known pate' was significantly preferred under blinded conditions, and the well-known pate was significantly preferred when the brand was revealed during tasting, again demonstrating the quality perception consumers attribute to well-known branded products. The effect of brand on product perception may be a subconscious effect and therefore difficult to measure in any direct survey situation. According to Mueller *et al.* (2010), processing visual cue, (such as a brand label), have been found to be unconscious and unintentional, therefore asking consumers about their preferences directly, may not result in accurate responses.

According to McClure *et al.* (2004), in a consumer evaluation of Coke and Pepsi, using fMRI imaging different regions of the brain were activated when consumers tasted the products with and without brand images. In another study of the brand effect of Coke and

Pepsi, scientists at the Human Neuroimaging Lab at Baylor College of Medicine in Houston Texas used fMRI imaging to document brain activity of consumers who consumed Coke and Pepsi when brand was not revealed, and again when consumers were aware of the brand they were consuming (Lindstrom 2008). According to the authors, respondents in the blinded condition preferred Pepsi. In the unblinded condition when consumers were informed which product they were consuming, Coke was preferred. FMRI results indicated different regions of the brain showed activity in the two test conditions. The authors concluded brand imaging greatly affected consumer's preferences of a tasted product demonstrating the importance of brand in product liking (Lindstrom 2008). Vickers (1993) reported a branding effect dependent upon food type. Bower and Turner (2001) investigated the effect of brand name, price, and intrinsic factors on the purchase intent for crisp snack foods. In this study, the researchers evaluated the effect of liking with and without brand label, and the effect of a well known name brand label compared to an economy label. The researchers reported intrinsic effects to be the predominant drivers of purchase intent for crisp snack foods. The researchers also reported a price effect where there was an increase in PI for higher prices and name brands performed better than economy products, indicating that for crisp snack foods, consumers were willing to pay more for perceived higher quality brand name. For crisp snack foods, liking was a stronger driver of repeat purchase intent than brand label and price.

The effect of brand and other extrinsic factors can be assessed in a blinded tasting environment but can also be assessed in other surveying methods such as conjoint or KANO analysis. Jervis *et al.* (2010) reported for latte-beverage purchase, location of purchase was

the most important attribute over intrinsic attributes such as fat content, lightener type, sweetener type, and flavor. In this study, location is the brand. Through ethnographic observations, consumers frequented coffee houses over other location types for latte-beverage purchase because of how they felt when they purchased in that environment. Clearly, for latte-beverages, there are extrinsic factors that affect purchase intent. An important follow-up study would be to conduct a blind and unblinded tasting session using location as a brand and determine the importance of intrinsic attributes compared to location. Kim *et al.* (2013), in a thorough study of chocolate milk drivers of liking, evaluated product attributes in a conjoint study, KANO study, and in a blinded and unblinded tasting condition. Conjoint results indicated brand names had a higher utility than store and unfamiliar brand names although unlike latte-beverages, brand was not the most important attribute. For chocolate milk fat content followed by sugar content were the most important attributes followed by brand. Overall brand names were indifferent attributes as assessed by KANO analysis however Kim *et al.* (2013) did report one consumer cluster that found Nesquik as a name brand as attractive, and a second consumer cluster that found PET as a name brand, attractive. In a blind and unblinded tasting condition, Kim *et al.* (2013) reported a brand effect for national brand chocolate milks with an increase in purchase intent when brand was known. Also reported was a decrease in purchase when consumers were informed the milk was whole milk. It is clear the importance of brand image in perceived product quality and purchase intent, however the degree of which appears to be product dependent. Therefore in assessing the factors important for purchase and repeat purchase of a product, the degree of

importance of brand image cannot be ignored and needs to be determined on a product-by-product basis.

Other Labeling Factors

Packaging and labeling of a food plays an important role at the point of purchase (Deliza *et al.* 2003). The extrinsic factors associated with the product packaging and labeling are of primary importance for initial purchase intent and setting up expectations for product liking and quality. Once consumer expectation is matched, consumer satisfaction may occur and repeat purchase (Deliza and MacFie 1996). It is important to understand the factors that influence consumer expectation as the weight of those factors may be as important as or more important than intrinsic factors depending on the product. Moskowitz (2001) investigated image related attributes of margarine to taste/texture attributes and compared if they were associated. The author reported liking, quality, similarity to butter, and healthfulness to be related demonstrating that non-sensory related attributes can be important to product liking on a product by product basis. Cardello (2003) investigated the importance of processing technologies on product liking by assessing intrinsic and extrinsic factors in a DOL study on chocolate pudding in a blinded and unblinded condition referring to the knowledge of processing technology. Consumers first evaluated three chocolate puddings in an unblinded condition, and then came back a month later to taste the same three chocolate puddings with additional information on processing technology used. The results compared the extrinsic factor of processing condition to liking; however, no sensory attributes were also evaluated to have a comparison of extrinsic and intrinsic factors. Cardello reported a greater effect for processing technology for females than males. Liking scores were

positively influenced when the tasting was accompanied with a safety and benefit statement in the unblinded condition. Deliza *et al.* (2003) investigated the utility of label attributes in a pictured conjoint study of passion-fruit juice. Deliza reported five consumer segments all driven by different labeling features. Each consumer segment employed different packaging features when evaluated expected sensory liking of the pictured product. Chrea *et al.* (2011) conducted an investigation of extrinsic factors that may influence purchase of Australian wines. For wine products, consumers have to primarily rely on extrinsic factors as the product cannot be tasted prior to purchase (Chrea *et al.* 2011). Chrea *et al.* (2011) conducted a conjoint and a label liking study to assess extrinsic factors associated with wine purchase. According to the authors, consumers rely primarily on price followed by label and bottle cues for wine purchase. Price was suggested to be an indication of quality which was supported by the highest price range having the highest utility across price levels. The information a label or packaging provides to the consumer, like brand image, affects the perceived quality and expectations of the consumer and will affect repeat purchase if the intrinsic factors do not meet the expectations set by the extrinsic factors. This degree and direction of this effect, (positively or negatively influence hedonics), must be determined in DOL studies in order to understand what the actual DOL will be in the purchasing environment. Otherwise, the degree of importance of the sensory attributes evaluated alone will not be an accurate measure of the degree of importance of the sensory attributes in the purchasing environment when brand labels are influencing purchase.

Cost/Price – Willingness to Pay

Product information raises sensory and hedonic expectations and price can be an indication of product quality (Cardello and Sawyer 1992; Rao 2005; Grunert 2005). Price can unconsciously influence the perception of product quality and the expectation of quality can then influence the actual product performance (Rao 2005). This effect has also been observed with nonpricing information such as advertising claims about product quality (Rao 2005). Willingness to pay (WTP) is defined as "the maximum price a buyer is willing to pay for a given quantity of a good." (Wertenbroch and Skiera, 2002). While price and WTP are two different things, they are inextricably linked as the set price by a manufacturer will be inevitably viewed in concordance with consumers WTP for that product based upon all perceived quality and sensory cues. Price is the best known extrinsic indicator of quality and in the absence of all other extrinsic variables, a higher priced product will be judged as higher quality than the lower priced alternative (Oude Ophuis and Van Trijp 1995).

The importance of price has been assessed in many studies using surveys, conjoint analysis, and auctioning studies. Grunert *et al.* (2009) investigated three techniques for assessing WTP; contingent valuation, (which is a survey based approach), experimental auctions, and choice based conjoint analysis. The authors reported conjoint analysis to yield lower estimates of WTP than contingent valuation and auctions for a ready-made soup product. Bower and Turner (2001) reported consumer responses to price labels in a survey were consistent with their responses to price in a taste environment, suggesting surveying consumers prior to tasting may be a reliable way to gain understanding of price as a DPI. Chrea *et al.* (2011) found price to be the most important attribute influencing wine purchase

with the highest price level having the highest utility. WTP and the importance of price are product specific. Xue *et al.* (2010) investigated consumers WTP for grass-fed beef after a blind evaluation of conventional and grass-fed beef. Nutritional information for grass-fed beef was also evaluated before or after tasting, or not at all, in three balanced consumer groups. Consumers who were given nutritional information on grass-fed beef before or after tasting were WTP more for grass-fed beef than the control group given no nutritional information. No significant difference between nutritional information groups was reported. The results of this study demonstrate the importance of nutritional information to consumers WTP for grass-fed beef. Barreiro-Hurle *et al.* (2007) investigated consumer WTP for resveratrol-enriched red wine of consumers in Granada Spain, using a choice experiment. The authors reported consumers were willing to pay more for a resveratrol-enriched red wine compared to a standard red wine. Janssen and Hamm (2012) investigated consumer preferences and WTP for different organic certification logos of apples and eggs. Consumers were from six different European countries. Overall consumers were WTP more for eggs and apples with organic labels that included either a European Union logo, government logo, or private logo. Authors also reported that overall, results were similar for eggs and apples with the exception of Germany where the WTP for the three logos was even higher for eggs than for apples. Consumers overall did not find products without a logo as trustworthy and credible, which was why organic certification with a logo was preferred. The authors also suggested that this result is in line with unfolding theory which suggests that consumers infer from the absence of a label that the product does not possess the respective attribute (Golan *et al.* 2001). Unfolding theory also implies that the presence of a label claim is a signal of

quality and that competitive products without such claims are indicating they lack that attribute (Golan *et al.* 2001). Van Loo *et al.* (2011) conducted a similar experiment for organic chicken breast using a choice experiment. Consumers were WTP more for an organic label however an organic label with a United Stated Agricultural Department (USDA) logo had a higher premium than a general organic label. Monaco *et al.* (2005) investigated the effect of price on chocolate bars with and without a health claim in a blinded tasting condition. The authors reported that health claim and price did not affect liking however the increase in price reduced the likelihood of purchase. Focus group results suggested chocolate gives pleasure, a reward; therefore, healthfulness was not an important factor. Solheim and Lawless (1996) investigated the effect of fat content and price on consumer purchase intent of Cheddar cheese and reported a decreasing price increased purchase probability and reported a gender effect for fat content effect on purchase probability. Costanigro *et al.* (2014) investigated consumer WTP for non-sulfited wine in a choice experiment. The authors reported that consumers who suffer from sulfite-induced headaches, were willing to pay a premium of $1.23 to avoid them, but were only slightly more likely to purchase a wine that did not contain sulfites. Price and perceived quality were reported to ultimately influence purchase with little influence from organic and sulfite labeling. Mueller *et al.* (2010) investigated consumer choice of wine by modeling sensory attributes and discrete choice attributes. According to the authors, price was the most important driver of liking however purchase intent was most strongly influence by product expectations in the purchase decision as measured by a computerized choice experiment.

Consumers may indicate a strong hedonic preference or purchase intent for a product perceived as high quality without actually buying the product once placed in a purchasing environment (Lange *et al*. 2000). One of the ways to assess consumers WTP for a product is in a blind and unblinded tasting condition followed by an auctioning study which determines hedonic preferences and confirms preferences in an actual purchasing situation. Vickrey auction method is a commonly applied auctioning method that involves asking individuals to submit a sealed bid which corresponds to the maximum price they would pay for a particular product. The winner is the highest bidder who actually has to pay for the product at the second highest bid (Vickrey 1961). This strategy allows consumers to purchase a product at a price lower than their maximum willingness to pay which motivates them to bid accurately. Lange *et al.* (2002) used a Vickrey auction method with a blind and unblinded tasting condition to assess consumers WTP for Champagne. According to the authors, the results of the auctioning study discriminated the Champagnes more so than hedonic ratings but both methods lead to the same overall conclusions about the Champagnes. Napolitano *et al.* (2010) investigated the role of information about organic product on beef liking and consumer willingness to pay using a Vickrey auction. The type of information significantly affected liking. Information on the organic production system had a larger effect on liking than information on animal welfare, and environmental pollution. Overall consumers responded to the fact that the beef was organic rather than to positive messages in general. Consumers were also WTP more for organic beef. Lawless *et al*. (2012) used auctioning to determine consumers WTP for a Concord grape and blackberry juice blend with a benefit statement about anthocyanins before (or after) tasting depending on the study group (n=4).

Reading the health statement after tasting increased WTP more so than reading the health statement prior to tasting. It was expected that additional beneficial information would increase WTP as a primer for expected sensory attributes, however for this product, this was not the case. The recommendation was to accompany new nutraceutical products with in-store tasting sessions. Chern and Lin (2012) investigated the importance of Country of Origin Labeling (COOL) on Taiwanese products versus imported products with Taiwanese consumers using an auctioning experiment with tasting. Chern and Lin (2012) reported that freshness, safety, and country of origin labeling are very important to Taiwainese consumers. In an auctioning study, Taiwainese consumers were WTP more for charcoal-smoked plums, and Oolong tea with a Taiwainese COO label. Lee *et al.* (2012) investigated the DOL of imported and domestic black olives. In a survey of consumers, the authors reported olive taste to be the primary influence of purchase followed by price and then country of origin. An investigation of sensory attributes in conjunction with labeling which includes price and country of origin would help understand the initial and following DPI. De Steur *et al.* (2012) investigated WTP for genetically modified (GM) rice in high risk regions of China using an auctioning study. Chinese female consumers of childbearing age were presented with a GM rice of higher folate concentration, and non-GM rice with an additional folate supplement. Overall, female participants were WTP more for GM rice than non-GM rice with a folate supplement. Information on GM foods was presented to the participants and auctioning bids were lower after providing information about GM technology. Knowledge of folate benefits was the main determinant of WTP more for GM rice, however, WTP for GM rice was affected by consumer acceptance of GM foods. Ginon *et al.* (2009) investigated consumer

WTP for French baguettes with and without fiber information. High and low fiber baguettes were evaluated in an auctioning study in the presence and absence of health claims associated with fiber. Consumers were not WTP more than a certain price for a baguette even when it had a high hedonic score. A 'source of fiber' label of either brown flour or whole meal flour, (product specific for the high fiber baguettes), had a positive effect on WTP. Stefani *et al.* (2005) investigated the effect of country of origin on WTP of spelt utilizing a blinded tasting condition, expected condition, and an unblinded tasting condition to determine the effect labeling information had on consumers WTP for spelt of different country of origin using auctioning and hedonic evaluation. According to the authors, country of origin does have an impact on WTP for spelt.

The importance of price as an important factor in the purchase decision is clear. Understanding the magnitude of price importance in comparing products in a WTP experiment yields crucial information regarding the importance of extrinsic attributes.

CONCLUSIONS

Perceived satiety/portion size, perception of brand and labeling information, and the influence of price and WTP based upon labeling attributes should be determined in order to fully understand how consumers perceive a product. The extrinsic factors can be assessed in surveying methods such as conjoint and KANO analysis, however to best understand how each factor affects hedonics, products should be evaluated in the presence and absence of extrinsic factors and willingness-to-pay through auctioning. Brand label, perceived satiety, and price will influence product performance therefore to accurately measure the importance of sensory attributes, the effect of these factors must be addressed.

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Table 1: Summary of Drivers of Liking Studies

Authors	Subject Studied	Key DOL
Allgeyer et al. 2010	Yogurt drinks with pre and probiotics	Sweet and honey aromas, medium sweet taste, and high viscosity.
Bayarri et al. 2012	Spreadable cheese	Cheese odor, cheese flavor, consistency, creaminess, smoothness, cohesiveness, and mouthcoating.
Cardello et al. 2003	Novel processing technologies, (irradiation, pulsed electric fields, etc.) - chocolate pudding as the subject	Females were more concerned about processing technologies than males. Negative perceptions of foods after being informed about the processing technology used to make the pudding varied by process. High levels of concern, genetic engineering, irradiation, pulsed X-ray and bacteriocins.
Childs et al. 2009	Wet and dry cheese sauces	Wet cheese sauces, beefy/broth, free fatty acid, salty taste, oiliness in mastication, residual particle mouth coating. Salty taste was the primary DOL for dry sauces.
Chung 2009	UHT and HTST milk, Korean female consumers	High cooked flavor. Preferred milks available in Korea.
Cruz et al. 2011	Probiotic yogurt	Taste and texture more important than appearance.
Delgado et al. 2013	Nectarines and peaches	Sweetness was the main driver. Fruity aromas and pit aromas were cluster specific drivers. High ripe soluble solids concentration and flesh firmness were correlated to overall liking
Drake et al. 2008	Mild Cheddar cheese	Color, cooked/milky, whey, brothy flavors, and sour taste. Four consumer clusters identified based upon preferences for flavor and color.
Drake et al. 2009	Sharp Cheddar cheese	Cluster preferences identified for brothy, free fatty acid, and nutty flavors, salty and sour taste; young/mild flavors; and milk fat flavor.
Herrera-Corredor et al. 2007	Corn tortillas, Mexican consumers	Chewiness, appearance, rollability, and taste.
Kim et al. 2010	Fermented soybean paste (doenjang), Korean consumers	Sweet & MSG primary DOL. Salty taste, meju (traditional Korean soy sauce), and fermented fish primary drivers of dislike.
Kim et al. 2013	Orange juice, Korean consumers	High intensity orange flavor.
Krause et al. 2007	Butter	Butter flavors, salty taste, and spreadability.
Kreger et al. 2012	Extruded high protein snack	Protein type primary DOL.
Lee et al. 2012	Imported and domestic sliced black ripe olives	Aroma and flavor attributes associated with country of origin were the biggest drivers. Californian olives were the most liked which were the most familiar to the consumers studied. Drivers of dislike were alcohol and artificial fruity/floral.
Leksrisompong et al. 2012	Sweet potatoes	Flavor and texture attributes more important than appearance. Smooth texture, brown sugar, dried apricot flavor, and sweet taste.
Leksrisompong et al. 2013	Lemon lime carbonated beverages, diet and regular	Mouthfeel for both regular and diet beverages.
Liggett et al. 2007	Swiss Cheese	Diacetyl (buttery), whey, milk fat, and umami. Cabbage, cooked, and vinegar were drivers of dislike.
Michon et al. 2010	Jam filled cakes	Age effect reported with highest age group having the highest liking. Gender effect , males preferred cakes more so than females.
Morais et al. 2014	Prebiotic gluten-free bread	Texture and sweetness. Rubbery, hard, and chewy were drivers of dislike.
Piombino et al. 2013	Tomatoes	Firmness, herbaceous aroma, sour taste, thick epicarp, and seeds were identified as primary drivers of liking. Drivers of dislike were identified as mealiness, diacetyl-like odor, fruity odor, and thin fruit pulp
Shepard et al. 2013	Sour cream	Cooked and milk fat flavors. Segmentation identified for dense, and highly cooked flavors. Across segmentation high fat content and milk fat attributes preferred.
Thompson et al. 2007	Chocolate milk, Hispanic consumers	Milk fat flavor, cocoa flavor. Cooked and malty specific to cluster membership.
Tomaschunas et al. 2013	Vanilla custard dessert	Medium fat contents, fat related texture attributes.
Williamson et al. 2010	Red wine, Chinese and Australian consumers	Australian and Chinese consumers had different DOL for red wine. Australian DOL primarily oak flavor and dark fruit. Chinese consumers preferred brown color and had stronger negative reactions to astringency.

CHAPTER 2:

THE EFFICACY OF USING PHOTOGRAPHS TO REPRESENT ATTRIBUTES OF SLICED SANDWICH BREAD IN AN ADAPTIVE CHOICE BASED CONJOINT

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RUNNING TITLE: Efficacy of individual attribute picture use in adaptive choice based conjoint

ABSTRACT

Pictures to represent product concepts in conjoint surveys are a useful tool however this technique limits the complexity of the survey design. A solution to this is to represent multiple product attributes as individual pictures. The objective of this study was to determine if pictures of individual product attributes of sliced bread products can be used to determine the utility of sliced bread in adaptive choice based conjoint (ACBC) analysis. Commercial sliced sandwich bread were photographed, formatted, sized, and composed for visual evaluation. All possible crust/crumb combinations (n=36) were first presented to pre-screened bread consumers (n= 1024) in an online survey to determine their overall appearance liking using the 9-pt hedonic scale. One month later, pre-screened bread consumers (n =891) evaluated the crust and crumb pictured attributes in an ACBC survey. Market simulations were conducted on the utility scores of bread products to predict bread performance. Subsequently, consumers (n=100) evaluated commercial bread representing select levels of crust and crumb for appearance liking using the 9-point hedonic scale and results were compared to the market simulation results to demonstrate the efficacy of the technique. Both composite and ACBC surveys revealed crumb with seeds/flakes to be more appealing than a uniform crumb, and crust with flakes/oats was more appealing than crust with no topping. Market simulator predictions were in general agreement with consumer overall appearance liking scores of commercial sliced bread ($p<0.05$). The utility scores estimated from the attribute pictures were representative of choice behavior in a consumer test.

PRACTICAL IMPLICATIONS

Whole wheat breads are important in the fight against obesity, however, despite best efforts, they are underrepresented in the American diet. It is important to understand how consumers currently perceive whole wheat and white breads to determine what features of bread are most attractive. The appearance of bread influences purchase intent of the consumer. Pictures, rather than descriptions of features, may be useful to determine the utility of crust and crumb attributes. Representing pictures of attributes as opposed to the entire product concept will enhance the complexity of conjoint studies allowing for more information to be gathered in a given study.

KEY WORDS

Adaptive Choice Based Conjoint, Whole Wheat Bread, Photographs

INTRODUCTION

Conjoint, as a method of determining attractiveness of product features, has been a widely used tool in sensory and marketing research. The efficacy of pictures represented in conjoint studies as part of a product concept has been clearly demonstrated. Deliza et al. (2003) used computer generated images of passion-fruit juice labels to determine the attractiveness of different features within the labels. Pictures used in conjoint studies for determining moving and housing preferences were reported to enhance respondent importance for housing characteristics (Jansen et al. 2009). Kildegaard et al. (2011) successfully used pictures of yogurt and smoothies in a conjoint study with children to determine choice preferences. Reisfelt et al. (2009) used a conjoint design to present pictures of meals and compare preferences across demographic variables. Olsen et al. (2012)

presented pictures of buns and juices to children in a conjoint design and validated the conjoint results with a consumer test.

The pictures in these studies either represented the entire product concept or one attribute within a larger conjoint with written attributes included. The use of composite pictures to represent products can greatly limit design complexity of the conjoint. For example, a conjoint study with pictures representing sliced sandwich bread would include the crust and the crumb (center of the bread). Each picture represents one level of crust and one level of crumb for one product picture concept. If crust is represented by two colors, light and dark, and crumb by two colors, white and brown, a 2 X 2 design or 4 product concepts are generated. Pictures at this level of complexity can easily be represented as one attribute in a conjoint study included with other written attributes. If toppings on the crust, oats and flakes are represented, the factorial design is increased to 6 X 2 or 12 product concepts. Increasing the complexity of the crumb attribute to include 'mix-ins' of seeds and flakes now increases the picture factorial to a 6 X 6 or 36 levels of pictures. This is too large of a number of levels to have enough exposure per respondent to ensure reasonable individual-level utility estimation while included other written attributes. The solution to this would be to break the composite picture of crust and crumb into two pictures; one of crust and one of crumb so that they are two attributes instead of one, each with 6 levels. While this approach allows for reasonable exposure of each level to a respondent, the question then becomes, can respondents look at two pictures that represent one feature, form the product concept in their minds, and evaluate as if it were one composite picture?

One of the newest forms of conjoint that is gaining in popularity is called Adaptive Choice Based Conjoint or ACBC. This form of conjoint marries two existing forms of conjoint; Choice Based Conjoint (CBC) and Adaptive Conjoint Analysis (ACA). In an ACBC, respondents exhibit choice behavior while having individually adapted scenarios presented to them based upon their choice preferences. This technique is comprised of three sections starting with a build your own (BYO) sequence where respondents select their ideal level of each product feature. Responses in the BYO section are factored into the subsequent choice tasks. A screening task is the second section where respondents are presented with product concepts that they can indicate if the concept is a possibility for them or not. The final section is a tournament section where product concepts are shown with only select differences in order to fine tune the utility score estimations. ACBC has been suggested to yield more accurate individual level responses and require fewer respondents than a CBC (Jervis *et al*. 2012; Yu *et al*. 2011; Orme 2010; Toubia *et al.* 2004, 2007).

The objective of this study was to determine if respondents can evaluate multiple attributes represented by pictures as well as written attributes in evaluating an entire product concept and to determine if that evaluation was representative of behavior in an actual choice scenario. The subject chosen for this study was sliced sandwich bread. Sliced sandwich bread was chosen because it can be represented visually by two attributes, crust and crumb, testing the technique in the simplest form. Sandwich bread is also a common grocery purchase in American households making it an ideal product for this study.

METHODS

This study was conducted in four parts. The first part involved a composite survey to determine the general liking trends of the bread features using composite picture evaluation. The second part was an adaptive choice based conjoint evaluating the utility of the pictures of crust and crumb used to make the composite pictures. In part three, a market simulator of select bread products from the ACBC utility score estimations was conducted. Finally a confirmatory consumer test (CLT) was conducted where consumers visually evaluated five commercial bread products that represented the levels of crust and crumb evaluated in the market simulator.

Picture Generation

Commercial whole wheat and white sliced bread products were photographed, formatted, sized, and color corrected using Adobe Photoshop CS6 (San Jose, CA). All photographs were color corrected using a Munsell Color checker Chart (Color Accuracy.com, Lincroft, NJ). Photographs were taken using a Kaiser 205360 Copy Stand Reprokid with 55W lamps (Amazon.com). The pictures generated for the composite survey and ACBC study are represented in Figure 1.

Participants in this study

All participants in any facet of this study were recruited using an online database of participants (n=5600) maintained by the Sensory Service Center of North Carolina State University. Participants were residents in the Raleigh/Durham/Chapel Hill, NC area. All participants had to be purchasers of sliced sandwich bread, at least 1 loaf per month. Participants in the composite study were invited to also participate in the ACBC study. In

the follow-up confirmatory consumer test, consumers were recruited from the same database and had the same requirements as the previous two surveys however they could not have participated in the composite survey or the ACBC survey. This was done to confirm the efficacy of the conjoint results.

Composite Survey

A survey of the composite bread pictures was created using SSIWeb (Sawtooth Software version 8.0.22, Orem, UT). An explanation of the composite picture was first given to all respondents before beginning the survey (Figure 2). All 36 composite pictures were presented to each respondent in a monadic sequential randomized design (Figure 3). As each picture was presented, respondents were asked to evaluate their overall liking of the appearance of the bread product in the picture using the 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely. At the conclusion of the study, respondents were entered into a drawing to win one of five twenty dollar gift cards and one, one hundred dollar gift card. Bread pictures were then compared for overall differences in crust and crumb. A total of 1024 respondents participated in this study. These respondents were contacted one month after the conclusion of this study and invited to participate in the ACBC study.

Adaptive Choice Based Conjoint

An ACBC survey was created using SSI Web (Sawtooth Software version 8.0.22, Orem, UT). Crust and crumb picture levels are represented in Figure 1. The non-picture attributes also used in this study are represented in Table 1. Prices represented the range of sliced sandwich bread cost regionally. The ACBC study was designed with one BYO task followed by ten screening tasks with three product concepts per task with the possible

responses of “a possibility” or “won’t work for me” for each product concept. A minimum of two and a maximum of three attributes varied from the BYO selections for each product concept. Five unacceptable questions and four must have questions were built in through the survey. The screening task section was followed by a ten question choice task tournament section. A maximum of 20 product concepts were brought into the tournament section with a minimum of three concepts per choice task. A total of 891 respondents participated in this section of the study. At the conclusion of the study, respondents were entered into a drawing to win one of five twenty dollar gift cards and one, one hundred dollar gift card. The same respondents were used for both surveys to allow direct comparison of utility scores and overall liking scores.

Market Simulator

A market simulator was used to predict the share of preference of select bread products from the ACBC study using the utility scores from the ACBC. The market simulator operated on a First Choice Rule also referred to as the “Maximum Utility Rule.” (Sawtooth Software Inc.) The simulator assigned the product with the highest utility overall for that respondent as the winning product for that respondent. All other less preferred products were assigned zero share for that respondent. If two or more products were exactly the same in terms of utility, then the preference was split evenly amongst the choices for that respondent. Select combinations of bread levels were chosen for simulation that was representative of commercial bread products to be evaluated in the consumer test. Products evaluated in the market simulator are represented in Table 2.

Consumer Test

One hundred sliced bread consumers evaluated five commercial sliced sandwich bread products that were representative of select levels of crust and crumb (Table 2). Consumers were presented the breads in a sequential monadic balanced block design (Compusense 5.2, Guelph CA). The heel of the bread and the next three slices off of either end of the loaf were discarded so that each slice used for visual evaluation was of uniform size, shape and thickness. Commercial product chosen for this test was of identical size, shape, and slice thickness. Bread slices were presented on 6'' white Styrofoam plates labeled with an identifying unique three digit code. When presented with a sample, consumers were instructed to only handle the plate and not touch the bread. They were asked to indicate their overall liking of the entire appearance of the bread using the 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely. They were then asked to indicate their overall liking of the crust appearance and the crumb appearance separately using the 9-point hedonic scale. Consumers then returned their sample before receiving the next sample. It is important to note consumers were never permitted to touch/handle the bread samples as this was to be a direct comparison to the visual evaluation by the ACBC. Consumers were instructed that if they handled the bread they would be disqualified from further participate and compensation. After successful completion of the visual test, consumers were compensated with a ten dollar gift card.

Statistical Analyses

Overall appearance liking scores from the composite survey were compared using a one-way analysis of variance (ANOVA) with the Fisher's least significant difference (LSD)

as the post hoc test using XLSTAT Addinsoft version 2010.5.02 (New York, NY). Individual utility scores were extracted by Hierarchical Bayesian estimation and rescaled using a zero-centered differences method (Orme 2010; Jervis *et al*. 2012). The zero-centered differences method standardizes all attribute utility scores so that easy comparisons are able to be made. A one-way ANOVA with Fisher's LSD as the post hoc test was used for analysis of the zero-centered utility scores (XLSTAT). Importance scores were determined by calculating the utility score range of each attribute and dividing by the total utility range multiplied by one hundred (Orme 2010). Comparison of importance scores was conducted using a one-way ANOVA with Fisher's LSD as the post hoc test (XLSTAT). Market simulation results were compared using a Chi Square statistic to determine differences between the proportions of respondents preferring each bread product evaluated by the simulator. Overall appearance liking, crust appearance liking, and crumb appearance liking from the CLT were analyzed using a one-way ANOVA with Fisher's LSD as the post hoc test (XLSTAT). All statistical analyses were carried out at a 95% significance level.

RESULTS AND DISCUSSION

Composite Survey

Results of the composite survey are shown in Figure 4. All 36 combinations (Figure 3) of bread were evaluated for overall appearance liking. Composite pictures with no topping on the crust had significant decreases in overall liking scores compared to composite liking scores where the crust had an oat or flake topping ($p<0.05$). The decrease in overall liking was consistent for light crust and dark crust ($p<0.05$). Crumb with a mix-in of seeds or flakes increased overall appearance liking. The increase was greater for a light crumb than a

dark crumb ($p<0.05$). Overall a light crumb was liked more than a dark crumb ($p<0.05$). Challacombe et al. (2011) reported a dark crumb to be more acceptable in appearance in a consumer test with 81% of the consumers being self-reported whole wheat bread consumers. Bakke and Vickers (2011) also reported a darker colored bread to be associated with liking from whole wheat bread consumers. Consumers in this study were made up of whole grain and white bread consumers (Table 3). Overall, respondents liked a crust with a topping and a non-uniform crumb.

Adaptive Choice Based Conjoint

Percent importance scores represent the importance of each attribute in the choice task decision. Price was the most important attribute in the choice decision of bread (Figure 5). The picture of the crumb was the next most important attribute, followed by the picture of the crust and the flavor/taste claim at parity. It is important in conjoint studies to have respondents consider all information given in the product concept when making choice decisions. A potential area of concern with including pictures is respondents may give too much importance to those attributes and therefore they are not considering all information when making their decisions. Because price was the most important attribute and a picture attribute (crust) was at parity with a written attribute (flavor/taste claim), respondents were considering all information when making their choices therefore pictures were not distracting from the choice decision. Consumers consider more than hedonic responses to products in making their choice decisions. This is seen in conjoint studies by importance scores of attributes as well as in taste tests. Kohlberg et al. (2005) compared consumer liking of bread with and without additional product information. Researchers reported an organic label had a

positive influence and an interaction was reported between health statement and bread type (Kihlberg *et al*. 2005).

Assessment of each individual level utility score by Bayesian estimation revealed a light crust with oats or flakes, and a dark crust with oats to have the highest utility followed by dark flakes, followed by dark no topping and light no topping (Figure 6) ($p<0.05$). This is in agreement with the composite survey where having some sort of topping increased overall liking/utility. Pictures of the crumb were evaluated as white seeds having the highest utility at parity with brown seeds which was at parity with brown flakes ($p<0.05$). This was followed by white flakes, brown uniform crumb, and white uniform crumb ($p<0.05$). This is also in agreement with the composite survey that a crumb with seeds or flakes increased liking/utility. The results of the ACBC study were consistent with the composite study. Respondents were able to look at individual pictured product attributes and evaluate them as if they were shown a composite pictured product.

A benefit of an ACBC over a survey showing the composite pictures, (besides increased complexity of product feature combinations), is the additional information gained about other attributes of the bread product. In the ACBC, texture claims of crust and crumb, label claim, flavor/taste claim, and price were also determined. Price, as would be expected, was sorted in utility by the lowest price having the highest utility followed step-wise until the highest price, which had the lowest utility (results not shown). A soft crust had a higher utility than a hard crust ($p<0.05$) (Figure 6). A soft crumb had the highest utility followed by moist and smooth at parity. A chewy, compressible, gummy, dense, firm crumb had lower utility, respectively. Charoenthaikij et al. (2010) reported 3 day and 5 day old bread to be

harder, less cohesive and less springy compared to 0 day bread by descriptive analysis. In a consumer test the 3/5 day old bread had overall liking scores lower than 0 day bread; 3/5 day old bread was also disliked in texture attributes. A label claim of "whole grain" had the highest utility followed by "great homemade flavor" at parity with "no artificial ingredients". "Great taste," "high fiber", and "all natural" were all at parity ($p > 0.05$). The label claim with the lowest utility was "soft texture." This is counterintuitive from the crust and crumb texture claims where "soft" had the highest utility in both attributes. Respondents found a soft crust texture and crumb texture attractive but did not like the idea of "soft" as a label claim. The flavor/taste claim with the highest utility was "wheaty" followed by "buttery" and "nutty" at parity. This was followed by "mild" and "toasty" at parity, "earthy", "sweet", and "yeasty" with the lowest utility ($p<0.05$). Overall, sliced sandwich bread that appeared to be higher in whole grain attributes had a higher utility than a traditional refined white bread.

Market Simulator and Consumer Testing

In order to confirm the results of the ACBC study, the utility scores were loaded into an online market simulator that predicts percent market share preference of products represented in the ACBC. Bread products represented in the consumer test and market simulator crust and crumb combinations are shown in Table 2. Breads selected for the consumer test represented the crust and crumb pictures in figure 1 and were identical in size, shape, and slice thickness. This was done so that no other visual attributes could confound or influence liking scores. Overall, market simulator predictions of market share preferences and overall consumer appearance liking scores were in agreement (Figure 7). The only slight

deviation between prediction and actual appearance liking occurred with the Dark None and Brown Seeds combination. The market simulator predicted this bread to be significantly different from the top two performers (DO BS, WF BS), however in the CLT DN BS was at parity with DO BS and WF BS ($p>0.05$). Comparing just crust appearance, market simulator predictions and CLT results were in alignment with the exception of DN, the same sample that deviated in the overall appearance liking prediction score (Figure 8). All crumb appearance predictions were in agreement with CLT scores (Figure 8). The slight deviations observed in the confirmatory CLT and the market simulator are predictable. The pictures used in the ACBC and composite surveys were formatted and composed using Photoshop for evaluation. This level of control of appearance is not possible with commercial product as natural variations in baking and processing are going to occur. This demonstrates the differences in researcher control between a composed survey evaluation and a consumer test with real product. Overall, the use of pictures to represent sliced bread products was predictive of consumer choice behavior.

Representing multiple product attributes as pictures offers a wide range of product application and can greatly aid developers in determining which product features to focus on when developing new products. This technique can save time and money in the product development process by determining quickly and relatively inexpensively the product features of most importance before they have to be physically created. Traditional conjoint surveys serve the same purpose however with the addition of pictures of individual product attributes; this technique allows for more robust conjoint design and provides an easily

communicable blueprint between consumer researcher and product developer on the physical appearance of product attributes of most importance.

Annett et al. (2008) reported health information related to organic labeling of whole wheat bread increased liking scores in a side-by-side taste test with a commercial whole wheat bread. The researchers baked two treatments (conventional and organic) and presented to consumers in a taste test along with environmental and health information. A conjoint study with pictures would allow for researchers to gain understanding of the utility of an organic label claim and/or health/environmental information while presenting multiple physical attributes in the form of attribute photographs. This technique can save time and money while assessing multiple physical attributes that make the creation of multiple treatments for taste evaluation logistically difficult.

Bakke and Vickers (2007) reported consumers who were self-reported refined bread or whole wheat bread consumers, preferred those breads respectively in a consumer taste test of laboratory-manufactured breads, commercially available breads, and artisan breads. Breads with crumb, including seeds or flakes regardless of color, had higher utility than a uniform crumb suggesting a less refined appearance would be more liked than a refined appearance. This was confirmed in the consumer test with brown crumb with seeds having higher hedonic scores than brown and white uniform crumbs. Crusts with topping were also scored higher in liking than crusts with no topping (Figures 7 and 8). The majority of the respondents (64.7%) in this study purchase a whole grain or multigrain sliced bread as their primary sliced bread (Table 3). Less than 30% purchase a refined white or wheat bread as their primary sliced bread. A partial least squares regression model of pictured attributes

utility scores across primary bread type purchased, reveals across respondent groups a crust without a topping is unattractive as a bread feature (Figure 9). Crust with an oat or flake topping was attractive to purchasers of white bread. Wheat and whole grain white purchasers were also associated with a flake/oat crust topping as well as a brown crumb. Multigrain purchasers were associated with a white crumb. Wheat, whole wheat, and whole grain white purchasers were similarly grouped.

Conjoint methodology with pictures has been applied to adults of all ages and has been applied to children (Olsen *et al.* 2012; Kildegaard *et al.* 2011; Reisfelt *et al.* 2009; Jansen *et al.* 2009; Deliza *et al.* 2003). This method included with behavior, value, and demographic questions could be used to reveal segmentation within the sample size surveyed. An extension of this research is to apply this same technique to school-aged children.

CONCLUSIONS

Pictures to represent more than one attribute of a product can be used in an adaptive choice based conjoint to determine the utility of those features. The utility determined from product features is predictive of choice behavior in a consumer test. This technique greatly enhances the depth and breadth of conjoint survey design by enhancing the number of attributes and levels that could traditionally be represented by pictures of product concepts. This technique will aid the product development process by identifying key product features that affect choice.

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Figure 1. Pictures of crust and crumb used for composite and ACBC survey evaluation

Figure 2. Example composite pictures for composite survey

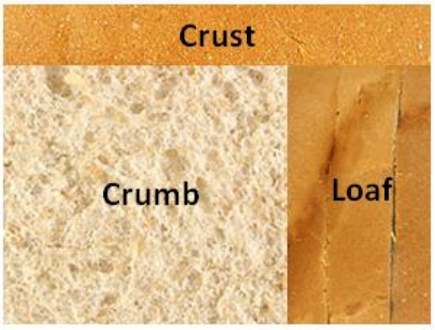


Figure 3. Thirty-six Composite Pictures for Composite Survey

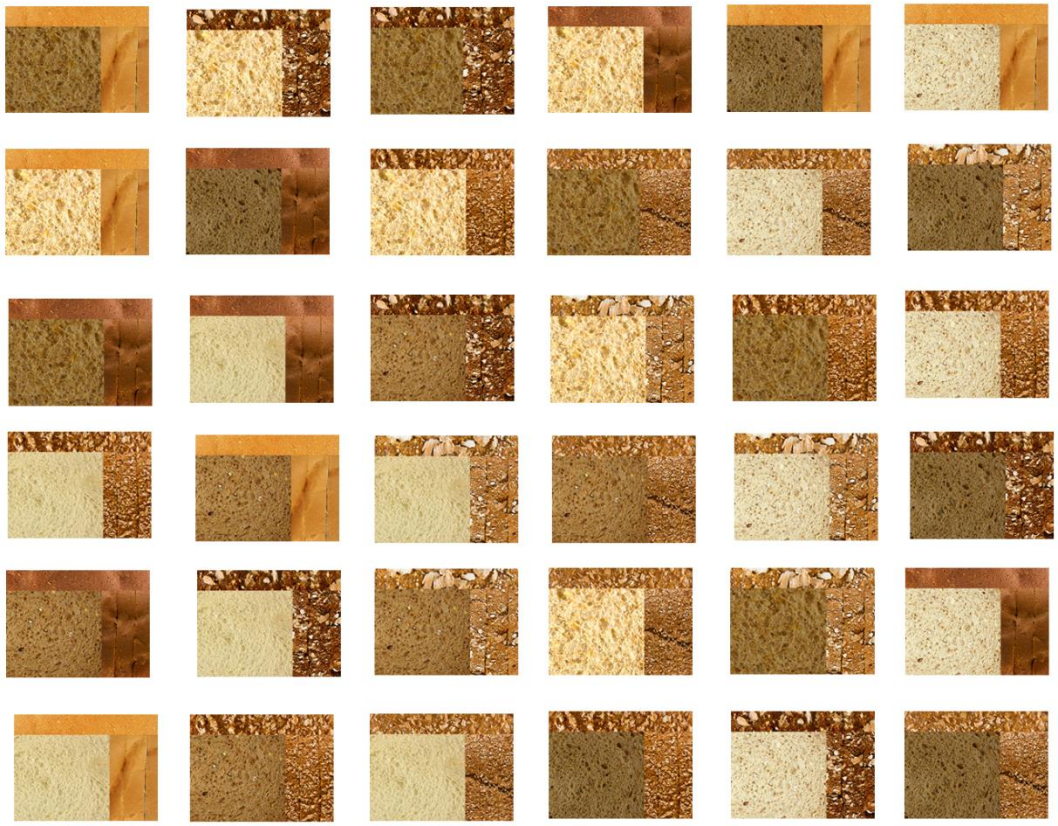


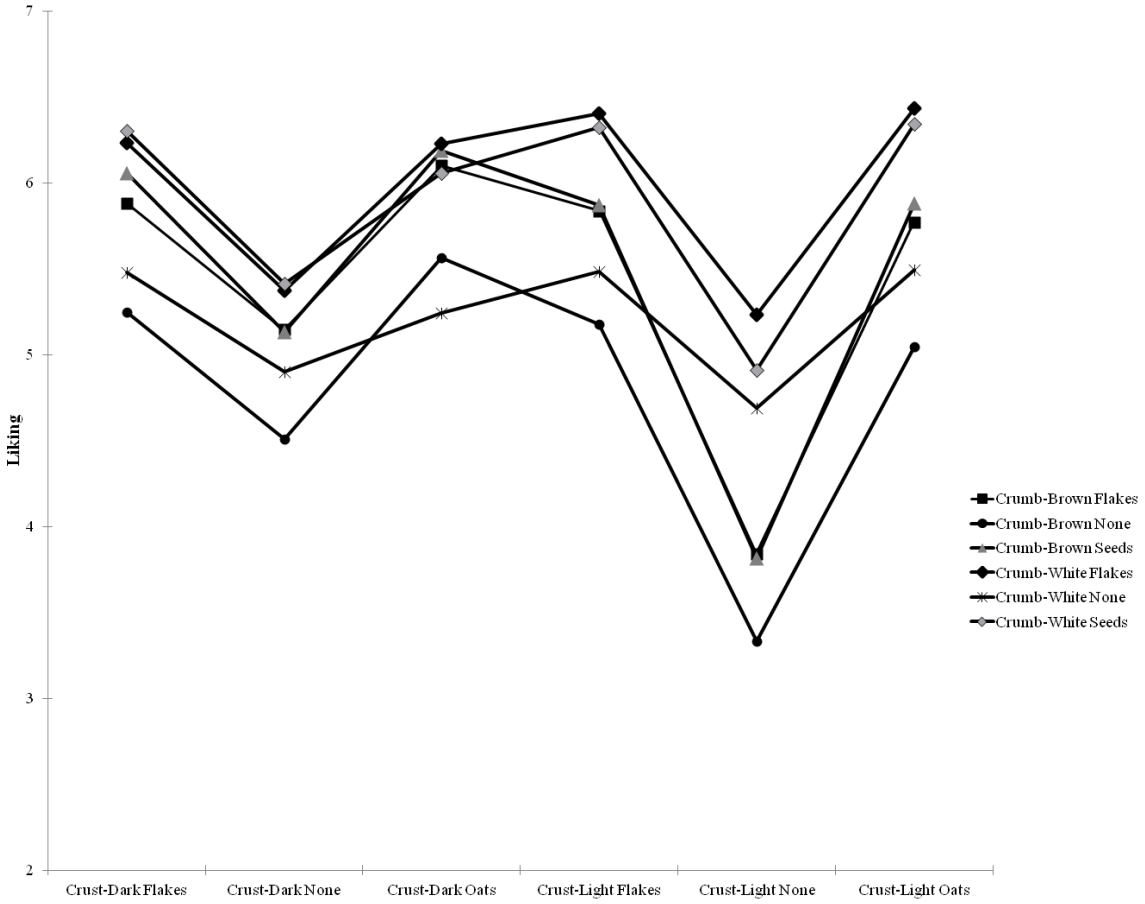
Table 1. Non-picture attributes and levels represented in ACBC study

Attribute	Level
Crust Texture	Hard
	Soft
Crumb Texture	Moist
	Soft
	Chewy
	Smooth
	Compressible
	Grainy
	Dense
	Firm
Label Claim	Great taste
	Whole grain
	Great homemade flavor
	High fiber
	Soft texture
	All natural
	No artificial ingredients or preservatives
Flavor Claim	Wheaty
	Buttery
	Sweet
	Toasted
	Mild
	Nutty
	Yeasty
	Earthy
Price	$1.99
	$2.49
	$2.99
	$3.49
	$3.99
	$4.49
	$4.99
	$5.49

Table 2. Levels of Crust and Crumb Represented in the CLT and Market Simulator

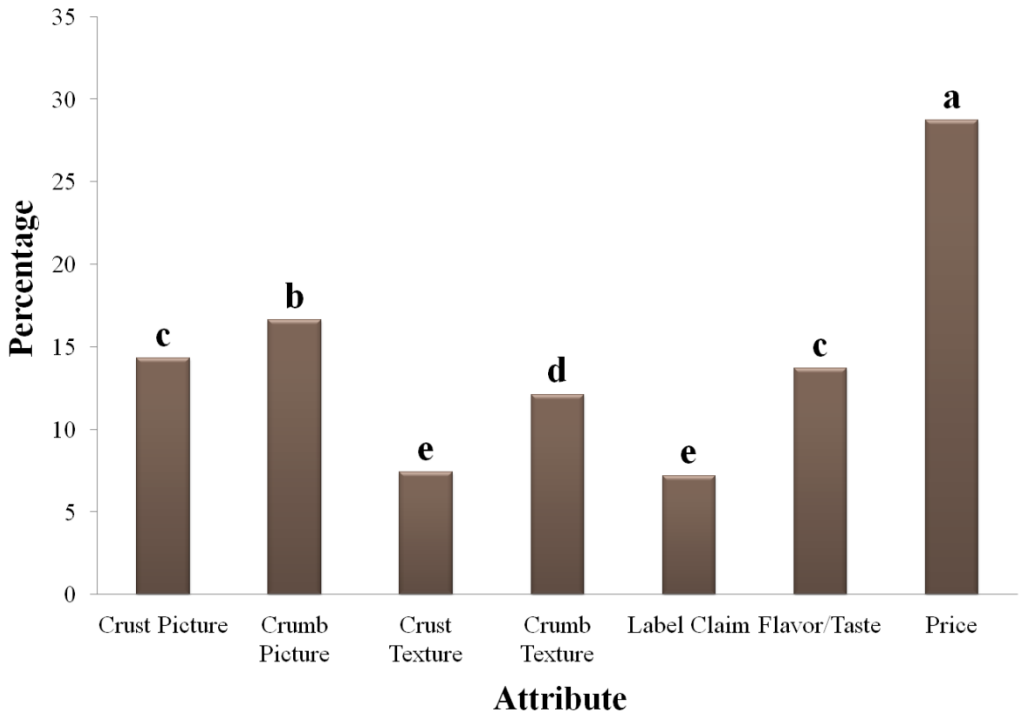
Crust	Crumb	ID
Dark Flakes	Brown None	DF BN
Dark Oats	Brown Seeds	DO BS
Dark None	Brown Seeds	DN BS
White Flakes	Brown Seeds	WF BS
White None	White None	WN WN

Figure 4. Composite Survey Results of Hedonic Appearance Liking of Breads



*Liking scores based upon 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely
*Data represents n=1024 respondents

Figure 5. Percent Importance Scores of Bread Attributes by ACBC



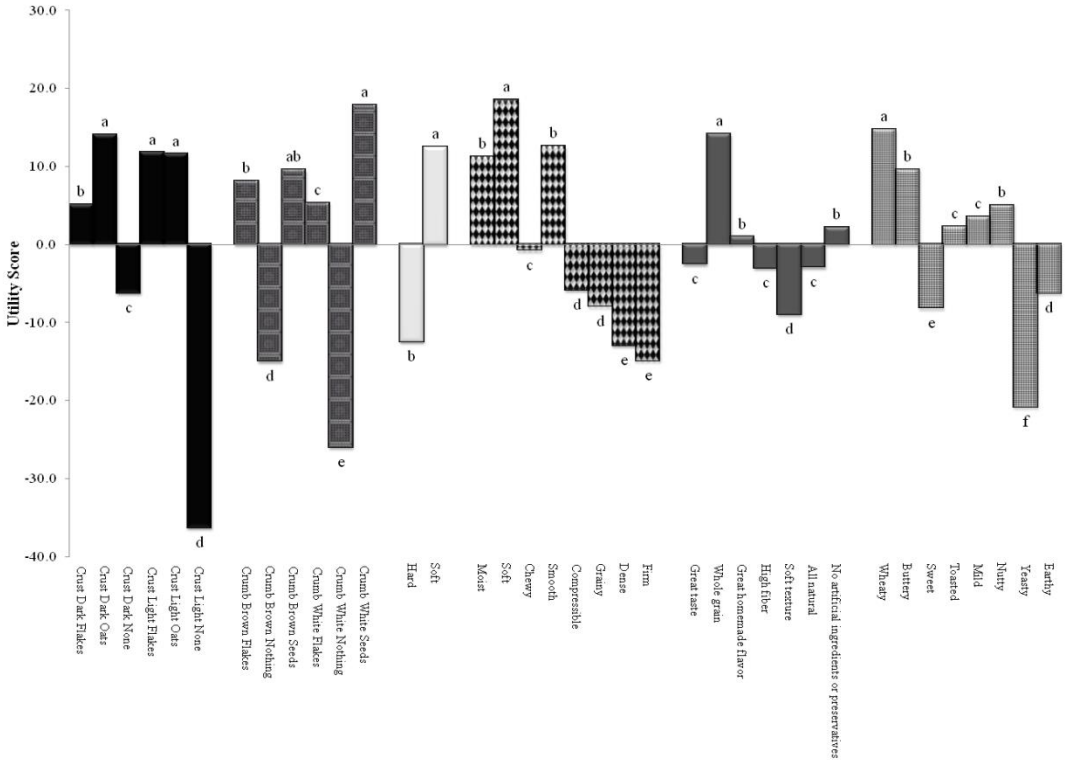
*Importance scores represented by a different letter are statistically different ($p<0.05$)
*Data represents n=891 respondents

Table 3: Percent Distribution of Select Demographic Information of Survey Respondents

Gender	Male	20.2
	Female	79.8
Age	18-24	13.9
	25-29	10.1
	30-34	14.2
	35-39	10.7
	40-44	12.2
	45-49	10.7
	50-54	11.0
	55-59	7.6
	60-64	6.1
	65-69	2.8
	70+	0.7
**Types of sliced bread typically purchase	White	43.9
	Wheat	49.3
	Whole wheat (100% whole wheat flour)	69.7
	Multigrain	61.9
	Whole grain white	34.0
	Oat/specialty variety	29.1
	Flavored variety	30.7
	Gluten-free	3.4
	Other	3.5
Sliced bread type purchased most often	White	16.5
	Wheat	13.0
	Whole wheat (100% whole wheat flour)	35.4
	Multigrain	18.7
	Whole grain white	10.5
	Oat/specialty variety	3.4
	Flavored variety	1.0
	Gluten-free	0.4
	Other	0.9

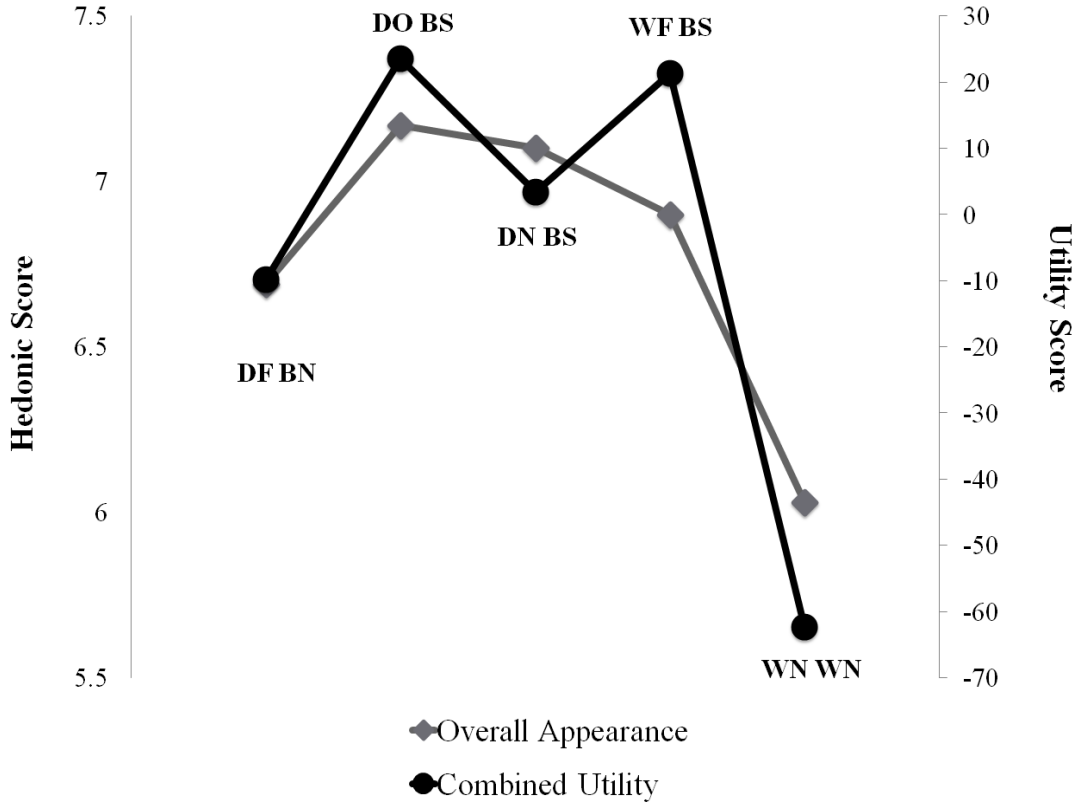
*Data represents n=683 respondents
*Percentage of respondents selecting each option is presented
**Represents a check all that apply question. Total percentages will be greater than 100%

Figure 6. Overall Utility Scores of Bread Attributes by ACBC



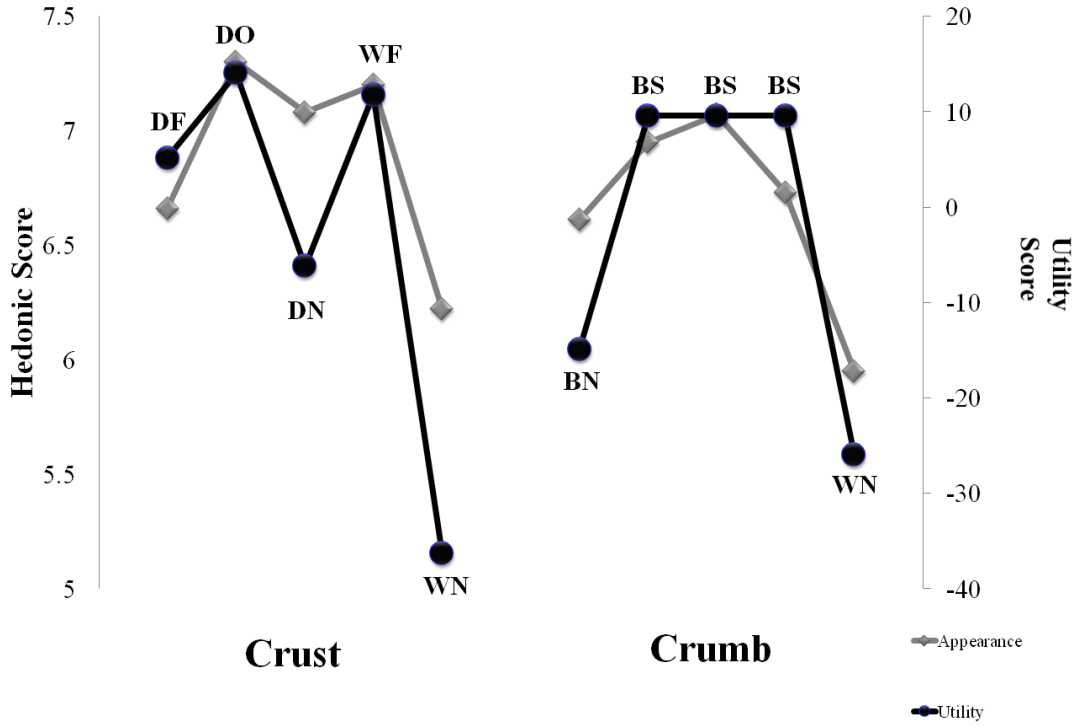
*Only levels within an attribute can be compared
*Levels within an attribute represented by a different letter are statistically different ($p<0.05$)
*Data represents n=891 respondents

Figure 7. Market Simulator Prediction vs. Overall Appearance Liking of Breads



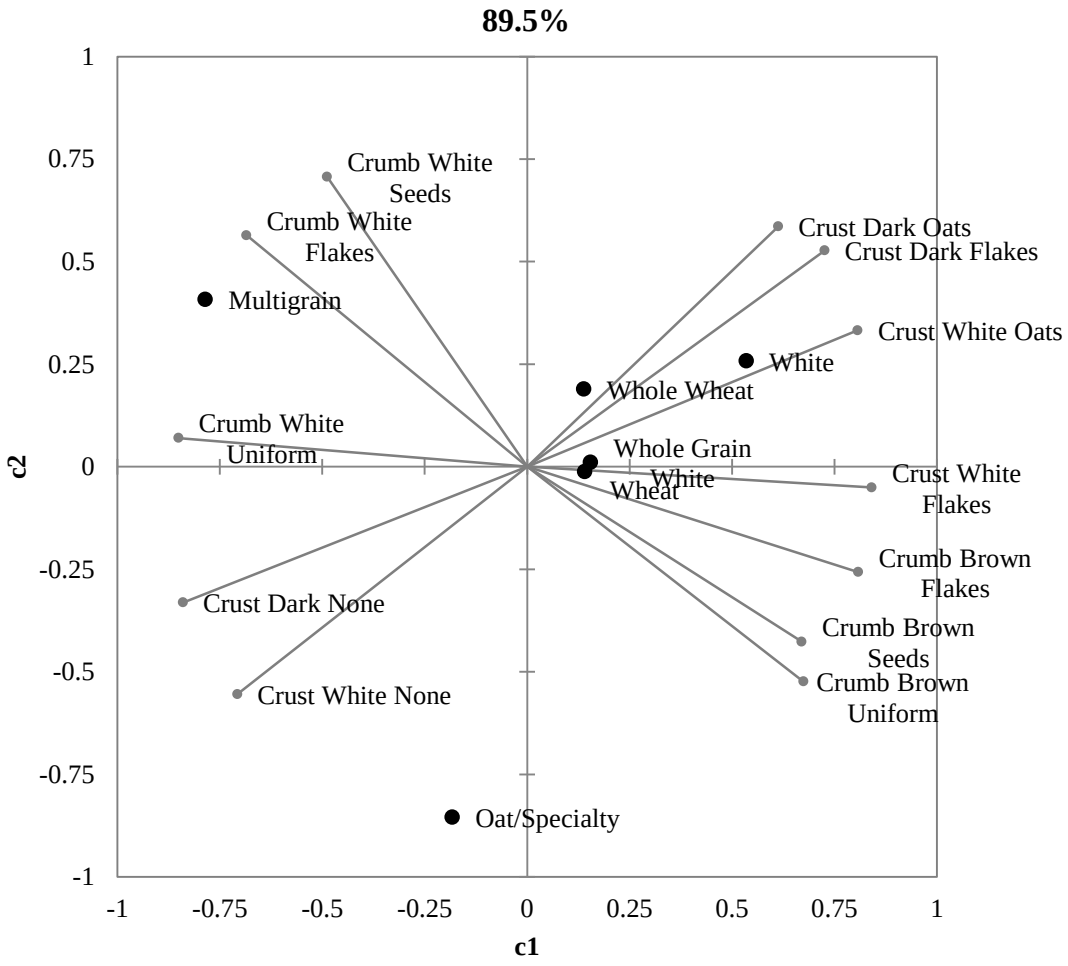
*Overall appearance liking was scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely
*Utility scores were determined using Hierarchical Bayesian estimation and rescaled using the zero centered differences method
*Consumer test data represents n=100 consumers; market simulator results represent n = 891 respondents

Figure 8. Market Simulator Prediction vs. Crust and Crumb Appearance Liking of Breads



*Crust and crumb appearance liking were scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely
*Utility scores were determined using Hierarchical Bayesian estimation and rescaled using the zero centered differences method
*Consumer test data represents n=100 consumers; market simulator results represent n = 891 respondents

Figure 9: Partial Least Squares Regression of Pictured Attribute Utility Scores Across Primary Bread Types Purchased



*Data represents n=683 respondents

CHAPTER 3.

Comparison of Preference Mapping Methods on Commodity Foods with Challenging Low-Variance Attributes: Sliced Whole Wheat Sandwich Bread Example

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RUNNING TITLE: Comparison of External Preference Mapping Methods for Sliced Sandwich Bread

ABSTRACT

Traditional preference mapping methods can suffer where attributes with larger variances dominate the analysis thus detracting attention from attributes of potential importance as drivers of liking. This study compared traditional external preference mapping methods (PLS and PREFMAP) with a new method PrefHMFA designed to control dominance of high variance attributes and to reveal the sensory dimension that align with liking dimensions. Twenty-five sliced whole wheat breads were profiled by descriptive analysis (DA) for flavor, appearance (crust and crumb groups), and texture (oral, hand) attributes. Breads were subsequently presented to bread adult consumers (n=360). Data were also subjected to path analysis (PATH-PLS) and three different preference mapping analyses (PLS and PREFMAP, and PrefHMFA). Traditional methods (PLS/PREFMAP) showed broad ideal points. PrefMFA partial axes showed that the main hedonic dimensions were aligned with higher sensory dimensions. PrefHMFA revealed a greater importance on appearance and hand-perceived texture attributes. Path-PLS revealed the importance of family in the drivers of liking for sliced sandwich bread.

PRACTICAL APPLICATION

External preference mapping is used to relate analytical sensory data to consumer acceptance. Traditional techniques have been criticized since attributes with large variances can dominate the traditional PCA or PLS-based methods. New preference mapping techniques of PrefMFA and PrefHMFA have been suggested to account for attribute dominance. These techniques will aid in determining drivers of liking for commodity-type foods where attribute dominance poses a problem with traditional methods.

KEY WORDS

External preference mapping, PrefHMFA, Whole Wheat Bread

INTRODUCTION

Product optimization is the aim of every food manufacturer, and external preference mapping is a method utilized for this purpose (McEwan 1996). Preference mapping is a way to statistically consider both analytical sensory results and consumer information in product perception. By using analytical sensory data and consumer techniques in conjunction, a complete picture of the product can be obtained (McEwan 1996). External preference mapping is a multivariate technique in which sensory attributes are first evaluated by trained panelists and scaled according to their intensities. The attributes are then modeled by multivariate analyses. Consumers evaluate their acceptance of the same products and the hedonic liking scores are then fit into the model using a polynomial model to regress the hedonic scores to the sensory space (Worch 2013; McEwan 1996; Carroll 1972). Four polynomial regression models can be used, linear, circular, elliptic, or quadratic which generates a two dimensional plot that can be used to estimate the optimum characteristics a

product would possess for consumer acceptance (Yenket *et al.* 2011; McEwan 1996; Carroll 1972). This type of preference mapping technique is often referred to as PREFMAP (Yenket *et al.* 2011). Partial Least Squares Regression (PLS) is another commonly used method for preference mapping which regresses both the descriptive and the consumer data to maximize the covariance between the two data sets whereas PREFMAP only maximizes the variance explained by the sensory attributes (Yenket *et al.* 2011). External preference mapping is essentially regression analysis where the dimensions of the profile space (trained panel sensory attributes) are the predictor variables and liking is the response variable (McEwan 1996; Schlich 1995).

Preference mapping techniques have been widely used in industry to categorize and identify drivers of liking (DOL) for commodity products based upon sensory attributes. Resano *et al.* (2010) reported significant consumer regional preferences for dry-cured ham with Spanish consumers using PREFMAP. Spanish consumers preferred Spanish hams to French hams which were characterized by crumbliness, softness, flavor and sweetness. Drivers of dislike were mold odor, high saltiness, and crust. Lawless *et al.* (2013) recently reported optimization of black cherry, pomegranate, and concord grape juice blends using a mixed design where select treatments were profiled by descriptive analysis and evaluated by consumers and subsequently modeled in an external preference map. Morais *et al.* (2014) reported the drivers of liking of prebiotic gluten free bread with celiac consumers, Leksrisompong *et al.* (2012) reported the drivers of liking of lemon lime carbonated beverages, and Shepard *et al.* (2013) reported the drivers of liking of sour cream by modeling sensory attribute and consumer liking scores using partial least squares regression analysis.

Correct identification of DOL of consumer liking using external preference mapping is considered by some to be overly influenced by attributes with high numerical variance rather than the amount of importance given each by consumers in their liking decision process. Traditional methods identify key sensory attributes, but cannot address the degree of importance of the sensory attributes (Bi 2012). Traditional methods have also been criticized for the inability to provide ideal intensities of select attributes and do not address the issue of multicollinearity which often affects DOL studies (Bi 2012; Plaehn 2009; Meullenet *et al.* 2007). Yenket *et al.* (2011) compared different preference mapping techniques using three different products (milk, pain, and fragrance) and reported distinct differences in ideal points from the different methods. According to the authors, none of the methods tested, (which included PREFMAP and PLS from XLSTAT), consistently generated a high percentage of consumers who mapped close to their most liked product.

Attributes with high variance mathematically dominate common PCA analysis and mapping techniques, such as PREFMAP and PLS, because the algorithms used are trying to explain the most variance for each dimension. Not all sensory attributes will have equivalent variance. For example, for sliced sandwich bread, there is no reason to expect the variance of crumb appearance to be similar to the variance in crumb texture. The attributes with higher variance will be mapped better than attributes with low variance. The low variance attributes may be highly important as drivers of liking and as such, may not be revealed in traditional preference mapping methods, (PREFMAP and PLS). This effect is called attribute dominance**.** The high variance attributes in the first two dimensions "dominate" the sensory space (Worch 2013; Faber *et al.* 2003). When attribute dominance

occurs, attributes that may be important to consumer acceptance that may have lower variance appear unimportant when in fact, these attributes may be very important to consumer acceptance. This is a major limitation of traditional external preference mapping (PREFMAP) in that the techniques generally use only two dimensions for regression models, and there is no evidence that these dimensions are always the most relevant for liking (Worch 2013). Considering the main goal of preference mapping it to provide ideal points for product optimization, (Lawless *et al.* 2013), it is imperative to gain the right insight from these techniques.

A new methodology, called PrefMFA (Multiple Factor Analysis), has been proposed by Worch (2013) which has elements of both internal and external preference mapping because it takes the dimensions from the "common" space between sensory scores and hedonic scores in individual regressions (Worch 2013). PrefMFA, and its extension PrefHMFA are designed to control attribute dominance on data from products such as sliced whole wheat sandwich bread that will contain attributes that have a low variance (Worch 2013). The PrefMFA method combines MFA (multiple factor analysis) and PrefMap in the same analysis where a common space between hedonic and analytical sensory data is obtained by MFA as a starting point for PrefMap and is considered a combination of internal and external preference mapping (Worch 2013).

Also, it cannot always be assumed that the intrinsic sensory attributes of commodity-type foods, such as whole wheat bread, are the main drivers of purchase as opposed to the extrinsic factors such pricing or other family-associated considerations. Multi-block methods, such a multi-block PLS or Path-PLS models, allow variable paths, or structures, to be

evaluated and can reveal the relative importance of extrinsic and intrinsic drivers (Multi-block PLS) (Tenenhaus *et al.* 2005a; 2005b). The path coefficients generated by this analysis, quantify the orientation and the strength of the linear structural relations between the variables in the model which can aid in understanding how pricing and family considerations factor in to drivers of purchase (Terzi *et al.* 2014). These approaches have been used extensively in the social sciences to develop frameworks for human psychology, consumer behavior and other processes. Terzi *et al.* (2014) investigated the relationships between three institutions, (economic, political, and social), and three components of human development, (economic development, knowledge, and health). The authors reported a strong relationship between economic institutions and economic development confirming the assumption that institutions that imply government expenditure or create positive conditions for private investment determine economic development. These methods allow the evaluation and identification of extrinsic factors (other than sensory attributes) that can influence and drive consumer purchase intent. This analysis was performed in the current study in addition to preference mapping to attempt to understand the relative influence of sensory liking on purchase intent.

The objective of this paper was to compare traditional preference mapping techniques of PLS and PREFMAP against a new preference map techniques PrefHMFA on data from sliced whole wheat sandwich bread to determine if low variance attributes contribute to drivers of liking that are not explained by traditional preference mapping methods. Whole wheat sliced sandwich bread was chosen as the subject for this study. An additional

approach, path-PLS modeling, was used to validate the role of sensory attributes as drivers of purchase before performing drivers of liking analyses.

METHODS

Breads

Twenty sliced whole wheat bread treatments that ranged in crumb and crust texture, color, and addition of nuts/seeds, or flakes to crust/crumb, were prepared and baked in a commercial facility. Five commercial whole wheat sliced sandwich breads that represented the range in whole wheat sliced sandwich bread were also added to the study for a total of twenty-five treatments (Table 1). All commercial breads were evaluated within two weeks of their pull date, and test breads were evaluated within two weeks of manufacture.

Descriptive Analysis

Appearance, texture and flavor attributes of breads were evaluated using the Spectrum™ method with a 0 to 15 point product specific scale for texture and a 0 to 15 point universal scale for flavor (Meilgaard *et al.* 1999). All panelists (n=7 females, n=3 males, ages 21-50 y) had a minimum of 50 h of previous experience with descriptive analysis of foods using the Spectrum method, and an additional 60 h of training was conducted that focused on bread attributes. A lexicon for sliced sandwich bread was first developed using commercial sliced sandwich bread and previously published studies as a starting point for development (Callejo 2011; Elia 2011; Hayakawa *et al.* 2010; Lotong *et al.* 2000). Panelists participated in a series of one h training sessions (n=60) to develop and refine a final lexicon (Tables 2, 3). Analysis of variance from preliminary bread samples confirmed that panelists were able to use the lexicon consistently and that breads were discriminated. The twenty-five

breads were evaluated in triplicate across five days using Compusense version 5.2 (Compusense, Guelph CA). The breads evaluated each day were assigned based upon a balanced Williams design for five treatments. Three evaluation sessions occurred each day with a minimum of 1 h between each session. Crust and crumb attributes were profiled separately.

Consumer acceptance

Concurrent with descriptive analysis testing, sliced bread consumers were recruited to participate in a central location trial across five days at a testing site located on the North Carolina State University campus (Raleigh NC). Consumers were recruited through their participation in an online database of Raleigh/Durham/Chapel Hill consumers maintained by the Sensory Service Center with over 6,000 members at the time of recruitment. In order to qualify for participation, the consumers had to be 18 y or older and purchase at least one loaf of sliced sandwich bread per month. White bread and whole wheat bread consumers were both recruited for this study in order to capture the general preferences of sliced whole wheat bread across all sliced bread consumers, however, everyone in the study indicated they purchased whole wheat or other whole grain sliced sandwich bread at least occasionally. A total of three hundred fifty consumers was the participation goal for this test, therefore, n=375 were recruited with n=360 participating across all five days. For successfully completing all five days of testing, consumers were compensated with a $100 gift card to a local shopping store.

Consumers were presented with five breads each day in a balanced monadic design. The five breads chosen for presentation each day were based upon a balanced presentation of

the commercial treatments on day 1, and a balanced presentation of the test treatments on days 2 – 5. A balanced williams design for five treatments was used for each day, which coincided with the five treatments evaluated each day by descriptive analysis panelists. The treatments evaluated each day were randomly assigned with the exception of the commercial treatments which were all evaluated together on day 1.

On each day of testing, consumers were given paper ballots that were coded for their assigned panelist number and treatment identifying three digit codes in their balanced presentation orders. Consumers were presented with their samples in monadic fashion and evaluated the appearance of the bread followed by a tasting evaluation. Consumers evaluated their overall appearance liking, crust appearance, and crumb appearance using the nine point hedonic liking scale where 1 = dislike extremely and 9 = like extremely. This was followed by two just about right (JAR) questions on crust and crumb color where 1 = much too dark, 3 = just about right, and 5 = much too light. Consumers were then instructed to touch and taste the bread and were given specific instructions to consume both crust and crumb. Consumers then evaluated their overall liking of the bread, flavor liking, texture liking, moistness/consistency liking, and sweet taste liking using the nine point hedonic scale. This was followed by crust texture and crumb texture where 1 = much too soft, 3 = just about right, and 5 = much too hard. Moistness JAR was also asked and scaled where 1 = much too dry, 3 = just about right, and 5 = much too moist. Finally, the consumers answered a series of impression questions about the breads. Consumers were asked to rate how they would feel if the bread they had just evaluated was the bread they had at home to eat. This was scaled on a five point scale where 1 = feel awful, 3 = indifferent, and 5 = feel great. This was

followed by a met expectations question of a whole wheat bread that I would buy for my family which was scaled on a five point scale where 1 = definitely did not meet expectations, 3 = unsure, and 5 = exceeded expectations. Following this was a five point agree/disagree question if their family would eat this bread if it was purchased for them, where 1 = definitely agree, 3 = neither, and 5 = definitely disagree. The final question was also a five point agree/disagree of purchase intent question if the bread was available at a reasonable price and available locally. At the end of each session the consumers turned in their ballots. At the conclusion of the fifth day of testing, consumers received their gift card compensation.

Statistical Analyses

Descriptive analysis profiles of flavor and appearance/texture were analyzed using principle component analysis (PCA) using XLSTAT Addinsoft (New York, NY). Cluster analysis was performed using k-means using XLSTAT (New York, NY). External preference mapping was conducted using partial least squares regression (PLS) of descriptive analysis attributes and overall liking scores using XLSTAT Addinsoft (New York, NY). External preference mapping contour plots were conducted using PREFMAP within XLSTAT Addinsoft (New York, NY). All statistical analyses were conducted at a 95% significance level. PrefHMFA was conducted using R 3.0.3 (R Core Team, 2014) and the FactoMineR v1.25 package (Lê *et al.* 2008). The analysis was performed using the methods of Wortch (2013), with the PCA of sensory data (external data) as a correlation matrix and the liking data (internal data) as a covariance matrix. PathPLS was carried out using the Path-PM module of XLSTAT Addinsoft (New York, NY).

RESULTS AND DISCUSSION

Descriptive Analysis

The lexicons developed for sliced sandwich breads differentiated the twenty-five treatments by flavor, appearance, and texture attributes (Figures 1, 2). Flavor and appearance/texture attributes were plotted separately for clarity A total of 49% of the variability was explained on PC1 and PC2 for flavor attributes (Figure 1). Crust and crumb sweet aromatic/molasses, crust burned/toasted, crumb whole wheat flour paste, crust bitter, crust and crumb aftertaste initial, and crumb umami loaded positively on PC1 while crust and crumb sweet aromatic/caramelized, crust fatty/stale, and crust and crumb salty loaded negatively on PC1. Crust and crumb sweet taste, crumb toasted grain/bran, and crust fruity/fermented loaded positively on PC2 while astringent mouthfeel, crumb white flour paste, and crust sour loaded negatively on PC2. Flavor attributes of crumb rye, crust fruity fermented, crumb fatty/stale, crumb sour, and crumb sour aromatic were removed from the PCA because they were detected in less than three treatments. Key differentiating flavor attributes were crumb whole wheat flour paste and crumb white flour paste as well as crumb sweet aromatic caramelized and crust sweet aromatic molasses. Breads A-D,F, and K were characterized by crust sweet aromatic/caramelized crust. Bread R was characterized by crust sweet aromatic/caramelized crust and crumb and crumb_white flour paste. Breads O, S, U, V-Y were characterized by sweet aromatic/molasses for crust and crumb, crumb whole wheat flour paste, and toasted grain/bran flavor of crumb.

Appearance and texture attributes differentiated the breads with 55% of the total variability explained by PC1 and PC2 (Figure 2). Appearance attributes of crumb cell size,

cell uniformity, porosity, as well as texture attributes of top crust chewiness, crumb graininess, crumb chewiness, and crumb tooth packing loaded on PC1 (36%). Crust color and crumb color, as well as texture attributes of hand crumb springiness, hand crumb rate of recovery, crumb hardness, crumb moistness, and crumb cohesiveness of mass loaded on PC2 (19%). Breads were primarily differentiated in texture and appearance attributes by traditional white bread attributes versus whole grain bread attributes. Breads F, H, I, K, Q, R, V, Y were lighter in color, low in graininess, high crumb adhesiveness to palate, uniform crumb, and high rate of recovery and springiness of the crust and crumb. Breads A, B, J, M, O, T, and W were associated with darker color, harder crumb, larger pore size, and high chewiness and graininess, which can be considered whole grain bread attributes. Hersleth *et al.* (2005) reported differentiating a set of bread and rolls by a trained panel which correlated to the attributes of the ingredients used to make the breads/rolls. According to the authors, the whole wheat roll was more associated with crispiness of crust and crumb and the white roll was associated with crumb stickiness and crumb whiteness. Both rolls were associated with whole wheat odor and flavor (Hersleth *et al.* 2005). Pohjanheimo *et al.* (2010) reported softness/toughness and porosity to be key differentiating attributes for rye bread. Heenan *et al.* (2008) reported breads made of whole grains to be differentiated by grainy odor, sour flavor, and coarse texture. Multigrain treatments were correlated with grain, musty, nutty odor, sour taste, seedy flavor, and coarse texture. Lotong *et al.* (2000) reported wheat and yeasty flavors to be differentiating attributes for whole wheat sourdough crumb, and wheat, yeasty, and toasted flavors for whole wheat sourdough crust, in addition to sourdough specific flavor attributes for crust and crumb. This is all in agreement with the current

findings in that whole wheat breads have texture and flavor attributes associated with the whole wheat grain, namely, crumb toasted/bran and sweet aromatic molasses and whole wheat flour paste and for texture, high chewiness, graininess, and harder crumb.

Consumer Testing – External Preference Mapping

Cluster analysis was performed on the subjects in this test and two clusters were identified (Table 4). Cluster 1 (n=153) had a larger representation of younger consumers (18-29 y), a larger ($p<0.05$) proportion of no-child households, purchased white bread and flavored bread more frequently ($p<0.05$) than cluster 2, and had a larger ($p<0.05$) representation of African Americans. Cluster 2 (n=207) had a larger ($p<0.05$) representation of consumers 30 – 39 y as well as consumers > 60 y. This cluster purchased the most bread per month and had larger households with children living at home. Cluster 2 consumers had the highest purchase frequency for whole wheat and multigrain breads as well as oat/specialty breads, and had the largest representation ($p<0.05$) of Caucasian and Hispanic consumers.

A partial least squares regression analysis of the cluster preferences and bread attributes is shown in Figure 3. Overall, clusters were differentiated by preferences for traditional white bread attributes versus non-traditional white bread attributes (Figure 3). Cluster 1 consumers preferred breads R, Y, L, H, V, and I which were breads associated with traditional white bread characteristics (Figure 3). Cluster 2 preferred breads T, J, W, M which were the least preferred breads for cluster 1 and were the breads that most strongly associated with whole grain characteristics. This is in agreement with the self-reported

consumption data where cluster 1 primarily purchased white bread and cluster 2 primarily purchased whole wheat and whole grain breads (Data not shown).

PREFMAP results were similar to PLS results on cluster preferences. PREFMAP showed very broad ideal points similarly to PLS. The ideal point for cluster 1 was associated with attributes for breads I, C, K, G, Q, and L which have a crumb cohesive mass, moist crumb, crumb white flour paste, high crumb springiness and hand rate of recovery, sweet aromatic caramelized crumb flavor and uniform crumb, and light in crumb and crust color. These attributes can be considered white bread attributes based upon descriptive analysis (Figure 1,2, 4). Based upon external preference mapping and self-reported consumption habits, cluster 1 can be defined as, "white bread preferrers." The ideal point for cluster 2 consumers was associated with breads T, J, M, P, O, and W, which are dark in crust and crumb color, crumb bulgur wheat, crumb graininess, crumb harness, high crumb/crust chewiness, and high crumb cell size, which are whole grain bread attributes based upon descriptive analysis (Figure 1, 2, 4). Cluster 2 can be defined as, "whole grain bread preferrers," based upon external preference mapping and self-reported consumption habits.

The identification of two segment groups based upon traditional experiences with white bread versus whole wheat bread preferrers is consistent with other studies on bread preferences. Pohjanheimo *et al.* (2010) conducted a value study on rye bread preferences. According to the authors, two preference segments based upon food choice motives were identified as traditional consumers who placed value on "respect for tradition", "devout", and honoring of parents and elders" as most important to their choice in rye bread. The other segment, identified as hedonic consumers, were motivated by "pleasure", "enjoying life",

and “daring”. These value segments may be applicable in this study as traditional white bread preferences may represent traditional family experiences. Kihlberg and Risvik (2007) reported segmentation of consumers based upon liking of white pan breads differentiated on PCA analysis of Schwartz value sets, which is a set of 56 values designed to explore the importance of individual and collective interests of one’s internal and external world that can be used for segmentation purposes (Schwartz 1992). Consumers were differentiated by collective values of conservation versus self-transcendence. Consumers > 30 y represented traditional values while consumers < 30 y represented modern and materialistic values.

Contour plots of each cluster alone confirmed the cluster preferences demonstrated by the PLS map. The cluster 1 ideal point was focused on breads G, L, K, Y, Q, and breads T, J, M, W were strongly away from their ideal point (Figure 5) Cluster 2 consumers were the opposite with T, J, M, W close to their ideal point with breads and breads R, F, V, K, and Y far away from their ideal points. Slight differences in ideal points exist between PLS preference maps, and the contour preference map from PREFMAP. To confirm the cluster preferences, external preference map contour plots (PREFMAP) were performed on each cluster (Figure 5 and 6). Stark preference differences of preferred and not preferred breads were separated for cluster 1 by white bread and whole wheat bread attributes (Figure 5). The ideal point for cluster 1 remained around breads G, L, K with other breads that contained a light crumb (Y, V, Q, R, E, D, C,). Preference mapping of cluster 2 demonstrated the same stark differences in preference as cluster 1, with opposite ideal points (Figure 6). Bread W was strongly preferred by this group which had a dark crumb and crust, and hard crumb, whereas bread T, which was also highly preferred by this group, had a light crumb, dark

crust, and was more chewy, grainy, and moist. Texture attributes of high crumb chewiness, graininess, and porosity were important to this group (Figure 2). Both PLS and PREFMAP methods revealed somewhat similar ideal points for cluster 1 and cluster 2, however the ideal points were broad in that they were separated by traditional white bread attributes and whole wheat bread attributes, and between the methods, slight differences exist.

Further analysis by way of PrefHMFA revealed additional information and slightly different ideal points.

PrefHMFA

Multiple Factor Analysis (MFA) is a multivariate analysis used for multiple block data (Escofier and Pages, 1994) that shares some similarities with other multi-block methods such as Generalized Procrustes Analysis (Arnold, 1986), and STATIS (Lavit *et al.* 1975). MFA involves the use of weights to ensure that the data groups or blocks have equal influence on the ultimate global multivariate analysis. In MFA, PCA is first performed on each data group. The first eigenvalue from this analysis are then weighted to normalize the variables in the group. An overall PCA is then performed on the weighted groups. Worch (2013) reported that this method of weighting ensures the shape of the configuration of each group is unchanged and the groups are equally balanced and all groups are equally contributing to the first dimension of the MFA giving the maximum common information shared across the groups. In hierarchical MFA (HMFA), additional rounds of PCA and weighting are performed, according to the sub-groupings and groupings, or data hierarchies, defined by the researcher, before the final overall PCA is performed. The MFA and HMFA result in a combined space that maximizes the information (inertia) shared on both sensory

and hedonic blocks. Thus, MFA space is a sensory space which can explain as much as possible the consumer similarities and differences in liking and where products projected into this space are close if they have similar sensory profiles and are liked or disliked by the same consumers. Two criterions are used to evaluate the relationship between different groups obtained from MFA. For each group the Lg coefficient (or Ng if within a single group) reveals the dimensionality shared by groups (Lg) or within a group (Ng) (Escofier and Pages, 1994). The larger the Lg coefficient, the larger the common structure shared by the groups. The Lg is also used with the MFA dimensions to obtain a measure of the shared structure between the group and the global MFA solution. The RV coefficient reveals the linkages between variables of each group (Escoufier, 1973) taking values between 0 (completely orthogonal groups) and 1 (perfectly homothetic groups). The variance explained by the variables of each group in the MFA solution is also used in a manner similar to PCA as an indication of the overall quality of the variable and group representation of by each dimension of the MFA or HMFA solution. In PrefMFA and PrefHMFA, the product configuration related to the sensory space within the HMF or MFA is used by extracting the products' partial points from the (H)MFA solution. This configuration is then used like a PrefMap space with consumers' hedonic scores individually regressed on the coordinates on the first two dimensions using appropriates methods such PLS and models such as vector, circular, elliptical, quadratic or RSM to predict hedonic scores (Worch, 2013; Danzart, 1998).

The PLS sensory space (Figure 3) was complex with the clusters separated in sensory space mainly along the first PC. In order to balance the influence of all the bread

characteristics in the analysis and better see their relation to liking, external sensory data groups were formed including those focused on crust (aroma, taste), crumb (aroma, taste), appearance, hand texture and oral texture attributes, to give the same importance to all attributes in these groups in the generation of PrefHMFA sensory space. (Escofier and Pagès, 1994; Worch, 2013). The coordinates of the product partial points associated with external groups on the first two dimensions were extracted from the MFA solution. The mean-centered liking scores for individual consumers were regressed on these two dimensions using the quadratic model of (Danzart, 1998). This regression was used to generate an individual binary response matrix for the each consumer for the entire grid of the sensory space where each cell received a value of 0 for predicted liking values less than 0 and a value of 1 for predicted liking values greater than 0 (or the average liking of individual consumer). Contour-surface plots were then generated by the summation of the response matrices of all consumers tested.

For cluster 1 consumers, the hedonic information was slightly explained by the external configuration (Figures 7 and 8) (first eigenvalue of the PrefHMFA=1.45, RV=0.58). The first dimension of the hedonic data was highly correlated (negatively) to the second dimension of the external descriptive data, which corresponds to the first dimension of oral texture and of appearance. It is worth mentioning that the first dimension of the HMFA (explaining 18% of the total variance) explained 20% of the total variance of the hedonic scores (Figure 8), which means that liking information is still present on the other dimensions. This is the maximum liking variance obtained within any dimension. The second dimension explained 7% of the liking variance for cluster 1 consumers. The first dimension

of the HMFA also explained 19% of the variance in Appearance, and 18% of the variance in Oral Texture, 13% of the variance of crust group, 13% of the variance of the crumb group, and 12% of the variance of the hand texture. HMFA dimension 2 for cluster 1 consumers was also contained a high level of sensory variance with 27% of the variance of the crust, 18% of the variance of the crumb, 22% of the variance of the appearance, 34% of the variance of the hand texture, and of the variance of the 23% oral texture.

Individual regression of the External Preference Mapping technique adapted to the HMFA space provided a surface plot response (Figure 7). For cluster 1, the ideal point was large covering a significant portion of the sensory space. The maximum acceptability was associated with breads R, and Y (~80% liked above average), with many of bread well liked (70% - 80% liked above average). These results are closer to those using PLS but more clearly identifying Y as a product with high liking. Also, the PrefHMFA analysis revealed an ideal point with higher liking than the samples in the test ("white space") not predicted by the other methods.

For cluster 1, the key attributes for liking in PrefHMFA were crumb white flour paste, crumb adhesive and crumb cell uniformity. Crumb tooth packing, crumb graininess, top-crust chewiness, and nuttiness of crumb and crust were not liked by these consumers (Figure 9). The optimum product highlighted by the PrefHMFA corresponded to 94% of the consumers from cluster 1. PLS and PREFMAP techniques underestimated the importance of these attributes revealed as key drivers by this HMFA.

The PrefHMFA performed on Cluster 2 is provided in Figure 10. In this analysis, the first eigenvalue of MFA is 1.58, showing a reasonable relationship between sensory and

hedonic scores (RV coefficient between the hedonic and sensory groups is 0.63). More precisely, the first dimension of the HMFA is correlated to the second dimension of the sensory/external configuration, indicating that the main differences in liking are not explained by the main sensory differences between products (Figure 11). For cluster 2, liking behavior was related to the main differences in appearance and oral texture attributes, and to some differences related to the Crumb (second dimension). Hence, other sensory characteristics such as crumb toothpacking, crumb chewiness, crumb graininess, and, crumb toasted grain/burnt. are important to explain liking for cluster 2 consumers (Figure 11). It is worth mentioning that the first dimension of the HMFA (explaining 19% of the total variance of the combined sensory and hedonic space) explained 21% of the total variance of the hedonic scores a (Figure 10), which means that liking information is still present on the other dimensions. This is the maximum obtained within the HMFA dimensions observed, with the second HMFA dimension~~s~~ explaining 6% maximum of the remaining hedonic score variance in the HMFA space. This first dimension also explained 27% of the variance in appearance, and 24% of the variance of oral texture, 13 % of crumb-group attributes, 12% of crust-group attributes, and 7% of hand texture attributes. Overall, the second dimension of the PrefHMFA (14% of total variance explained) explained more of the sensory variability across the products (34% Hand texture, 23% oral texture, 22% appearance, 18% crumb, 27% crust) and less of the hedonic variation (6% explained). This is due to the fact that consumer information has been homogenized through the use of clusters.

For Cluster 2, maximum acceptability was close to breads J, T, W, and M. Although similar bread preferences were found for traditional and HMFA methods, traditional methods failed to capture the importance of the oral texture attributes for cluster 2 consumers.

For cluster 2, the attributes which impacted liking were tooth packing, grainy, cell size, and not springy, low flour paste flavor, not salty, not sour, (Figure 12). The individual regression procedure of the External Preference Mapping technique, adapted to the HMFA space provided a surface plot response (Figure 10).

Path-PLS model of purchase drivers

Global path-PLS purchase intent model, developed using the methods of PLS, is shown in Figure 13 (Tenenhaus *et al.* 2005a; 2005b). Manifest variables, those taken from the consumer CLT responses, are indicated by rectangular boxes and contain the acceptance data from the 360 adults. The "latent variables", those predicted from the manifest variables and not measured directly, are shown in ovals. The arrows indicate relationships (red indicates a positive correlation; blue indicates a negative correlation and is due to the polarity of the question as asked). The connectivity shows the flow and relation of the different latent and manifest variables. The regression coefficient and p values, associated with each arrow, are indicated for the significant relationships.

The highest regressions were found by forming relationships from attribute liking into overall liking (similar to the drivers of liking approach) and then "filtering" the liking with feelings and expectations before combining this with family eating practice to predict purchase intent. This structure seemed to be within the realm of decision models that could be used by some consumers. Flavor liking was the most impactful variable to explain overall

liking followed by texture liking. This is in agreement with the preference mapping results which showed clusters were separated by preference for white bread versus whole wheat bread characteristics. Sweet taste liking was the least impactful. The three appearance likings were grouped together as they all provided the same information (very high correlation). Liking (latent variable) predicted the "meet expectations" latent variable well (r^2 = 0.609).

"Meet expectations" and liking predicted "eat at home" well (r^2=0.777). In this model, the coefficient related to liking was larger than the coefficient for "meet expectations" (data not shown). "Eat at home" predicted the two PI variables. The arrows are in blue because the correlation coefficient is negative (the scale has been simply inversed, the lower the value, the higher the PI). The PI reasonable price was well predicted by the PI family and the rest of the PATH variables (r^2=0.797). PLS path modeling seems to provide a good predictability of the purchase behavior from liking, feelings and other factors. This analysis confirmed the importance and relationship of the sensory attributes to overall liking and hence the need for a deeper analysis of the sensory drivers. Path PLS analysis confirmed the importance of flavor and texture attributes to consumer preferences of sliced sandwich bread and also confirms the importance of extrinsic factors such as family drivers of purchase for sliced sandwich bread. The family impact is not modeled by external preference mapping, therefore, the additional insight gained by Path-PLS analysis is very useful for understanding the global picture for the drivers of liking for sliced sandwich bread, namely that family considerations are an important factor in the drivers of liking of sliced sandwich bread. Pages and Tennenhaus (2001) reported that Path PLS modeling of hedonic scores and

sensory attributes for orange juice explained consumer segmentation based upon orange juice attributes more directly than was revealed alone by multiple factor analysis. Path-PLS analysis helps tell the whole sensory story related to drivers of liking that multiple factor analysis or traditional preference mapping does not fully explain. Few published studies have demonstrated the role that Path-PLS modeling can play in clarification and validation of the role of the sensory drivers of liking and the current study represents a key demonstration of its role.

CONCLUSIONS

Descriptive analysis profiling and consumer profiling of sliced whole wheat sandwich bread revealed two distinct consumer clusters based upon preferences for traditional white bread characteristics and whole wheat bread characteristics. Partial least squares regression and PREFMAP, traditional external preference mapping techniques, revealed similar ideal points for clusters with slight differences between the two methods. Although the sensory description of the products is quite large, such information is only sufficient to explain part of the liking scores provided by the 2 consumer clusters. The optimum bread sensory profiles between the 2 clusters were distinct. In this case, PrefHMFA was a good solution to identify optimal products, especially when the products were described through different groups of variables (whether each group corresponds to different sensory characteristics or data of a different nature, or coming from different panels). Additionally, PrefHMFA, revealed the importance of the oral texture and appearance attributes that was not obvious using the tradition PLS and PrefMap methods. PrefHMFA also allow a better understanding of the relationship of key liking dimensions with sensory dimensions and ideal points.

Acknowledgements

Use of trade names does not imply endorsement nor lack of endorsement by those not mentioned. Special thanks to Cargill Inc. for sponsoring this research.

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Table 1: Treatment Identification Codes for Sliced Whole Wheat Sandwich Bread

Treatment	Identification
Experimental	A
Experimental	B
Experimental	C
Experimental	D
Experimental	E
Experimental	F
Experimental	G
Experimental	H
Experimental	I
Experimental	J
Experimental	K
Experimental	L
Experimental	M
Experimental	N
Experimental	O
Experimental	P
Experimental	Q
Experimental	R
Experimental	S
Experimental	T
Commercial	U
Commercial	V
Commercial	W
Commercial	X
Commercial	Y

Table 2: Sliced Sandwich Bread Flavor Lexicon

Descriptor	Definition	Reference & / or Example
aroma description	list of aromatics perceived while sniffing both the crust and crumb	Kroger® white bread = white flour paste, toasted crust
sweet aromatic caramelized	light sugary aromatics associated with lightly burned sugar	Smuckers caramel syrup
sweet aromatic molasses	dark, sweet aromatics associated with molasses	Grandma's® original unsulphured molasses
sour aromatic	aromatics associated with acidic foods	acetic acid, lactic acid
white flour paste	aromatics associated with white flour and white flour paste	1:1 King Arthur® unbleached all purpose flour: DI water
whole wheat flour paste	aromatics associated with whole wheat flour and whole wheat flour paste, including a green note	paste of 1:1 King Arthur® premium 100% whole wheat flour: DI water
bulgur wheat	aromatics of parboiled wheat groats, or hulled wheat grains	Red Mill® quick cooking bulgur wheat prepared according to package directions
toasted grain / bran	aromatics associated with wheat bran or grains that have been toasted	Red Mill® wheat bran toasted at 350°F 9 minutes, All Bran® cereal
burned / toasted	aromatics of over baked / over toasted bread due to excessive Malliard browning	bread slice toasted at darkest setting, twice
nutty	aromatics typical of freshly roasted nuts, pyrazine compounds	Food Lion® sunflower kernels, Fisher's® macadamias
fatty/stale	aromatics associated with old oil or stale ingredients	2,4 decadienal, 100 ppm
yeasty	aromatics of moistened instant yeast	Red Star instant yeast moistened with water and allowed to stand 10 minutes
fruity / fermented	aromatics of overripe fruit	overripe mashed banana
astringent mouthfeel	sensation of drying, drawing or puckering of any of the mouth surfaces; possibly tooth etching	0.01% alum solution = astringent 1
sweet	Basic taste elicited by sugars and high potency sweeteners	3% sucrose solution = sweet 3
sour	basic taste elicited by acids	0.05% citric acid solution = sour 2
salty	basic taste elicited by salts	0.2% NaCl solution = salty 2
bitter	Basic taste elicited by alkaloids	0.05% caffeine solution = bitter 2
umami	basic taste elicited by glutamates; fullness, savoriness	0.5% monosodium glutamate solution = umami 3
aftertaste intensity	the intensity of the all after tastes up to 1 minute after expectoration	Brownberry whole wheat aftertaste intensity of 1.9 for the crust and 2.2 for the crumb

Table 3: Sliced Sandwich Bread Appearance and Texture Lexicon

Attribute	Definition	Reference and / or Example
Appearance		
crust color	Degree of darkness of the top crust, ranging from light brown to dark brown.	King Arthur unbleached all purpose flour = 2, King Arthur whole wheat flour = 4, Red Mill unprocessed miller's wheat bran = 9, Red Mill quick cooking bulgur wheat = 12, Arnold Dutch Country 100% WW smooth texture bread = 11
crumb color	Degree of darkness of the crumb, ranging from off white to dark brown.	King Arthur unbleached all purpose flour = 2, King Arthur whole wheat flour = 4, Red Mill unprocessed miller's wheat bran = 9, Red Mill quick cooking bulgur wheat = 12, Arnold Dutch Country 100% WW smooth texture bread = 8
crumb cell size	Overall cell size in the crumb, ranging from small to large.	Arnold Dutch Country 100% WW smooth texture bread = 5, Thomas's whole wheat English muffin = 13, Lysol antimicrobial household sponge = 2, O-Cel-O handy size sponges = 10
crumb cell uniformity	The homogeneity of the cell size in the crumb.	Arnold Dutch Country 100% WW smooth texture bread = 13, Thomas's whole wheat English muffin = 6, Lysol antimicrobial household sponge = 14, O-Cel-O handy size sponges = 8
crumb porosity	The depth of the cells in the crumb, ranging from shallow to deep.	Arnold Dutch Country 100% WW smooth texture bread = 3, Thomas's whole wheat English muffin = 14, Lysol antimicrobial household sponge = 2, O-Cel-O handy size sponges = 10
Hand Texture		
side crust springiness	Compress the middle of the side crust (still attached to the crumb) 50% and immediately release. The degree to which the crust recovers to its original shape.	Arnold Dutch Country 100% WW smooth texture bread = 15
side crust rate of recovery	Speed (rate) that the crust recovers its original shape after compression (above).	Arnold Dutch Country 100% WW smooth texture bread = 14
crumb springiness	Compress the crumb 50% and immediately release. The degree to which the crumb recovers to its original shape.	Arnold Dutch Country 100% WW smooth texture bread = 14
crumb rate of recovery	Speed (rate) that the crumb recovers its original shape after compression (above).	Arnold Dutch Country 100% WW smooth texture bread = 12
Oral Texture		
crumb hardness	Bite the crumb (with the topmost part closest to where the crust was) with the front teeth and determine the force required to bite through the sample.	Arnold Dutch Country 100% WW smooth texture bread = 4, Arrowhead Mills puffed rice cereal = 10
crumb adhesiveness to palate	Press the square of crumb to the roof of the mouth with the tongue and evaluate 4 seconds. Evaluate the force required to remove the sample from the roof of the mouth.	Arnold Dutch Country 100% WW smooth texture bread = 4
top crust chewiness	While chewing at a rate of 1 chew per second, the number of chews required to break down the sample until ready to swallow or expectorate.	Arnold Dutch Country 100% WW smooth texture bread average = x
crumb moistness	Degree to which moistness is perceived in the sample during the first 3 chews.	Arnold Dutch Country 100% WW smooth texture bread = 11
crumb cohesiveness of mass @ 4 to 7 chews	Degree to which the sample remains in a mass at 4 to 7 chews.	Arnold Dutch Country 100% WW smooth texture bread = 13
crumb graininess	Degree to which grains and / or seeds are detected during mastication.	Arnold Dutch Country 100% WW smooth texture bread = 4
crumb chewiness	While chewing at a rate of 1 chew per second, the number of chews required to break down the sample until ready to swallow or expectorate.	Arnold Dutch Country 100% WW smooth texture bread average = x
crumb tooth packing	The amount of sample remaining packed into the teeth surfaces.	Arnold Dutch Country 100% WW smooth texture bread = 3

* Crumb refers to a 1-inch square of bread cut at least 1/2-inch from the top and side crusts and at least 1 inch from the bottom crust.
* Crust, except where otherwise specified, refers to a 1-inch strip cut from the top of the slice.
* First Bite - Take and swallow a sip of water, wait 15 seconds and evaluate a one-inch square
* Crust Mastication - Take and swallow a sip of water, wait 15 seconds and evaluate a one-inch strip
* Crumb Mastication - Take and swallow a sip of water, wait 15 seconds and evaluate a one-inch square
* Crumb Residual - After swallowing or expectoration evaluat

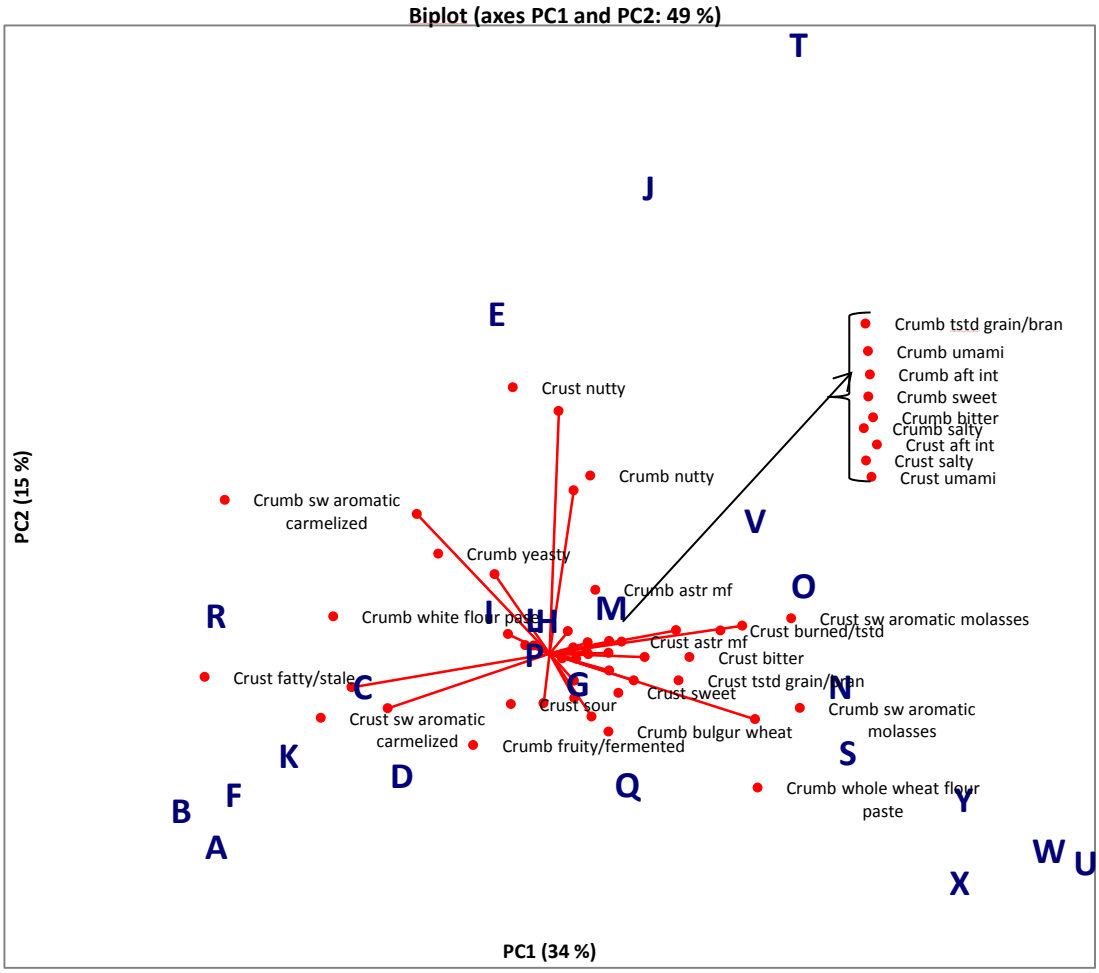

Figure 1: Principle Component Analysis of Flavor Attributes Evaluated by Descriptive Analysis

*Flavor attributes removed because present less than three treatments; crumb rye, crusty fruity fermented, crumb fatty/stale, crumb sour, crumb sour aromatic.

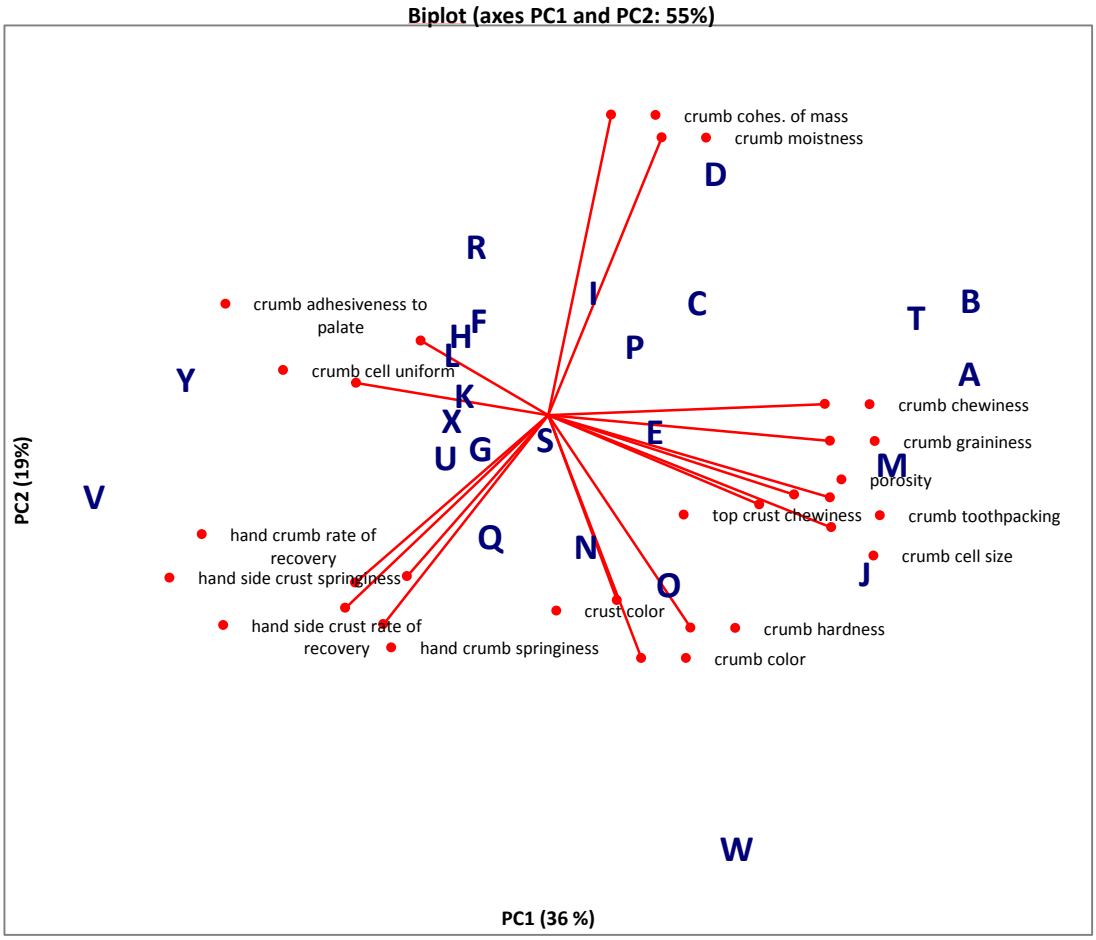

Figure 2: Principle Component Analysis of Appearance and Texture Attributes Evaluated by Descriptive Analysis

Table 4: Cluster Demographics and Membership

	Cluster 1 n=153	Cluster 2 n=207
Male	21.6	23.9
Female	78.4	76.1
18 - 24 years old	15.7	10.7
25 - 29 years old	15.0	8.8
30 - 34 years old	12.4	18.5
35 - 39 years old	9.2	14.6
40 - 44 years old	13.7	11.2
45 - 49 years old	11.1	5.9
50 - 54 years old	9.8	13.2
55 - 59 years old	9.8	7.3
60 - 64 years old	2.0	6.8
65 - 69 years old	0.7	2.9
70 years old and older	0.7	0.0
Under $20,000 per year	6.5	4.9
$ 20,000 - $ 29,999 per year	7.8	8.3
$ 30,000 - $ 39,999 per year	17.0	11.2
$ 40,000 - $ 49,999 per year	9.8	10.7
$ 50,000 - $ 59,999 per year	7.2	11.7
$ 60,000 - $ 69,999 per year	10.5	9.8
$ 70,000 - $ 79,999 per year	13.7	11.7
$ 80,000 - $ 89,999 per year	2.6	5.4
$ 90,000 - $ 99,999 per year	6.5	9.3
$100,000 per year or greater	12.4	10.2
Prefer not to answer	5.9	6.8
More than 3 loaves per month	49.7	54.6
3 loaves per month	32.7	29.3
2 loaves per month	16.3	11.7
1 loaf per month	1.3	2.9
Less than 1 per month	0.0	1.5
1	11.1	14.1
2	20.3	18.5
3	5.2	6.8
4	2.0	1.5
5 or more	0.0	1.5
There are no children in my household	61.4	57.6

Table 4: Continued

	Cluster 1 n=153	Cluster 2 n=207
White	69.9	55.6
Wheat	79.1	77.6
Whole wheat (made with 100% whole wheat flour)	77.8	86.8
Multigrain (made with one or a variety of grains, such as wheat, oats, rye, etc)	73.2	85.4
Whole grain white (offers the color and texture of white bread, with the nutrient value of whole wheat)	56.9	59.5
Oat/Specialty varieties (e.g., pumpernickel, rye, flax)	33.3	58.5
Flavored varieties (e.g., cinnamon swirl, raisin, honey, nut)	62.7	50.7
Gluten-free	7.2	6.8
Other (Please specify)	2.0	2.9
American Indian or Alaska Native	0.0	0.5
Asian	2.6	2.9
Black or African American	21.6	10.2
Hispanic (Mexican, Central American, Cuban, Puerto Rican, etc)	12.4	15.1
Latino (Brazilian, Portuguese, Spanish, etc)	2.6	1.5
Native Hawaiian or other Pacific Islander	0.0	0.0
White	61.4	72.2
Other (please specify)	0.0	0.0
Prefer not to answer	2.6	1.0

*Percentages of consumers selecting each option is presented
*Ethnicity and type of sliced sandwich bread purchase were check all that apply. Total percentages may exceed 100%

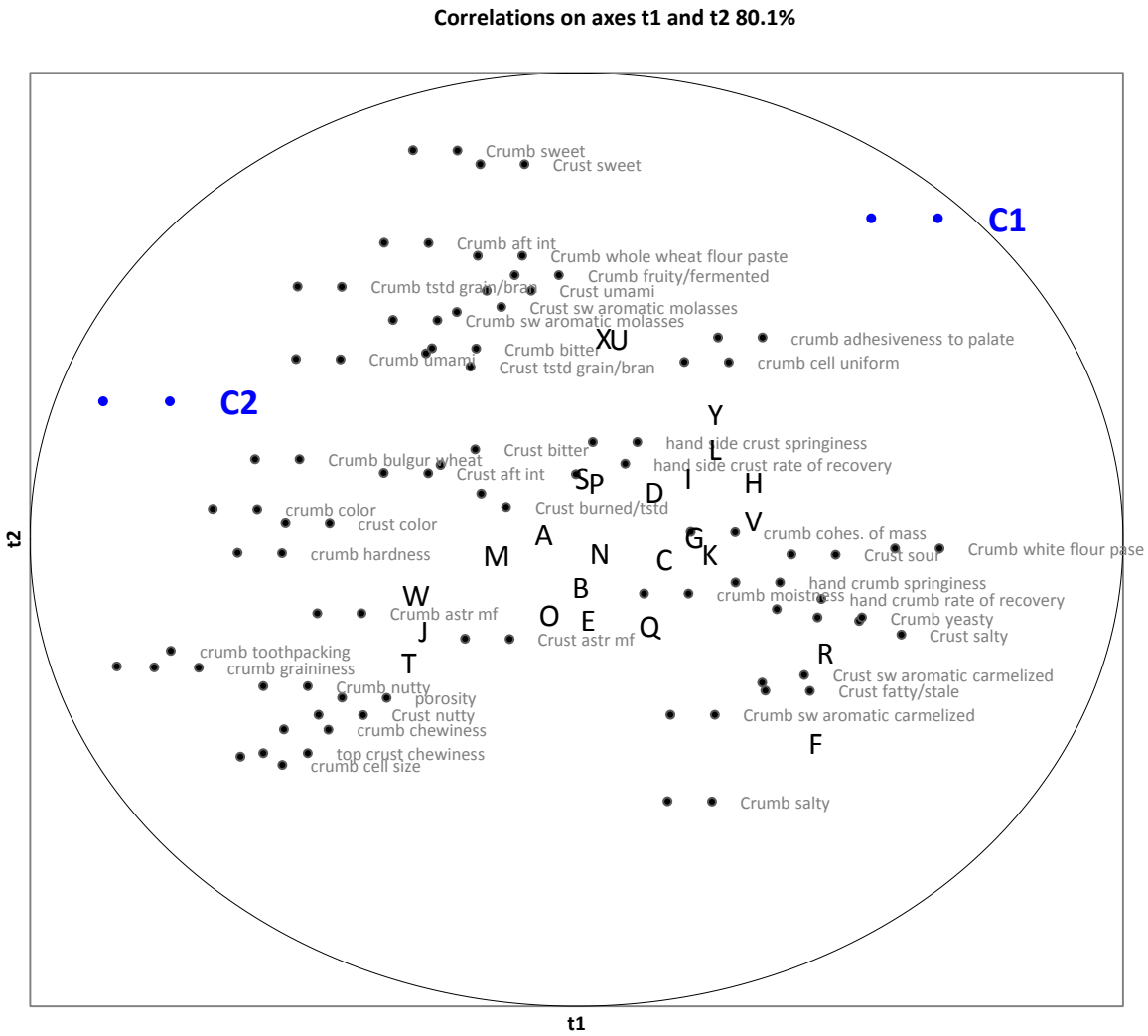

Figure 3: Partial Least Squares Regression Analysis of Cluster Membership across Flavor, Texture, and Appearance attributes

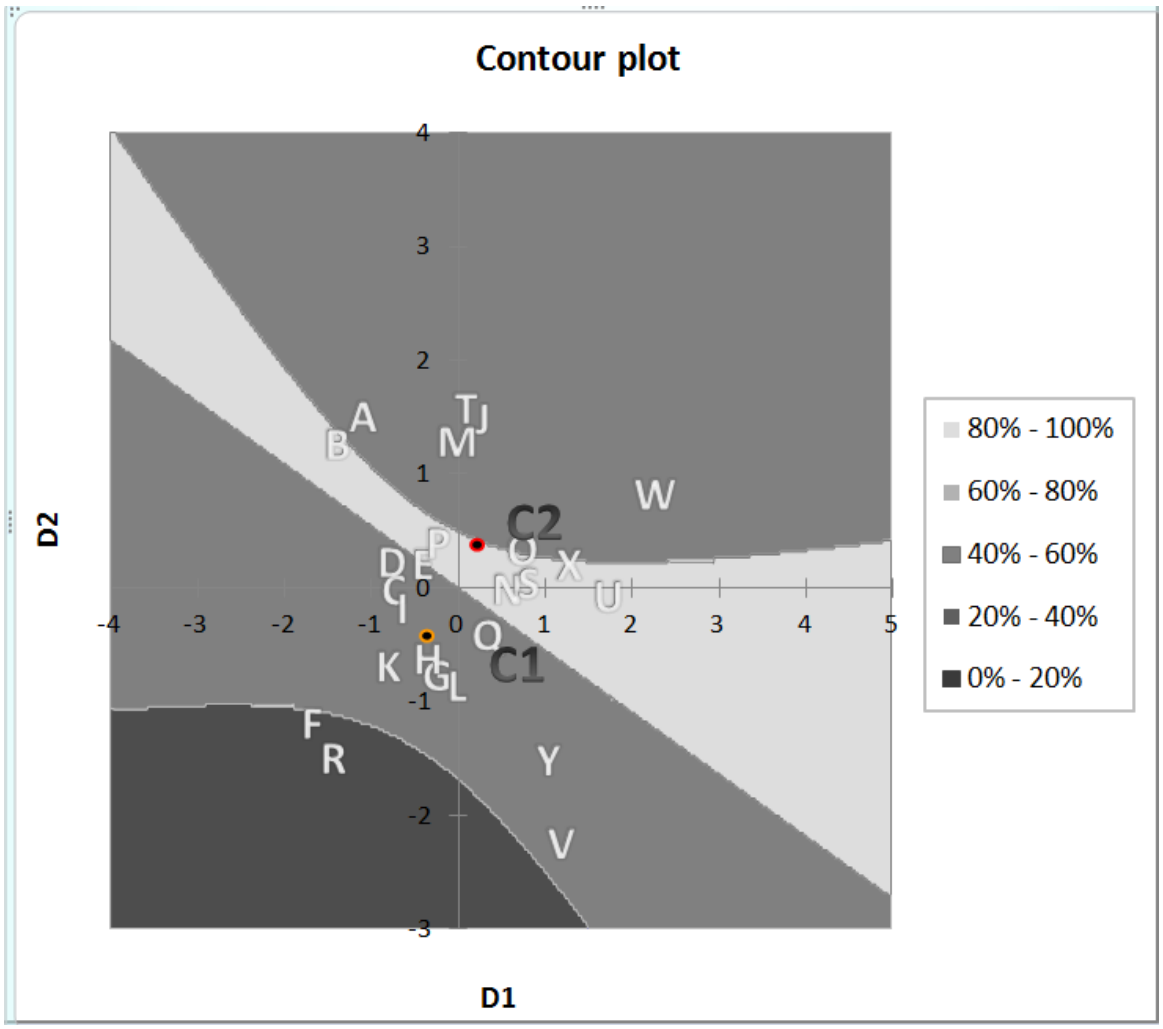

Figure 4: External Preference Maps of Cluster 1 and Cluster 2

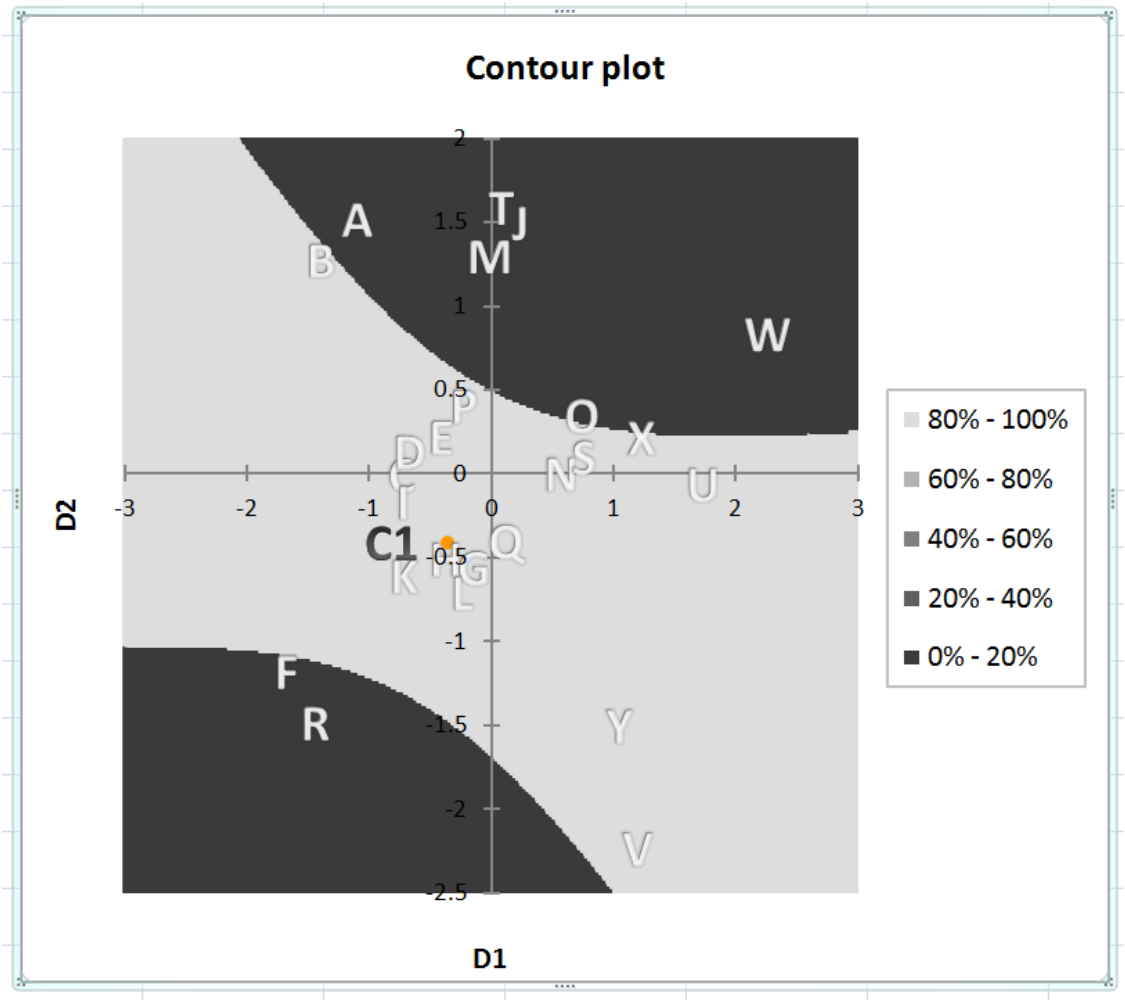

Figure 5: External Preference Maps of Cluster 1 Only

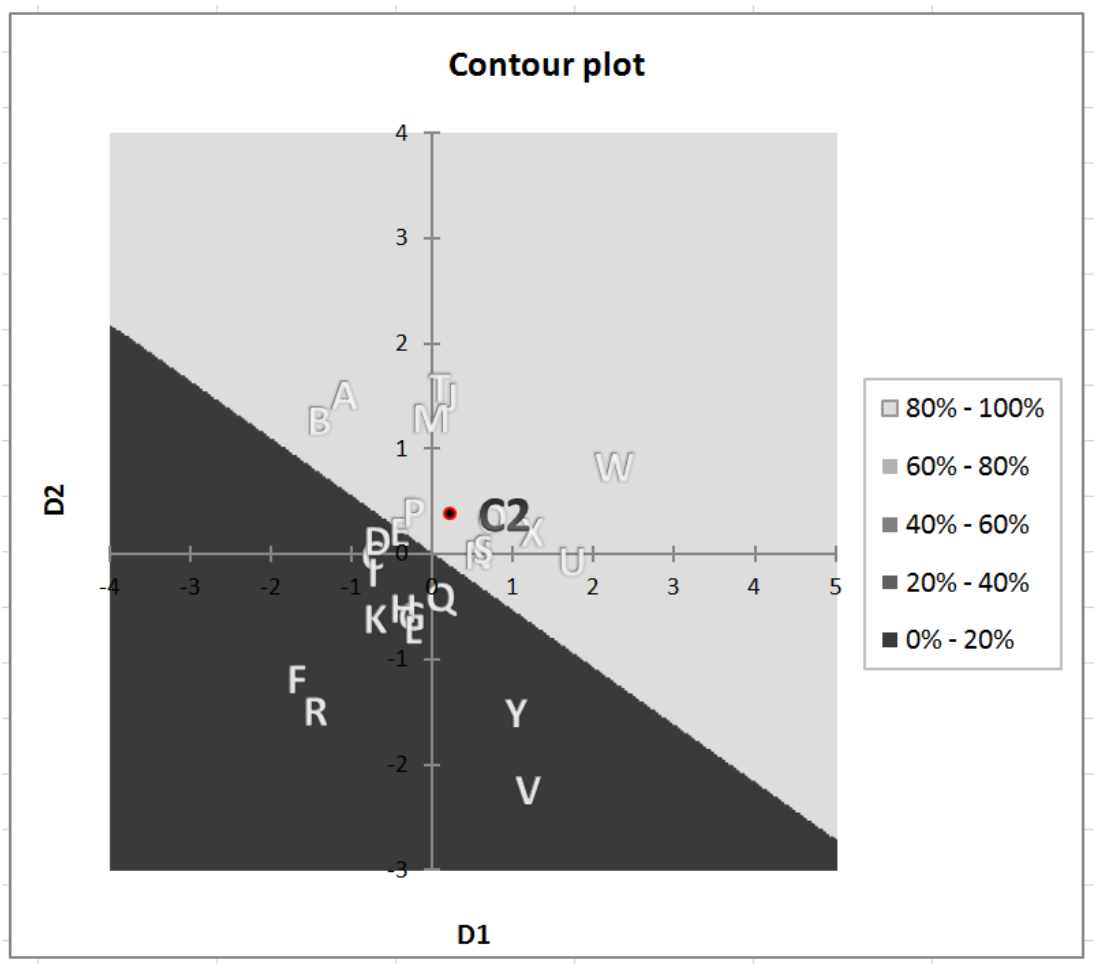

Figure 6: External Preference Maps of Cluster 2 Only

Table 5: Bread Treatments Sorted by Preference by Cluster

Cluster 1	Cluster 2
R	T
F	J
V	W
K	M
Y	R
L	A
G	F
H	O
I	X
C	B
Q	P
D	S
E	N
P	E
N	U
S	D
B	K
O	L
U	V
X	H
A	G
M	C
J	Q
T	I
W	Y

*Most preferred at the top, least preferred at the bottom

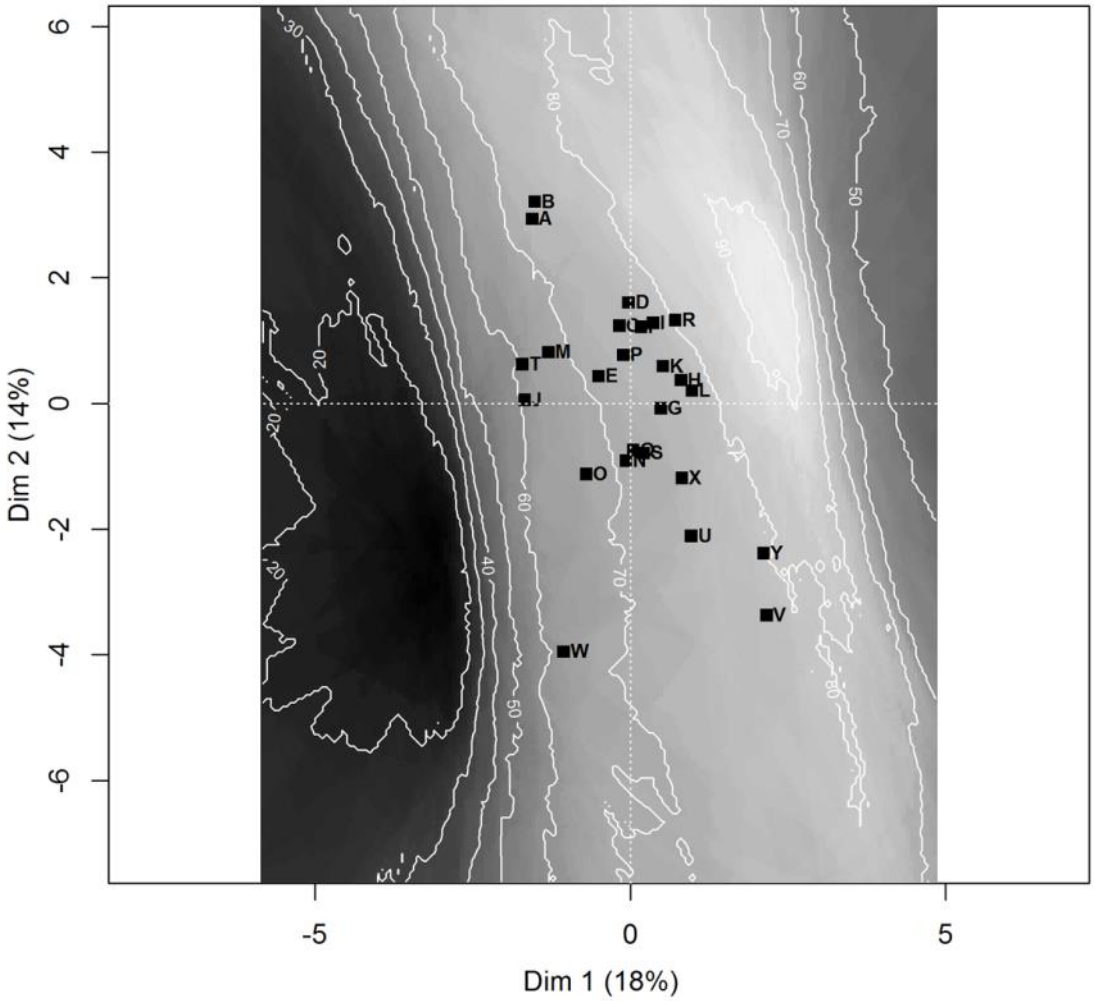

Figure 7: PrefHMFA Surface Plot, Cluster 1 Sensory Attributes

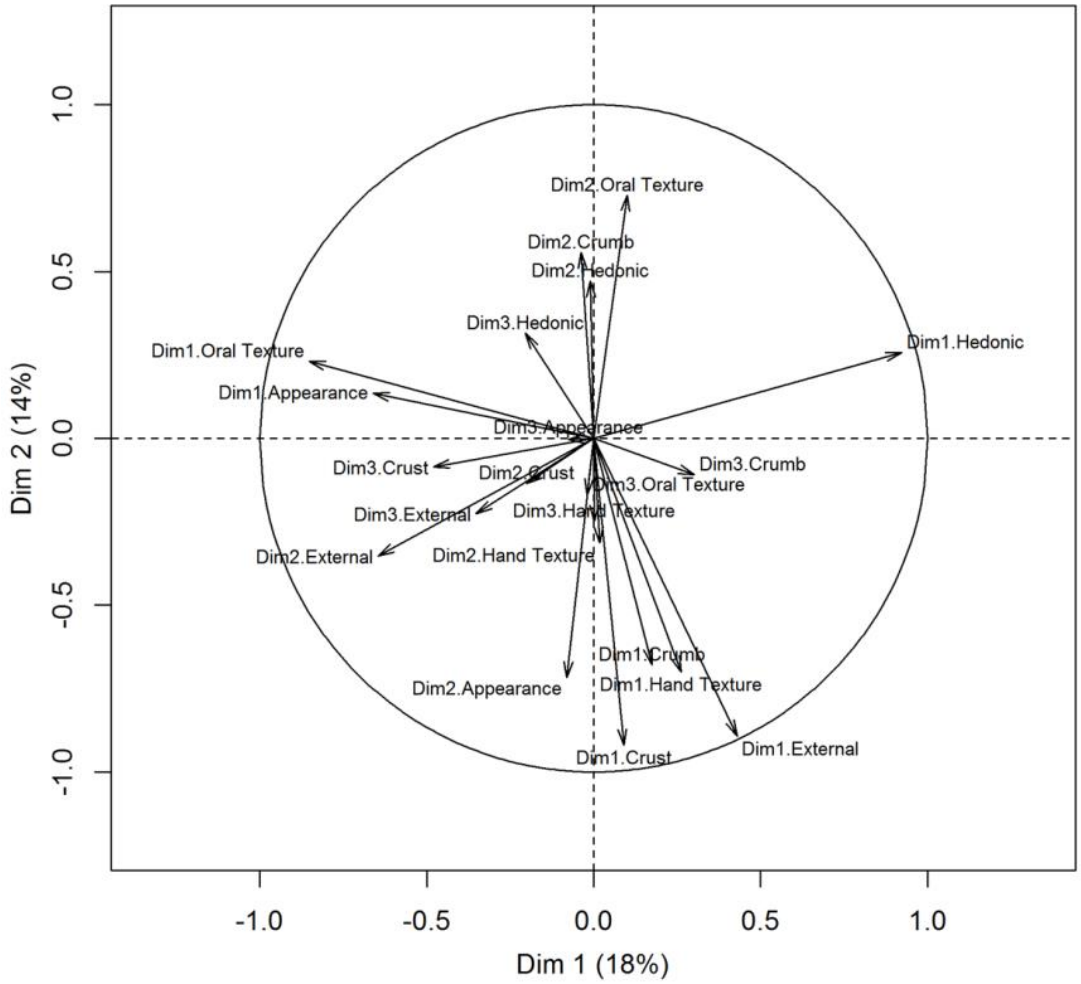

Figure 8: Partial Axis Representation from Multiple Factor Analysis of Cluster 1 Sensory Attributes

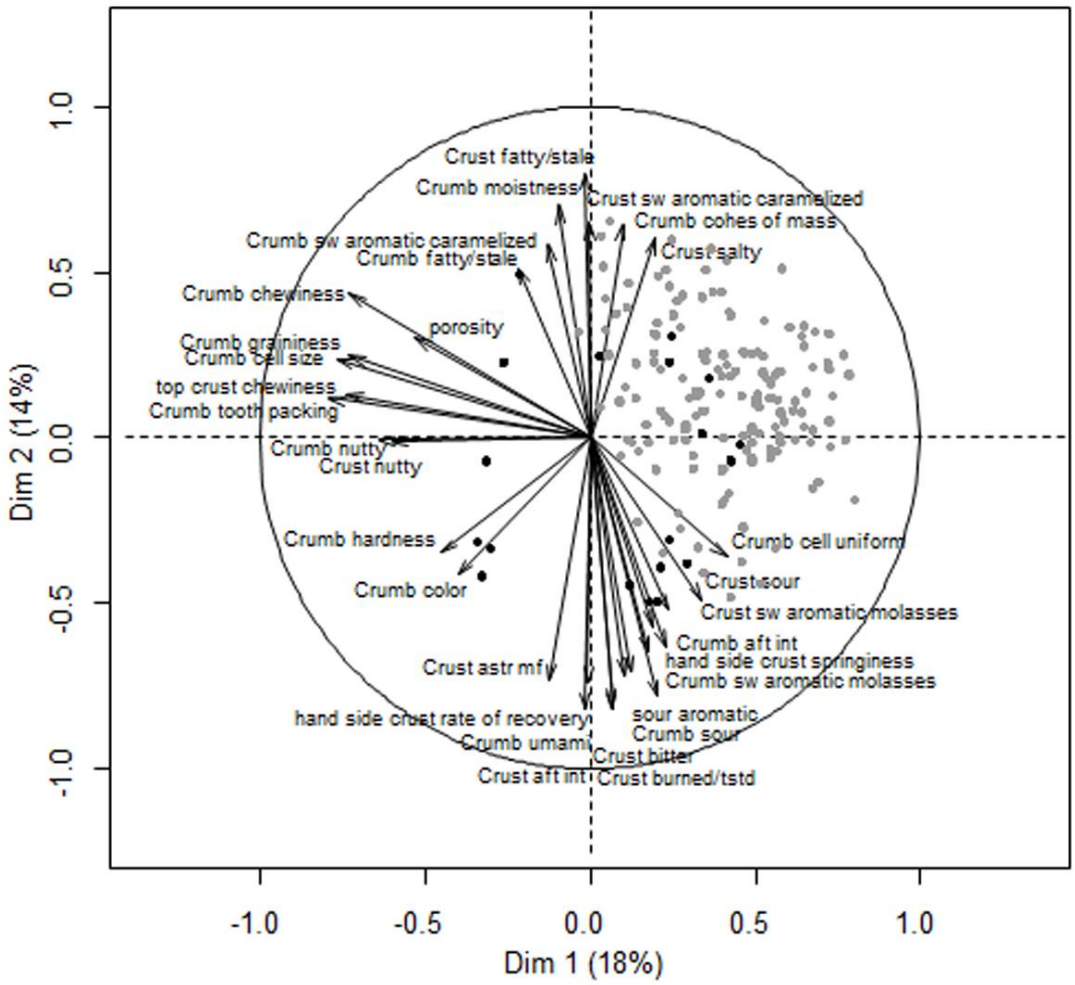

Figure 9: Variable Representation from Multiple Factor Analysis of Cluster 1 Sensory Attributes. Gray arrows indicate attributes that are well liked by this cluster.
(gray dots indicate attributes with high postive correlation with liking)

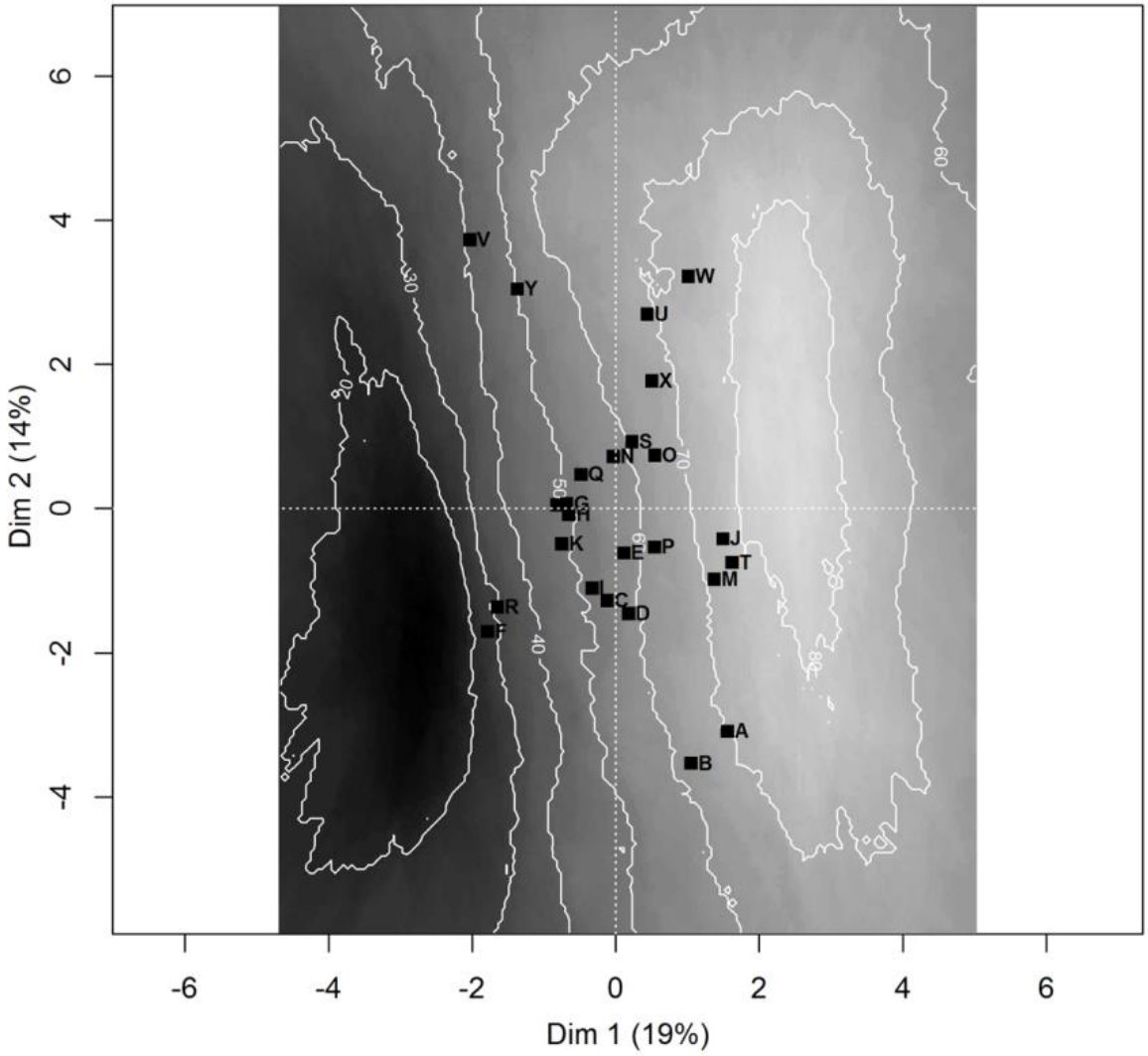

Figure 10: PrefHMFA Surface Plot, Cluster 2 Sensory Attributes

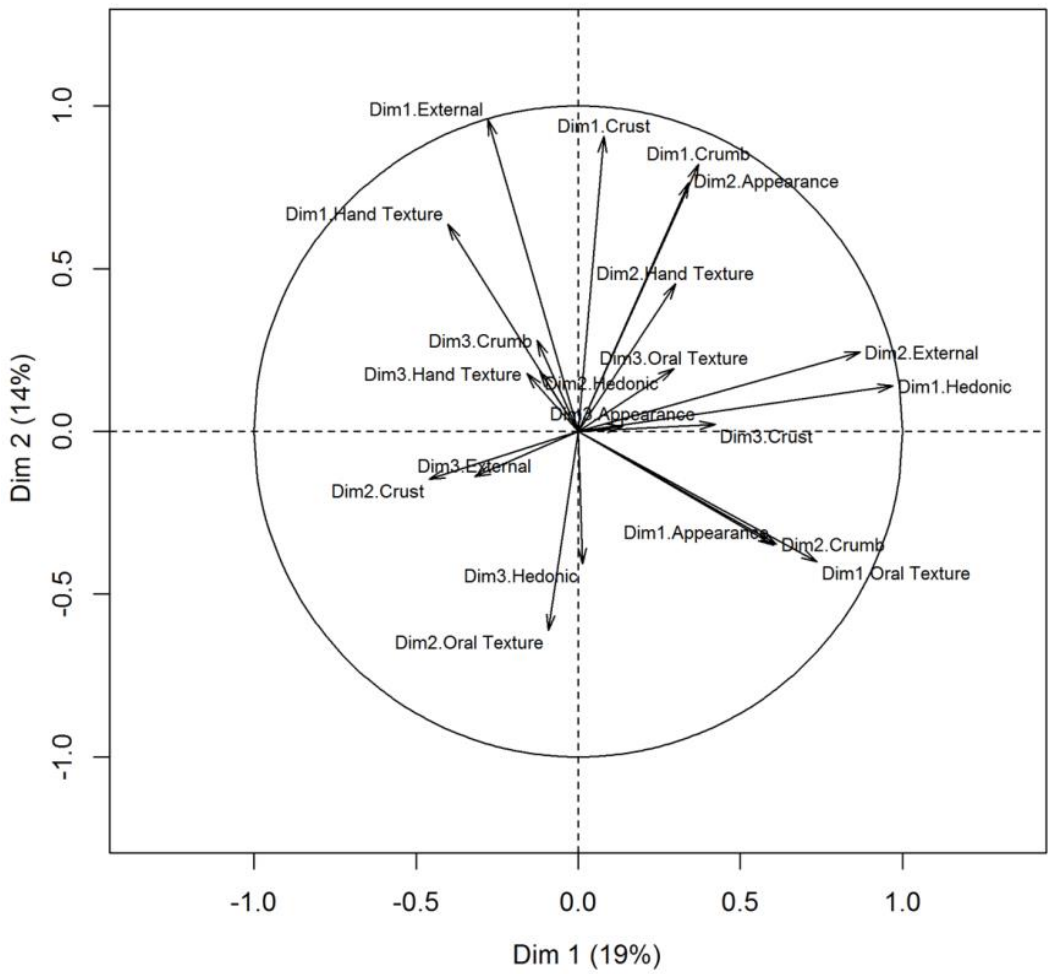

Figure 11: Partial Axis Representation from Multiple Factor Analysis of Cluster 2 Sensory Attributes

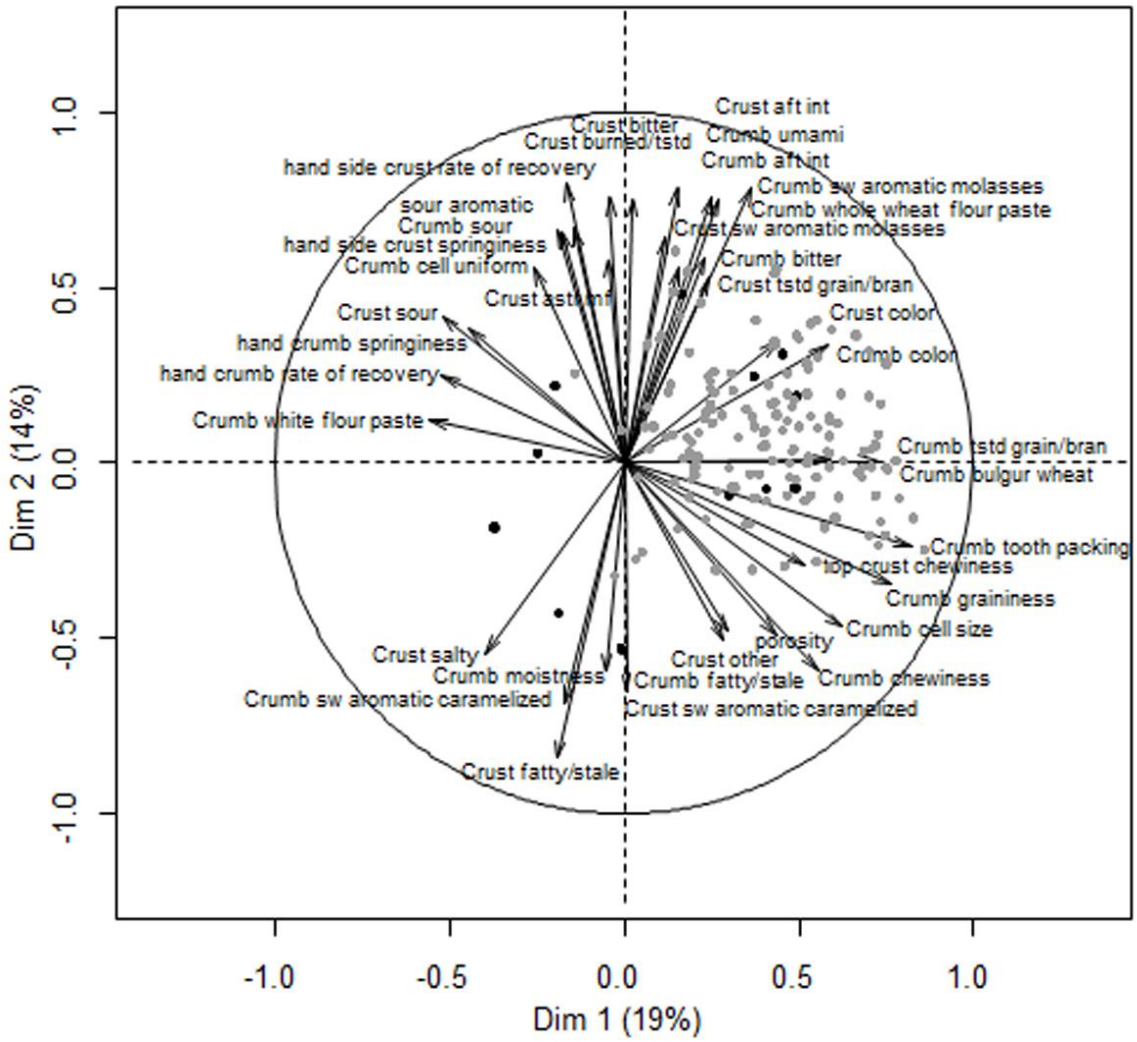

Figure 12: Variable Representation from Multiple Factor Analysis of Cluster 2 Sensory Attributes

(gray dots indicate attributes with high postive correlation with liking)

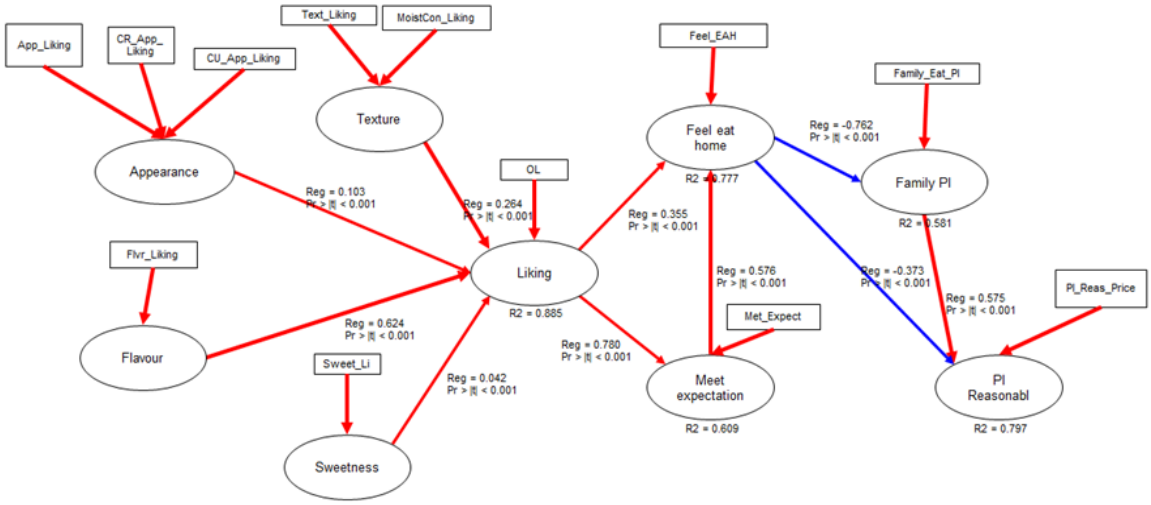

Figure 13. Path-PLS model of purchase intent.

CHAPTER 4.

THE PERCEPTION OF CREAMINESS IN SOUR CREAM

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RUNNING TITLE: Creaminess Perception in Sour Cream

ABSTRACT

Creaminess is a consumer attribute that is frequently used to describe sour cream, however creaminess is difficult to define or describe and is poorly understood because the mechanism or modality (s) for its perception remain uncertain. The objective of this study was to determine what sensory modality, or combination thereof, was responsible for the perception of creaminess in sour cream. Consumers, (n=274 baseline, n=100 each modality study), evaluated creaminess and overall liking of 12 representative commercial sour creams. Subsequently, in separate sessions, the effect of each sensory modality was evaluated: visual only, stirring, blindfolded stirring, blindfolded tasting, blindfolded tasting with nose clips, and tasting with nose clips. An eleven point creaminess rating scale was used to evaluate creaminess perception and overall liking was evaluated using the nine point hedonic scale. The effect of session type (modality), panelist, and fat content on creaminess and overall liking was evaluated using a mixed model analysis of variance. Flavor had the greatest impact on creaminess perception ($p<0.05$) followed by visual assessment of sour cream while stirring. Creaminess perception of sour cream is by milk fat content assessed by an olfaction related mechanism and also by flow characteristics while stirring.

PRACTICAL IMPLICATIONS

In the wake of the health and wellness trend as well as the adult and childhood obesity epidemic, low fat and fat free dairy products are poised to fill a healthy diet niche. These products have historically performed poorly in comparison to their full fat counterparts. Creaminess is associated with dairy product liking. It is also an attribute that is difficult to measure due to the complexity of how it is perceived by consumers. This study established that flavor is the most important sensing modality when assessing the creaminess of sour cream orally, but that textural components also exist.

KEY WORDS

Creaminess, Sour Cream, Modality

INTRODUCTION

Dairy products are commonly described as *creamy*, an attribute associated with consumer acceptance. Creaminess is an attribute that consumers can identify and describe however there is a lack of consistency among consumer descriptions. Finding a consistent consumer definition of creaminess is difficult as genetic variability, regional/cultural differences, and familiarity with the product may all factor into an individual consumer's perception and description of creaminess (Keller 2012; Antmann *et al.* 2011a; 2011b; Frost and Janhoj, 2007; Kirkmeyer and Tepper 2003; 2005). A genetic component has been suggested to influence creaminess perception (Kirkmeyer and Tepper 2003; 2005). Semi-trained panelists and consumers pre-screened for PROP sensitivity evaluated commercial dairy products (yogurt, milk, cream cheese, ice cream, and sour cream) for creaminess. Kirkmeyer and Tepper (2003, 2005) reported that semi-trained PROP sensitive tasters used a

more complex language to describe creaminess in dairy products and relied more heavily on flavor and texture attributes than semi-trained non-PROP tasters.

Regional/cultural differences can also affect creaminess perception. Consumers in Spain and Uruguay were asked to indicate words/descriptions/thoughts/feelings that they associated with creaminess of dairy products. Both countries are Spanish-speaking with different consumption habits of dairy products. Differences in how each group described creaminess were reported between the two countries (Antmann *et al.* 2011a). In a second study comparing consumers in Argentina, Spain, and Uruguay, Antmann *et al.* (2011b) reported that consumer perception of creaminess from a word association task but no actual test products, to mainly relate to tactile and kinesthetic sensations with significant differences between the three consumer groups.

Creaminess has been linked to milk fat in dairy products (Bruzzone *et al.* 2013; Frost and Janhoj 2007; Richardson-Harman *et al.* 2000; Richardson *et al.* 1993). Bruzzone *et al.* (2013) reported modified yogurts to be perceived as increasing in creaminess with increased fat content independent of starch content or gelatin content. Richardson *et al.* (1993) reported that size of fat globules influenced creaminess of dairy emulsions of equal viscosity. Richardson-Harmen *et al.* (2000) reported both dairy-type flavor and textural attributes to be related to the perception of creaminess in liquid dairy products. Initial research on the perception of creaminess was linked to viscous forces of the tongue (Richardson and Booth, 1993). Homogenization has been linked to the perception of milk fat, thickness, and creaminess rating (Richardson and Booth, 1993). Coalescence of fat droplets in emulsions is expected to significantly affect creaminess perception in dairy products including sour cream.

Previous literature has suggested smaller particle size of fat droplets results in reduced in-mouth friction which might increase the sensation of creaminess, fattiness, thickness, slipperiness, and smoothness (Sarkar and Singh, 2012).

Research also suggests that the sensation of milk fat in-mouth during mastication is key to creaminess perception. Other aspects of the food experience must be considered when trying to find a way to characterize creaminess. The oral sensation of fat perceived by the human brain works in conjunction with other sensory aspects of food such as taste, texture, and olfactory inputs (Rolls, 2012). Interactions of flavor and texture of low fat yogurts have been reported (Paci Kora *et al.* 2003). Weenen *et al.* (2005) reported texture attributes to positively correlate to creamy mouthfeel in mayonnaises/custard desserts/sauces, and taste/flavor to affect creamy mouthfeel and fattiness of custard desserts. This experiment did not combine effects of other sensory modalities or individual effects of single modalities independent of in-mouth texture and flavor. A follow-up study proposed a creaminess perception model based upon fat globule in-mouth lubrication during mastication in conjunction with the release of fat-soluble flavors (de Wijk *et al.* 2006a).

Odors and tastes have been shown to have interacting modalities as they are experienced (Small and Prescott, 2005). This phenomenon is observed with odor and taste when they are complementary, such as benzaldehyde (cherry/almond aroma) and sweet taste. Contrasting or unrelated tastes and odors, such as benzaldehyde and monosodium glutamate have not been shown to have this same relationship (Delwiche, 2004). Rolls *et al.* (1996a, 1996b) performed a series of experiments on monkeys and identified unimodal taste, smell, visual, fat, and texture cells that were interspersed with multimodal cells that responded to

independent stimulation of two or more modalities. The perception of creaminess may stimulate multimodal cells, requiring signals from more than one sensory modality in order for a product to be perceived as creamy. Frost and Janhoj (2007) suggested that sensory perception of fat involved several senses including vision, olfaction, gustation, and haptics (physical stirring) and proposed "creaminess" to be a meta-descriptor. These researchers reported plain yogurt to have high creaminess when it had a relatively high viscosity and high intensity of fat-related flavors. Glossy appearance and flavor notes like cream and butter were reported to have a positive correlation with creaminess (Frost and Janhoj, 2007). Fat replacers used in low fat products or processing techniques to mimic texture, target one modality and these products are often perceived as less creamy and not as liked as their full fat counterparts (Rolls, 2012; Frost and Janhoj, 2007). Mimicking the texture of full fat dairy products accounts for one facet of what appears to be a multisensory experience. If creaminess is multimodal, then reduced fat products must account for each sensing modality in order to be perceived as creamy. There is still a lack of confirmation of what sensory modality or combination thereof is responsible for how consumers perceive creaminess in products. The objective of this test was to determine what sensory modality or combination thereof was responsible for consumer perception of creaminess in sour cream by holding select sensory modalities constant while having consumers evaluate representative sour creams. Sour cream was chosen for this study because it is a semisolid cultured dairy product within which creaminess is an expected consumer attribute, similar to yogurts and puddings (Shepard *et al.* 2013). Sour cream is also an ideal dairy product for a study on

creaminess perception as it has a larger range in milk fat concentration compared to other dairy products such as yogurts and puddings.

MATERIALS AND METHODS

Sour Creams

Thirty-nine commercial sour creams were profiled by descriptive analysis (Shepard et al. 2013), out of the 39, n=12 were chosen for further profiling in this study based upon an equal distribution of the flavor and texture sensory space by principal component biplot analysis. Specific brands chosen for this study were influenced by regional availability in the Raleigh/Durham/Chapel Hill grocery market and based upon grocery store ability to provide sour creams with at minimum a two week pull date prior to testing. Only sour creams that had at least a two week pull date were profiled in this study in order to ensure end of shelf-life was not a factor in the perception of creaminess throughout modality testing. These limitations did affect the ability to evenly represent in frequency the different fat contents, however, the four quadrants of flavor and texture principal component biplots were represented (Shepard et al. 2013). The purpose of this investigation is to determine what sensory modality, or combination, is responsible for creaminess perception, flavor and texture are two of those modalities, therefore, proper representation of the variety of flavor and texture attributes is of key importance. (Table 1).

Consumer Testing

A series of seven consumer tests were conducted to study each sensory modality (Table 2). Three hundred sour cream consumers were recruited. Consumers were recruited from an online database of consumers maintained by the Sensory Service Center of North

Carolina State University. At the time of recruitment, the database had over 5,000 members. Consumers recruited were 50/50 full fat and reduced fat consumers, and consumed sour cream at least once a month. Consumer testing was conducting in accordance with the North Carolina State University Institutional Review Board for the Protection of Human Subjects in Research regulations.

All consumers participated in the baseline week of testing where all modalities were engaged. Three hundred sour cream consumers were originally recruited for the baseline, (control), study; n=274 participated and became the baseline control group from which all subsequent modality tests were recruited from. This session is the control session in which all other test sessions would be compared. Consumers were then able to participate in a maximum of two subsequent modality tests with a minimum of a two week wait in between tests to prevent memory effects. Target participation for all subsequent modality tests was one hundred consumers. All tests were presented using a balanced block Williams design for twelve treatments using Compusense Five v.5.2 (Guelph, Canada). Consumers were compensated with a food treat for completing the baseline test. After completing a second session, consumers were compensated with a $20 gift card to a local shopping store. After completing their third session, consumers were compensated with a $15 gift card to a local shopping store. This would conclude their maximum participation in this study.

Sour creams used for all tests were a minimum of two weeks before pull date. Each container was pre-screened by an experienced taster prior to serving to consumers. All sour creams were stored and served at 4°C. As needed, containers of sour cream were opened, evaluated by an experienced taster, and cleared for sampling for consumers. Containers were

not pre-stirred. A 60g (2oz) portion was scooped into a soufflé cup labeled with a unique identifying three digit code, lidded and presented to the consumer with a white plastic spoon. Consumers then evaluated the creaminess of the sample using an 11-pt rating scale where 1 = not at all creamy and 11 = extremely creamy. Eleven was chosen because an 11-pt scale has been reported to be an appropriately discriminating scale and can yield a high level of discrimination with a large number of products (Friedman and Friedman 1989). Further, the use of only 2 word-based anchors limits consumer5 bias (Stone et al. 2012).

Consumers then evaluated their overall liking of the sample using a 9-pt hedonic scale. Unsalted crackers and room temperature distilled water were served as palate cleansers. There was an enforced two min rest between samples.

For the control session 1, consumers were instructed to consume the sour cream as they typically would and rate creaminess intensity followed by overall liking using the 9-pt hedonic liking scale (Table 2). Session 2 consumers were instructed to only look at the sour cream and indicate the level of creaminess and then overall liking. Session 3 consumers were instructed to immediately stir the sour cream upon receipt and then indicate the level of creaminess and then overall liking. Session 4 consumers wore a blindfold and then stirred the sour cream. No tasting occurred on sessions 2, 3 and 4. Session 5 and 6 consumers were given blindfolds to wear prior to receiving their sample of sour cream, (MaskCraft, San Antonio TX), and served a measured spoonful of sour cream (1 Tbsp ~ 15g) to taste. Samples were not stirred prior to evaluation and were instead broken down in the mouth. Session 6 consumers wore nose clips, (Medical Support Products, Lancaster PA), in addition

to blind folds. Session 7 consumers wore nose clips only. As with other sessions, consumers rated creaminess intensity followed by overall liking in sessions 5 – 7.

STATISTICAL ANALYSIS

A mixed model analysis of variance was used to evaluate the impact of fat content and session type on creaminess rating using SAS version 9.2 (Cary, NC). Fat content of sour cream, session type and their interaction were fixed effects in the model. Panelist and sour cream product with each fat content classification were considered random effects. Differences between session types were evaluated using least squares means in a mixed model procedure. A significance level of 0.05 was used for all hypothesis tests. All sessions where a modality was held constant (sessions 2 – 7) were compared back to the control session (session 1) in order to determine when the perception of creaminess deviated from control and to therefore identify important modalities for creaminess perception in sour cream. If no effect was reported relative to the control sessions (all senses engaged), then the modality(s) blocked in that session was concluded to not be an important contributor to creaminess perception.

RESULTS AND DISCUSSION

Sour creams that were highest in creaminess rating were associated with high overall liking scores. Creaminess intensity had an R-squared value of 0.78 with overall liking ($p<0.05$). The sour creams most liked were full fat sour creams (Table 3). Shepard *et al.* (2013) also reported that sour creams that were just about right (JAR) in creamy were the most liked. Those sour creams were also all full fat sour creams. Creaminess has been associated with overall liking of other dairy products (Frost and Janhoj, 2007, Tournier *et al.*

2007, Elmore *et al.* 1999, Richardson-Harman *et al.* 2000). The fat free treatment was more liked in sessions where no tasting occurred (Table 3). Overall liking was included in this study to demonstrate that overall liking and creaminess rating are highly correlated (R^2 = 0.78) as is reported by other studies for other dairy products, demonstrating the importance of understanding how creaminess is perceived.

Mean creaminess rating scores are presented in Table 4. In comparing each session to the control session, sessions 2, 4, 6, and 7 were significantly different in creaminess perception across all sour creams; sessions 3 and 5 were not (Table 5). When consumers were only instructed to look at the sour creams (session 2), their rating of the creaminess of those sour creams was different than how they were rated in the control session ($p<0.05$), suggesting that appearance alone was not sufficient for creaminess perception. In session 3 where consumers immediately stirred the sour creams upon receipt, creaminess intensities were not different from the control session ($p>0.05$), which would suggest that stirring was sufficient for creaminess perception. Drake *et al.* (1999) reported that in-hand texture terms used by trained evaluators, discriminated a diverse set of cheeses similarly to mouth texture terms. Pereira *et al.* (2004) also reported that non-oral (visual and tactile) texture evaluation of acidified skim milk gels by descriptive analysis, discriminated samples similarly compared to an oral evaluation. These previous studies demonstrate that textures of dairy products can be discriminated by non-oral mechanisms and accounts for the perception of creaminess of the sour creams by way of stirring. However, it is unclear from session 3 if stirring or the visual appearance of the sour cream while stirring is important, which is why session 4 was conducted. In session 4 where consumers wore blindfolds and stirred the sour creams,

creaminess ratings were different from the control session ($p<0.05$), confirming that the visual assessment of the sour cream while stirring was required for consumer perception of the creaminess of sour cream. Texture evaluated by flow characteristics from stirring is important to creaminess perception. This does not suggest that the non-oral, visual perception of creaminess by stirring is as sensitive as an in-mouth evaluation. Ringel *et al.* (1970) reported that fingertips are less sensitive than the tongue when evaluating paired comparisons of oral and tactile stimuli. Oral evaluation of sour cream and other foods results in a series of oral responses to texture changes from mastication and salivation. The mastication and salivation constantly alter the food resulting in changing textural sensations perceived by the oral cavity (Christensen 1984). Oral contact with food can occur through the lips, tongue, palate, cheeks, and teeth, all of which provide textural information (Engelen and de Wijk 2012). Oral contact with food provides more information regarding the texture of a food product as opposed to non-oral contact such as stirring. This would allow for greater sensitivity in detecting textural differences due to milk fat content in sour cream by oral pathways rather than non-oral pathways such as stirring. This is evidenced by the significant difference in fat free and full fat creaminess rating across sessions (Table 6).

In session 5 where visual and stirring were removed, creaminess perception was not different from the control session ($p>0.05$), suggesting the sensing modalities for an in-mouth evaluation were still engaged. However, in session 6, where flavor and visual were removed and only in-mouth texture was engaged, the perception of creaminess was different from the control session ($p<0.05$). In-mouth texture alone was not sufficient for the perception of creaminess. Jowitt (1974) defined texture as ‘the attribute of a substance

resulting from a combination of physical properties and perceived by the senses of touch, sight, and hearing.' In-mouth texture alone was not enough to perceive the differences in creaminess of the sour creams overall, but texture was important for creaminess as evidenced by the results of session 3 (Table 6). Spence *et al.* (2000) reported visual cues to olfactory stimuli improved response accuracy of the perception of that olfactory stimulus. In session 7 where only flavor was removed so visual, physical stirring, and in-mouth texture were engaged, creaminess perception was different from control ($p<0.05$). The results demonstrate that olfaction was important in the perception of creaminess and must be present in order for a sour cream to be perceived as creamy in the mouth.

There was a fat content effect in the control session and session 7 (nose clips only) ($p<0.05$) (Table 6). The full fat sour creams were rated the highest in creaminess followed by reduced fat/light and then fat free sour creams in sessions 1 and session 7 ($p<0.05$). Within a fat content, sour creams were perceived as different in creaminess intensity in sessions 2 – 6 compared to control and compared to session 7 (Table 7). The differences within fat content across sessions were within the full fat and fat free sour creams primarily. The extremes in fat content exemplify the importance of milk fat to creaminess perception, specifically flavor(s) associated with milk fat. Visual, stirring, and in-mouth texture perception can aid in creaminess perception when olfaction and taste are removed if the fat content is high enough for perception of the flow properties of the sour cream by visual assessment and physical stirring.

A closer examination of session x session revealed that session 3 (stirring only) was different from the control and different from session 7 (nose clips) for full fat sour creams;

but that session 7 was not different from control for full fat sour creams. The perception of creaminess from visual flow while stirring was less sensitive for the differences in creaminess for full fat sour creams than an oral evaluation, as expected (Table 7). Session 7 sour creams were different in creaminess from session 1, 3, 4, 5, and 6 sour creams for reduced fat/light sour creams ($p<0.05$). Session 7 was different from sessions 1, 2, 3, 4, 5 and 6 for fat free sour creams ($p<0.05$). When milk fat was removed from sour cream, it was more difficult for consumers using the remaining modalities, (olfaction was removed), to perceive creaminess. The pair-wise comparisons of creaminess rating across milk fat contents demonstrate the sensitivity of flavor when assessing the creaminess of full fat sour creams (Table 7). For full fat sour creams, session 7 was the only session not different from the control. Reduced/light/low fat sour creams were rated similarly to the control across all sessions except session 7 (Table 7). Flavor was the most important attribute when assessing the creaminess of full fat sour creams however when the signal for creaminess from flavor was diminished (by removing milk fat), the other sensing mechanisms (visual, physical stirring, in mouth texture) become more important. The signal becomes further difficult to assess when milk fat is removed to 0.5g/100g serving for a fat free label claim, where all sessions were different from the control session except session 5 (blind folds only). Sessions 5 (blind folds only) and 6 (blindfolds and nose clips) were not different from each other in creaminess scores for fat free sour cream (Table 7). Sessions 6 (blindfolds and nose clips) and 7 (nose clips only) were different from each other for fat free sour cream. This result suggests in mouth texture is important for assessing fat free sour cream and that a visual component confuses the signal as evidenced by session 7 being different from session 6 for

fat free sour cream (Table 7). If only in mouth texture was important, then session 6 would not be different from session 7. It is important to note that only one of the samples in this study was fat free.

Creaminess perception and milk fat are linked (Frost *et al.* 2001). Mattes (2005) suggested that the sensation of dietary fat was detected by textural, olfactory and taste mechanisms. Milk fat flavor is of primary importance for the perception of creaminess in sour cream by olfaction. Multimodal neurons in the caudal orbital frontal cortex (OFC) respond only if the taste, odor, or visual stimuli are congruent across modalities (Small and Prescott, 2005). Creaminess may be a multimodal mechanism perceived by the OFC in which removal of flavor active volatiles from olfaction results in a loss of signal towards creaminess perception. Milk fat and creaminess are synesthetic. Rolls (1997, Rolls and Baylis, 1994) argued that bimodal taste/odor neurons developed from unimodal neurons which originally responded only to olfactory information, through learning of appropriate combinations of signals during repeated co-exposure of particular tastes with odors. The more exposure to non-fat and reduced fat dairy products, the more they will be liked (Prescott, 2012). Mattes (1993) reported that a small test sample of individuals under a free-living environment, (not strictly confined to a metabolic ward), who adhered to a reduced-fat diet for 12 weeks, had a reduction in hedonic ratings for high-fat foods. If this concept can be translated to creaminess perception, consumers have been ‘taught’ to expect the flavor of milk fat to correspond to a specific in-mouth texture and therefore texture can aid in their perception of creaminess, however the mechanism ultimately responsible for creaminess perception in the mouth is a flavor mechanism for full fat sour creams. This idea can be

extended in that consumers may expect a full fat sour cream to flow a certain way, (while stirring), which signals to the consumer the sour cream will be creamy.

Previous studies have also suggested that creaminess has a distinct flavor component (Frost and Janhoj 2007; Schlutt *et al.* 2007; de Wijk *et al.* 2006b; Kilcast and Clegg 2002; Richardson-Harman *et al.* 2000). Schlutt *et al.* (2007) reported spiking of dairy cream with δ-tetradecalactone, (a lactone present in full-fat dairy cream), enhanced creaminess perception by trained panelists confirming the role of olfaction observed in this study. Several researchers have tried to measure creaminess using rheological parameters. Using whey protein enriched yogurts; Krzeminski *et al.* (2013) reported a relationship between creaminess perception by trained panelists and graininess and viscosity using particle size measurements and deformation tests. Kilcast and Clegg (2002) suggest creaminess may differ between structural types having assessed different solid particle model systems, chocolate mousses, and artificial creams; which limits overarching rheological methods for measuring creaminess. Penna *et al.* (2001) reported a positive correlation between consumer acceptance of acidified milk drinks and flow behavior index and the consistency coefficient. Janhoj *et al.* (2008) found a moderate relationship between oral viscosity and the consistency coefficient. Frost *et al.* (2001) attempted to account for a loss of milk fat flavor in 0.1% fat milk by the addition of cream aroma and reported similar sensory properties of the 0.1% fat milk compared to 1.3% fat milk with the addition of cream aroma, thickeners and whiteners. No rheological parameter has been found to be a consistent metric for measuring creaminess in relationship to consumer perception of creaminess. The previous rheological studies mentioned here have correlated parameters to trained panel in-mouth attributes. A possible

extension of this study could be to correlate rheological parameters to trained panel assessment of sour cream stirring attributes.

According to Mattes (2005), texture does not fully account for dietary fat detection. This is evidenced by oils when heated have a change in texture but research suggests the perceived fat content does not. This may be due to the inability of rheological measurements to capture flavor perception which is ultimately responsible for the perception of creaminess in full fat sour cream based upon the results presented in this paper. Fat is perceived by multiple mechanisms (Mattes 2005). While texture may play a role, it is ultimately an olfactory and taste mechanism that is primarily responsible for creaminess perception of full fat sour cream.

CONCLUSIONS

The perception of creaminess in sour cream is primarily due to milk fat perception specifically from the flavor from the milk fat. These results suggest that in mouth perception of creaminess of full fat sour cream is primarily assessed through olfaction of milk fat associated flavors. Removing milk fat makes the assessment of creaminess solely by olfaction related mechanisms more difficult. In order to make low fat and fat free sour cream products that are perceived as creamy, milk fat associated flavors must be accounted for. Textural creaminess assessment mechanisms become more important than olfaction related mechanisms with reduced/light/low fat sour creams. Fat free sour creams can be perceived as creamy by in mouth texture assessment alone, however the engagement of other sensing modalities makes the perception of a fat free sour cream as creamy more difficult. Non-oral assessment of the creaminess of sour cream can be done by way of visual assessment of flow

while stirring however this method is not as sensitive as an oral assessment. The assessment of the creaminess of sour cream is a complex mechanism dependent upon milk fat content.

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Table 1. Sample IDs

Sample ID	Label	Fat Content (g)
A	Full Fat	5
B	Full Fat	5
C	Full Fat	6
D	Full Fat	5
E	Full Fat	5
F	Full Fat	6
G	Full Fat	10
H	Reduced Fat	2
I	Light	2.5
J	Light	2.5
K	Low Fat	2
L	Fat Free	0

*Fat content is per a 30g sample

Table 2: Modality Breakdown by Session

Session	Testing Parameter	Modality Engaged
1	Baseline	All modalities
2*	Visual observations only	Visual
3*	Stirring only	Physical stirring and visual
4*	Blindfolds and stirring	Physical stirring only
5	Blindfolds	In-mouth texture and flavor
6	Blindfolds and nose clips	In-mouth texture
7	Nose clips only	Visual, physical stirring, in-mouth texture

*No tasting occurred during these sessions

Table 3. Overall Liking Scores of Sour Creams for Each Session

Sample ID	Session 1 All Modalities	Session 2 Visual Only	Session 3 Stirring	Session 4 Blindfolds and stirring	Session 5 Blindfolds	Session 6 Blindfolds and nose clips	Session 7 Nose clips
A	5.8 bc	5.1 fg	5.0 efg	5.9 bc	4.1 e	5.0 def	6.2 abc
B	5.9 b	5.4 def	4.8 fg	5.8 cd	6.0 bc	5.3 cd	6.6 a
C	6.6 a	6.5 a	6.9 a	6.6 a	6.8 a	6.5 a	6.3 abc
D	5.5 cd	6.3 ab	6.8 a	5.3 d	6.5 ab	6.3 a	5.9 c
E	6.6 a	5.8 cd	5.4 de	6.4 ab	5.6 cd	5.4 cd	6.5 ab
F	6.5 a	5.1 fg	5.0 efg	6.9 a	3.8 e	3.5 g	5.9 cd
G	5.5 d	5.6 cde	5.7 cd	4.7 e	6.8 a	6.4 a	6.1 bc
H	4.1 f	5.9 c	6.1 bc	6.5 a	4.1 e	4.7 ef	3.9 g
I	5.6 bcd	4.9 g	5.2 ef	6.4 ab	5.8 cd	6.0 ab	5.4 de
J	4.7 e	5.3 efg	5.2 ef	6.7 a	6.0 bc	5.6 bc	5.0 ef
K	4.3 f	5.7 cd	5.9 bc	3.9 f	5.3 d	5.2 cde	4.8 f
L	3.7 g	6.0 bc	6.2 b	5.4 d	4.1 e	4.6 f	3.7 g

*Means within a column followed by a different letter are significantly different $p<0.05$
*Liking was scored on a 9pt hedonic scale where 1 = dislike extremely and 9 = like extremely
*Session 1 had n=274 consumers
*Sessions 2 and 3 had n=109 consumers
*Session 4 had n=100 consumers
*Sessions 5 and 7 had n=111 consumers
*Session 6 had n=101 consumers
*A-G (full fat), H (reduced fat), I-J (light), K (low fat), L (Fat Free)

Table 4. Creaminess Rating Scores of Sour Creams for Each Session

Trt	Session 1 All Modalities	Session 2 Visual Only	Session 3 Stirring	Session 4 Blindfolds and stirring	Session 5 Blindfolds	Session 6 Blindfolds and nose clips	Session 7 Nose clips
A	7.3 efg	7.1 bcd	7.2 cde	6.9 a	6.7 cd	7.4 ab	7.7 abc
B	7.5 def	6.8 cd	6.9 de	6.7 a	7.5 ab	6.8 bc	8.3 a
C	8.1 a	7.7 a	8.0 a	6.5 a	7.8 a	7.6 a	7.5 bcd
D	7.5 de	7.5 ab	7.8 abc	6.4 ab	7.9 a	7.5 a	7.5 bc
E	7.7 cd	7.3 abc	7.3 bcd	5.8 cd	8.0 a	7.3 ab	7.5 bc
F	8.1 ab	6.9 cd	6.6 e	4.7 e	6.4 d	6.1 c	7.5 bcd
G	8.0 abc	6.7 cd	7.0 de	3.5 f	7.8 a	7.7 a	8.0 ab
H	6.9 g	7.0 bcd	7.2 cde	6.4 ab	7.1 bc	7.0 ab	6.6 ef
I	7.1 fg	7.5 ab	7.9 ab	5.9 bc	7.4 abc	7.5 a	6.9 de
J	7.7 bcd	6.6 d	7.9 ab	5.4 d	7.8 a	7.2 ab	7.3 cd
K	7.1 g	6.9 cd	7.0 de	5.3 d	6.8 cd	6.7 bc	6.9 de
L	6.5 h	7.1 bcd	7.4 bcd	6.6 a	6.9 bcd	7.0 ab	6.1 f

*Means within a column followed by a different letter are significantly different $p<0.05$
*Liking was scored on a 11pt rating scale where 1 = not creamy at all and 11 = extremely creamy
*Session 1 had n=274 consumers
*Sessions 2 and 3 had n=109 consumers
*Session 4 had n=100 consumers
*Sessions 5 and 7 had n=111 consumers
*Session 6 had n=101 consumers
*A-G (full fat), H (reduced fat), I-J (light), K (low fat), L (Fat Free)

Table 5: Session Comparisons to Control (p<0.05)

Session Number	Session Description	Modality Engaged	SE	t value	p value
2	Visual only	Visual	0.085	3.82	**0.0002**
3	Stirring only	Physical stirring and visual	0.085	1.88	0.0620
4	Blindfolds and stirring	Physical stirring only	0.088	3.03	**0.0024**
5	Blindfolds	In mouth texture and flavor	0.085	1.71	0.1104
6	Blindfolds and nose clips	In mouth texture	0.087	3.46	**0.0009**
7	Nose clips only	Visual, physical stirring, in mouth texture	0.083	2.90	**0.0049**

*****A sessions are compared to control session 1
*p values in bold are significantly different from control

Table 6: Fat Content Effect per Session for Creaminess Intensity

Session/Fat Content	F value	P value Creaminess
Control	12.89	**<0.0001**
Visual only	0.23	0.7968
Stirring and visual	0.24	0.7890
Blindfolds and stirring	0.35	0.7014
Blindfolds	1.32	0.2659
Blindfolds and nose clips	0.23	0.7973
Nose clips only	16.82	**<0.0001**
Full Fat	9.55	**<0.0001**
Reduced Fat/Light	1.85	0.0863
Fat Free	5.08	**<0.0001**

*p values in bold for sessions signify sessions with a fat content effect
*p values in bold for fat content indicate which fat contents effects were determined

Table 7: Fat Content Effect of Creaminess Perception Session X Session

Fat Content	Session	Session	p < 0.05
Full Fat	Control	Visual only (session 2)	**Yes**
Full Fat	Control	Stirring only (session 3)	**Yes**
Full Fat	Control	Blindfolds and stirring (session 4)	**Yes**
Full Fat	Control	Blindfolds (session 5)	**Yes**
Full Fat	Control	Blindfolds and nose clips (session 6)	**Yes**
Full Fat	Control	Nose clips only (session 7)	No
Full Fat	Visual only (session 2)	Stirring only (session 3)	No
Full Fat	Visual only (session 2)	Blindfolds and stirring (session 4)	No
Full Fat	Visual only (session 2)	Blindfolds (session 5)	No
Full Fat	Visual only (session 2)	Blindfolds and nose clips (session 6)	No
Full Fat	Visual only (session 2)	Nose clips only (session 7)	**Yes**
Full Fat	Stirring only (session 3)	Blindfolds and stirring (session 4)	No
Full Fat	Stirring only (session 3)	Blindfolds (session 5)	No
Full Fat	Stirring only (session 3)	Blindfolds and nose clips (session 6)	No
Full Fat	Stirring only (session 3)	Nose clips only (session 7)	**Yes**
Full Fat	Blindfolds and stirring (session 4)	Blindfolds (session 5)	**Yes**
Full Fat	Blindfolds and stirring (session 4)	Blindfolds and nose clips (session 6)	No
Full Fat	Blindfolds and stirring (session 4)	Nose clips only (session 7)	No
Full Fat	Blindfolds (session 5)	Blindfolds and nose clips (session 6)	No
Full Fat	Blindfolds (session 5)	Nose clips only (session 7)	No
Full Fat	Blindfolds and nose clips (session 6)	Nose clips only (session 7)	**Yes**
Reduced Fat/Light	Control	Visual only (session 2)	No
Reduced Fat/Light	Control	Stirring only (session 3)	No
Reduced Fat/Light	Control	Blindfolds and stirring (session 4)	No
Reduced Fat/Light	Control	Blindfolds (session 5)	No
Reduced Fat/Light	Control	Blindfolds and nose clips (session 6)	No
Reduced Fat/Light	Control	Nose clips only (session 7)	**Yes**
Reduced Fat/Light	Visual only (session 2)	Stirring only (session 3)	No
Reduced Fat/Light	Visual only (session 2)	Blindfolds and stirring (session 4)	No
Reduced Fat/Light	Visual only (session 2)	Blindfolds (session 5)	No
Reduced Fat/Light	Visual only (session 2)	Blindfolds and nose clips (session 6)	No
Reduced Fat/Light	Visual only (session 2)	Nose clips only (session 7)	No
Reduced Fat/Light	Stirring only (session 3)	Blindfolds and stirring (session 4)	No
Reduced Fat/Light	Stirring only (session 3)	Blindfolds (session 5)	No
Reduced Fat/Light	Stirring only (session 3)	Blindfolds and nose clips (session 6)	No
Reduced Fat/Light	Stirring only (session 3)	Nose clips only (session 7)	**Yes**
Reduced Fat/Light	Blindfolds and stirring (session 4)	Blindfolds (session 5)	No
Reduced Fat/Light	Blindfolds and stirring (session 4)	Blindfolds and nose clips (session 6)	No
Reduced Fat/Light	Blindfolds and stirring (session 4)	Nose clips only (session 7)	**Yes**
Reduced Fat/Light	Blindfolds (session 5)	Blindfolds and nose clips (session 6)	No
Reduced Fat/Light	Blindfolds (session 5)	Nose clips only (session 7)	**Yes**
Reduced Fat/Light	Blindfolds and nose clips (session 6)	Nose clips only (session 7)	**Yes**
Fat Free	Control	Visual only (session 2)	**Yes**
Fat Free	Control	Stirring only (session 3)	**Yes**
Fat Free	Control	Blindfolds and stirring (session 4)	**Yes**
Fat Free	Control	Blindfolds (session 5)	No
Fat Free	Control	Blindfolds and nose clips (session 6)	**Yes**
Fat Free	Control	Nose clips only (session 7)	**Yes**
Fat Free	Visual only (session 2)	Stirring only (session 3)	No
Fat Free	Visual only (session 2)	Blindfolds and stirring (session 4)	No
Fat Free	Visual only (session 2)	Blindfolds (session 5)	No
Fat Free	Visual only (session 2)	Blindfolds and nose clips (session 6)	No
Fat Free	Visual only (session 2)	Nose clips only (session 7)	**Yes**

Table 7: Continued

Fat Content	Session	Session	$p < 0.05$
Fat Free	Stirring only (session 3)	Blindfolds and stirring (session 4)	No
Fat Free	Stirring only (session 3)	Blindfolds (session 5)	No
Fat Free	Stirring only (session 3)	Blindfolds and nose clips (session 6)	No
Fat Free	Stirring only (session 3)	Nose clips only (session 7)	**Yes**
Fat Free	Blindfolds and stirring (session 4)	Blindfolds (session 5)	No
Fat Free	Blindfolds and stirring (session 4)	Blindfolds and nose clips (session 6)	**No**
Fat Free	Blindfolds and stirring (session 4)	Nose clips only (session 7)	**Yes**
Fat Free	Blindfolds (session 5)	Blindfolds and nose clips (session 6)	**No**
Fat Free	Blindfolds (session 5)	Nose clips only (session 7)	**Yes**
Fat Free	Blindfolds and nose clips (session 6)	Nose clips only (session 7)	**Yes**

APPENDIX

APPENDIX A.

A COMPARISON OF ADAPTIVE CHOICE-BASED CONJOINT AND CHOICE-BASED CONJOINT TO DETERMINE KEY CHOICE ATTRIBUTES OF SOUR CREAM WITH LIMITED SAMPLE SIZE

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RUNNING TITLE: Choice Based vs. Adaptive Choice Based Conjoint Analysis of Sour Cream Drivers

ABSTRACT

Adaptive choice based conjoint (ACBC) analysis is a technique which uses choice data and incorporates it into an adaptive interviewing experience. ACBC analysis has been suggested to provide more accurate information at the individual level which can lead to better predictions even when using smaller sample sizes. A comparison of a traditional choice based conjoint survey (CBC) and an ACBC survey was undertaken to compare the overall utility scores and importance values of attributes determined by both techniques using sour cream as the subject. A CBC and an ACBC survey were conducted. More respondents participated in the CBC (n=777) survey than the ACBC version (n=250). Respondents to the ACBC version were from the same pool of respondents to the CBC version. A random sample of 250 respondents from the CBC survey was also analyzed. Results were analyzed by overall utility scores, importance values, landscape segmentation analysis, and cluster analysis via latent class. The ACBC and CBC results were similar in overall utility scores for all attributes with similar respondent clusters. Both techniques revealed fat content as the most important attribute followed by price followed by brand. The CBC result for 250 respondents overestimated the importance of brand. The ACBC utility scores were not as distinct as CBC results in all categories; however the direction of the mean utility scores was the same in all categories. Overall ACBC and CBC revealed similar outcomes for different sour cream product types when price was excluded however the CBC results differentiated products to a greater extent than ACBC with the same sample size considered.

PRACTICAL APPLICATIONS

Conjoint analysis is a research technique widely utilized across multiple industries as a way of determining the utility of a product or a product feature. Adaptive choice based conjoint (ACBC) is a new form of conjoint analysis. Because of the format of ACBC studies, respondents may be more engaged in the survey-taking experience and provide answers that are more in-line with their actual choice behavior. Because of this, ACBC studies may reveal more accurate responses for specific attributes such as brand and/or price. ACBC studies may also require fewer respondents which is advantageous when the audience is highly selective, or if money and/or time is a concern.

KEY WORDS

Adaptive choice based conjoint, choice based conjoint, sour cream

INTRODUCTION

Conjoint analysis is a widely used method for determining consumer preferences towards components of a product. Conjoint analysis has evolved with increasing access to technology and knowledge of consumer behavior. Conjoint analysis and discrete choice methods (choice based conjoint) did not originate with marketers but were originally based upon the work of mathematical psychologists Luce and Tukey (1964), and work by McFadden (1974) (Orme 2004). A marketing professor, Paul Green, applied the published work to marketing research using a full-profile card-sort conjoint analysis method (Orme 2004). Green and Rao (1971) then published the seminal conjoint article "Conjoint Measurement for Quantifying Judgmental Data" (Orme 2010). Since then, conjoint analysis has expanded greatly in the marketing sector and into the sensory community (Gensler *et al.*

2012; Olsen *et al.* 2012; Sichtmann *et al.* 2011; Melo *et al*. 2010; Childs and Drake 2009; Cardello *et al*. 2007; Gofman 2006; Nelson *et al*. 2005; Orth and Lopetcharat 2005; Beckley *et al*. 2004; Moskowitz *et al*. 2004; Krieger *et al*. 2002; Vickers 1993; Cheng *et al*. 1990).

There are three main types of conjoint analysis in use today; traditional full-profile conjoint analysis (also known as conjoint value analysis (CVA)) which was the first method developed, adaptive conjoint analysis (ACA) which followed full-profile, and choice based conjoint (CBC), the most widely used method today. Each method possesses its own advantages and disadvantages and subsequent design specifications. Most researchers recognize that not every conjoint technique is suitable for every research situation (Orme 2010). Full-profile is limited by the volume of attributes and levels that can be presented to the respondents before they become fatigued. This method was originally designed for pencil and paper surveys but has been adopted for computer based surveys. With access to computers, the robustness of conjoint methodology has expanded.

The second form of conjoint, ACA, has the advantage of measuring more attributes than is possible in full-profile or CBC because not all attributes are presented to respondents at the same time. ACA questions ask respondents to rank or rate attribute levels and then assign an importance value to each attribute (Orme 2010). ACA cannot measure attribute interactions and has been suggested to be a poor method for measuring the importance of price. Choice based conjoint became popular in the 1990s and is currently the most widely used method (Orme 2010). CBC measures consumer responses by presenting questions that reflect how consumers actually make decisions. CBC can also measure interactions between all attributes which can be very important in determining if an attribute alone has an effect on

choice or if there is an effect when two attributes are presented together (Orme 2010). In choice based conjoint analysis, consumers are presented with different product concepts and are asked to choose which concept is the most appealing. Each choice task also includes a "none of these" option. In a CBC, no more than six attributes and no more than nine levels for each attribute are recommended (Orme 2010; Green and Srinivasan 1990). CBC surveys can be overwhelming for respondents despite the optimized statistical efficiency of the design (Cunningham *et al.* 2010). Another concern with full profile CBC designs is the occurrence of extreme selection behavior, either frequent choice of the none of these option or avoidance of this option. Such behavior can make the estimation of price very difficult in CBC studies (Gensler *et al*. 2012).

ACBC is a relatively new conjoint technique which utilizes the best aspects of choice based conjoint in an adaptive learning experience. An ACBC survey has three sections. ACBC surveys begin with a consider-then-choose model where respondents consider different product concepts and then in a second section, choose products based upon the responses in the previous section. Each respondent has an individually designed survey based upon their responses. The third part of the survey is a tournament section in which respondents choose products from a series of product concepts in a format similar to at traditional CBC. Adaptive choice based conjoint-type designs have been previously presented by Toubia *et al*. (2004 and 2007), Yu *et al*. (2011) and Gensler *et al*. (2012). ACBC surveys have been reported to provide more accurate individual level responses than traditional choice based conjoint methods (Hauser *et al.* 2009; Yu et al. 2011; Toubia *et al.* 2004, 2007) and have been suggested to require fewer respondents and/or fewer questions

(Yu *et al*. 2011; Toubia *et al.* 2004; Cunningham *et al*. 2010). Cunningham *et al.* (2010) reported that ACBC studies had lower standard errors and provided better estimates of real-world product decisions compared to conventional choice based surveys.

Adaptive choice based conjoint has been suggested to be more accurate at measuring consumer response to price when price is included as an attribute over choice based conjoint (Gensler *et al.* 2012; Chapman *et al*. 2009). ACBC has also been suggested to be a more engaging experience for the respondents and may require fewer respondents than a traditional CBC to obtain similar results (Orme 2010). Sichtmann *et al*. (2012) examined the ability of CBC analysis in predicting the accuracy of consumer willingness-to-pay (WTP) for bars of chocolate and reported CBC to overestimate consumer WTP even after segmentation of consumers based upon brand awareness, consumers who had strong preference patterns, or were highly involved in the survey. Gensler *et al*. (2012) directly compared CBC and ACBC techniques in predicting consumer WTP and reported adaptive designs to be better predictors of WTP than traditional CBC designs. If ACBC is a better method for determining the impact of price on a product, it is possible ACBC may be a better method in other areas as well. Brand can be an important attribute in conjoint analysis to show the perceived utility of one brand over another. Orth and Lopetcharat (2005) proposed conjoint as an ideal method for determining brand importance as a product feature. Because there are limitations in the volume of information gained from CBC studies (only learn about the product selected and nothing about the products not selected) as well as the potential for consumer fatigue with CBC (Orme 2010), it is advantageous to determine if ACBC can perform at parity or better than a CBC when brand and price are attributes. Piqueras-Fiszman *et al.* (2011) reported

that older age groups consider the overall picture of a product whereas younger age groups associate more frequently specific meaning of labels. The design of an ACBC may be more beneficial for younger age groups than older age groups. The objective of this study was to compare ACBC to CBC analyses to determine the attributes that drive choice for sour cream.

MATERIALS AND METHODS

Sour cream was chosen as the subject for this study because it is a widely used fermented dairy product in the United States with 1,135 million pounds consumed in 2007 (Agricultural Statistics 2010). There are also only a few attributes (brand, fat content, container size, label claim, price) that can be measured making the conjoint itself a relatively simple design. Due to the simplicity of the design and the commonality of the product itself, any bias from exploiting the design limitations of either survey technique were eliminated.

Choice based conjoint

A choice based conjoint was created using SSI Web (Sawtooth Software version 7.0.22, Orem, UT). The attributes and levels chosen for this study are presented in Table 1 and were identical to the attributes and levels chosen for the ACBC study. The CBC design was a traditional full profile CBC. Sixteen choice tasks were created with three product concepts per choice task. In each choice task there was also a fourth “none of these” option. Each product concept was a random combination of levels for each attribute with each attribute represented in every product concept. This study used a balanced overlap design and 300 versions of the survey were created. A series of prohibitions were used in this survey to prevent unrealistic combinations of price and container size (e.g. 24oz container for $1.25) and therefore prevent potential bias (Jourdan 2002). A prohibition statement is a

logic statement that does not permit the design to present two options together in a product concept if they are "prohibited." Prices that were unrealistically low for a 24 oz container were not permitted to be combined in the conjoint, as were unrealistically high prices for an 8 oz container regardless of brand. Prohibitions were based upon current market prices of the various brands of sour cream in this study, sizes, and the advertised price at high end and discount grocery stores in the Raleigh/Durham/Chapel Hill, NC area. Also prohibited was the possibility of an organic product, (Organic Valley), being paired with a regular label claim. All other combinations were permitted.

The survey was uploaded to the internet and launched to a database of 3,500 consumers; 777 consumer responses were used for this survey. Consumers with a root likelihood value of less than 0.333 were removed from both the CBC and ACBC studies (Jervis *et al.* 2012). Consumers received an email explaining the study and were directed to a link. First consumers answered a series of demographic questions. Respondents who were above the age of 18y, consumed sour cream at least once per month, and did at least some of the grocery shopping for their household, were allowed to continue on with the study. Consumers who qualified then answered a series of sour cream behavior and consumption questions. This was done in an effort to describe the population and relate the responses back to the CBC results. Consumers were shown pictures of each brand to be used in the CBC section of the study and asked importance questions of different product features for each brand. This information was asked to better understand consumer perception and familiarity with each brand, and to ensure each consumer saw each brand before they entered the CBC so they would either have recognized the brand or confirmed that they were not

familiar with the brand while answering the questions. After completion of this section of the survey, consumers began the CBC section. Once consumers completed the entire survey they were entered into a drawing to receive a twenty dollar gift card to a local shopping store.

Adaptive Choice Based Conjoint

An ACBC was created using the same prohibition statements, demographic questions, behavior and consumption questions, attributes, and levels as the CBC study. The only difference between the two studies was the physical design of the ACBC section of the survey. An ACBC survey was created using SSI Web (Sawtooth Software version 7.0.22, Orem, UT). Using the same software for both studies removed any software bias and allowed for use of the same analysis software for both studies. The ACBC study was designed with one build your own (BYO) task followed by eight 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. A minimum of two and a maximum of three attributes varied from the BYO selections for each product concept. Five unacceptable questions and four must have questions were built in through the survey. The screening task section was followed by a ten question choice task tournament section. A maximum of 20 product concepts were brought into the tournament section with a minimum of three concepts per choice task. Once consumers completed the entire survey they were entered into a drawing to receive a twenty dollar gift card to a local shopping store.

Consumers recruited to take the ACBC survey were from the original 777 who took the CBC survey. The same respondents were used for both surveys so that direct comparison of results could be conducted to make conclusions about the effect of the design and

population size. There was a three month gap between the launch of the CBC survey and the ACBC survey to limit any learning/remembering from the first survey experience. The response to the ACBC survey was capped at 250 in order to compare the effect of population size on the different surveys. A random sampling of 250 respondents from the CBC survey was also compared to determine the effect of population size.

Statistical Analyses

Individual utility scores were extracted by Hierarchical Bayesian estimation and rescaled using a zero-centered differences method (Orme 2010; Jervis *et al*. 2012). The zero-centered differences method standardizes all attribute utility scores so that easy comparisons are able to be made. HB-derived individual utility scores were analyzed using latent class analysis to categorize respondents that were similar into groups (classes). HB estimation is a standard method employed in choice based and adaptive choice based designs (Allenby *et al*. 2005; Sichtmann *et al.* 2011; Yu *et al.* 2011; Gensler *et al.* 2012). The algorithm estimates the average utility score for the entire sample size studied and then uses respondent's individual data to determine how each respondent differs from the total sample average. The algorithm then adjusts each respondent's utilities to represent the optimal mix of individual respondent choices and total sample averages (Howell 2009). This technique allows for less variability in the overall utility estimation from individual respondent choices. Latent class analysis is a segmentation technique used to segment respondents using categorical and/or continuous observed variables based upon probability of membership to each group (latent class) rather than absolutely assigned to a class. Importance scores were determined by calculating the utility score range of each attribute and dividing by the total utility range

multiplied by one hundred (Orme 2010). Standard deviation of utility scores was determined. A random sampling of 250 respondents from the CBC study was also analyzed for overall utility scores, importance values, and standard deviation of utility values to compare population sizes between the large CBC (n=777) and the ACBC (n=250). A one-way ANOVA with Fisher's least significant difference as the post hoc test was used for analysis of the zero-centered utility scores for the total population for each study using XLSTAT Addinsoft version 2010.5.02 (New York, NY). Latent class analysis was performed with Sawtooth Software SMRT (Sequim, WA). Principal component analysis (PCA) of clusters was performed using XLSTAT. Landscape Segmentation Analysis (LSA) was performed on the ACBC utilities (n=250) and the sub-sampled CBC (n=250) utilities for each combination of product attributes with price excluded from the model. LSA is based on a similarity model developed by Ennis *et al.* (1998) and Ennis and Johnson (1993). Each consumer is represented by an ideal point instead of a vector from the individual overall utility score for a particular product and on each attribute-type with an "all else equal" for the other attributes in order to demonstrate how both the ACBC and CBC methods represented respondent perceptions of the varied attribute in relationship to the total population (n=250). See Rousseau *et al.* 2012 for more information regarding LSA. Demographic and behavior questions were also analyzed for frequency of choice. All statistical analyses were carried out at a 95% significance level.

RESULTS AND DISCUSSION

The same consumer population participated in both the CBC and ACBC surveys. Demographic results presented in Table 2 demonstrate the similarity between the two groups

of respondents. Cluster analysis of the ACBC and CBC responses demonstrated two clusters in both survey groups characterized by the same components (Figures 1 & 2). Segment 1 was characterized by consumers that purchased full fat and name brand sour creams. Segment 2 was characterized by consumers that preferred a reduction in fat (reduced, low, light/lite). The average response time for the full CBC (n=777) was 17.4 min, the average response time for the ACBC was 19.6 min. Chapman et al. (2009) reported that respondents took longer time in an ACBC than the corresponding CBC but reported that respondents found the ACBC less boring. The increased engagement in the survey may lead to more accurate consumer responses (Orme 2010; Cunningham *et al*. 2010).

Overall utility scores for both conjoint methods are presented in Figure 3. Overall, both the ACBC and CBC revealed the same trends in utility scores for all attributes with minor differences. The ACBC utility scores were lower for Wal-Mart as a brand of sour cream compared to all other brands ($P<0.05$). The CBC utility scores for Wal-Mart and Darigold (an unknown brand to NC consumers) were at parity. The ACBC utility scores for light/lite and low fat were not different ($p>0.05$), but they were separated in the CBC ($P>0.05$). Eight ounce containers were the least preferred container size by CBC results, while 8oz and 24oz containers were similar in the ACBC as the least preferred. In demographic questions asked previously to the CBC/ACBC sections, consumers responded to what container size they purchased the most often (Table 3). Eight ounce containers were the most popular followed by 16oz containers. The disagreement between the direct responses and both conjoint methods suggest that there is another reason why consumers buy 8oz containers but prefer 16oz containers, possibly a function of price or intended use of the

sour cream (dip, ingredient, etc) (Table 3). Zeithaml (1988) described price from the consumer perspective as a "give" component of the purchasing experience rather than a "get". In the conjoint survey, price was presented and considered, however there was no actual threat of a real purchase therefore it is possible consumers show their true preferences for the product itself in the conjoint, but in the grocery stores price becomes more important. All natural and organic were label claims of equal significance in the CBC, all natural was the most preferred in the ACBC. All natural as a label claim is very attractive to consumers and has been previously demonstrated to have value by conjoint analysis (Jervis *et al*. 2012). Price had the same separation in the CBC as in the ACBC ($P < 0.05$). Given the disparity in number of consumer responses (250 versus 777), the ACBC and full CBC were in agreement overall in the separation of utility scores.

A random sample of 250 respondents from the full CBC survey were selected and re-analyzed to directly compare to ACBC survey results when the sample sizes were equal. The sub-sampled CBC survey results (n=250) were in agreement with the full CBC survey results (n=777) with the exception that fat free utility scores were lower compared to the other levels of fat content than either the full CBC or the ACBC reported ($P<0.05$). Regression analysis of the utility scores for the CBC at both sample sizes had an R-squared of 0.99. This result suggests that the CBC became relatively stable in estimation of utility scores after a few hundred respondents. The ACBC with the full CBC utility scores had an R-squared of 0.96 and 0.94 for the sampled CBC. The results of the ACBC survey were more consistent with the full CBC survey results for estimating importance values compared to the sub-sampled CBC survey with the full CBC survey (Figure 4). From all surveys, fat content was the most

important attribute followed by price. The sub-sampled CBC survey overestimated the importance of brand and had it equivalent to price. The full CBC and ACBC surveys showed brand to be less important than price ($P<0.05$) (Figure 5).

LSA revealed similar trends among the ACBC and sampled CBC surveys (See Supplementary Figures in the Journal of Sensory Studies). Both survey techniques demonstrated that fat content and container size were the most differentiating attributes when price was removed. The CBC survey differentiated the products to a greater extent than the ACBC survey for fat content and container size as evidenced by the products overlaying the high density consumer segments to a greater degree in the CBC survey (See Supplementary Figures in the Journal of Sensory Studies). Neither method differentiated the products well based upon brand or label claim however the CBC survey overlaps high density areas to a greater degree than the ACBC survey (See Supplementary Figures in the Journal of Sensory Studies). Respondents are placed on the LSA map in close proximity based upon affinity for like products with large relative utility. These areas are considered high density areas.

A major benefit of an ACBC over a CBC survey is the added information of the BYO, must have, unacceptable, and tournament winner section which aid in understanding respondent choices to the product concepts. The information gained from an ACBC survey due to the design is presented in Table 4. The "winners" of the BYO for brand were Daisy and Breakstone followed by Horizon Organic; Kroger and Wal-Mart are store brands with only 8.0 and 8.8% of the vote (respectively). Darigold had the lowest response and this is likely due to brand unfamiliarity. Darigold is a regional brand located in the Northwest and would be unknown to North Carolina consumers. The top choice of fat content ranged across

levels in the BYO section. Smaller container sizes, 8oz and 16oz, were chosen over 24oz containers. Regular sour cream was also chosen over all natural and organic. Price was not included in the BYO section as it is unrealistic for respondents to be able to choose the price of their ideal product.

The standard deviation of the utility scores for each level was calculated and compared (Figure 4). Smaller standard deviations were noted for brand from the ACBC survey compared to either CBC survey with the exception of Wal-Mart. Analysis of the BYO demonstrated that Wal-Mart was chosen as "unacceptable" by 14.0% of the respondents (Table 4). Wal-Mart was removed from the rest of the dataset for the utility estimates for those respondents. The removal of this level would increase the standard deviation of the remaining utility scores as the standard deviation was calculated for the entire population. Overall for brand there is less individual-level consumer heterogeneity in the ACBC. Allenby et al. (2005) suggested that heterogeneity in individual-level preferences may impact the accuracy of parameter estimates of conjoint models. It is possible that ACBC may be a better predictor of brand preferences, however access to actual market data for sour cream preferences by brand would be necessary in order to compare to the prediction of brand choices from ACBC and CBC designs using market simulators. It is interesting to note that when consumers were asked directly if brand was important for sour cream selection, over 70% of respondents in both surveys indicated brand was not important however both conjoint methods showed the name brands of Breakstone and Daisy to have higher utility than all other brands (Table 3; Figure 3). Ewald and Moskowitz (2007) established the concept of brand as a "mental construct that helps to establish a frame of

reference that drives choice." Behaviors towards a brand are developed from habits associated with that brand (Farquhar 1989). There is also price and quality meaning of a brand that factor into purchase behavior (Ewald and Moskowitz 2007). Underlying subconscious associations with familiar brands may be responsible for the difference in brand association measured by direct questioning and the ACBC results, but this was not the focus of this study.

Full fat and fat free also had high percentages of respondents who marked them as unacceptable, (Table 4), and the corresponding standard deviations were also high (Figure 4). One may conclude that ACBC was a better estimator of these levels as well, however closer examination of the BYO results was necessary to fully understand how these attributes were evaluated by the respondents. The BYO results indicated that 29.2% of the population chose full fat in their ideal product and only 14.0% chose fat free (Table 4). Also, 22.4% of respondents marked full fat as "unacceptable." This indicates the levels of full fat and fat free are polarizing for a group of the respondents. Some respondents must have full fat or fat free, and some find full fat or fat free unacceptable. This was also evidenced by cluster analysis of respondents (Figures 1, 2). Segment 1 was characterized by full fat sour cream consumers whereas segment 2 was characterized by lower fat consumers. This result was the case in both the CBC and ACBC surveys. This dichotomy and high removal rate, accounts for the high standard deviation in the ACBC for fat content. The standard deviations of the full and subsampled CBC were also high for these two levels, indicating that these levels were indeed polarizing for respondents and not something observed solely in the ACBC. Because the standard deviations of the ACBC and CBC were similar for fat content, it cannot

be concluded that the ACBC is a better technique for estimating this attribute. What can be concluded is that fat levels in sour cream were polarizing for consumers and both methods captured this concept similarly. The other anomaly in standard deviation occurred with price, specifically $3.25 and $3.75 which were the highest two levels. In Table 4, these levels were considered unacceptable by 26.8% and 34.4% of the population respectively. The high standard deviation of the ACBC for these levels suggested that it was due to so many respondents removing those levels from the ACBC in the unacceptable section, similar to Wal-Mart, Full Fat, and Fat Free. The standard deviation for these levels of price was lower for the CBC but still high overall for that attribute. Because the standard deviations for these levels was higher, and the large number of respondents marking them as unacceptable; the ACBC yielded a better estimate of how price was viewed, at least on the high end, by the respondents. This result was consistent with the results by Chapman *et al*. (2009) who also concluded that ACBC was a better estimator of price for computer accessories. It is interesting to note that the middle range of price had the smallest standard deviations suggesting price in this range is not a strong driver of choice but a low price or a high price for sour cream are strong drivers (Table 4). Certain price categories may be acceptable to consumers for a top name brand but would be unacceptable for unfamiliar or generic labels and vice versa. Zeithaml (1988) described the consumer perspective of price as what is given up or sacrificed to obtain a product. Consumers do not always know or remember actual prices of products but instead encode prices in ways that are meaningful to them.

Closer examination of the BYO section and the actual utility estimates from the ACBC survey revealed what attributes were negotiable in the final chosen product.

Examination of the CBC survey utility estimates alone was insufficient for making the same conclusions. Regular as a label claim was chosen by 53.6% of respondents in the BYO section (Table 4). Overall, label claim was the least important attribute (Figure 5). Childs and Drake (2009) reported that a label claim for cheese was not as important as the texture and flavor of the product. When consumers get to choose, (as in the BYO), the majority chose regular sour cream as a part of the total product, but when given the choice of a select group of products each with attractive features, respondents were willing to sacrifice label claim to get the other more important features, such as fat content or price. The tournament winner section demonstrated that 54.4% of products with $1.25 won the selection, meaning if a product had a price point of $1.25, it was likely to be selected by a respondent over another product. It is understandable that consumers when faced with similar products differing by price will chose the least expensive product. And with price being of key importance (Figure 5), respondents may choose products solely or influenced greatly by price (Zeithaml 1988). The key take from this result is not that consumers prefer lower prices, but that overall an ACBC survey estimated how the importance of specific price point better than a CBC survey.

CONCLUSIONS

Choice based conjoint and adaptive choice based conjoint were both useful techniques in determining consumer preferences for different features of a product. The strengths of each technique should be considered before choosing a method for an intended purpose. ACBC conjoint analysis may be a better technique for estimating perception of brand for sour cream than traditional CBC conjoint analysis. ACBC surveys can be used

with smaller samples sizes as an alternative to larger CBC survey designs. ACBC surveys may also be a better estimator of price than larger CBC surveys. CBC differentiated sour cream products to a greater extent than ACBC based upon select features of the product when considering the same sample size and price is not considered. Access to market data coupled with market simulators of the ACBC and CBC data would be beneficial to confirm brand and price selection in the actual market.

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TABLE 1
ATTRIBUTES AND LEVELS FOR CONJOINT ANALYSIS

Attribute	**Level**
Brand	Daisy (National Brand)
	Kroger (Store Brand)
	Wal-Mart (National Brand)
	Breakstone (National Brand)
	Organic Valley (Organic Brand, sold in NC)
	Darigold (Regional Brand, not sold in NC)
Fat Content	Full Fat
	Reduced Fat
	Light/Lite
	Low Fat
	Fat Free
Container Size	8oz
	16oz
	24oz
Label Claim	Regular
	All Natural
	Organic
Price	$1.25
	$1.75
	$2.25
	$2.75
	$3.25
	$3.75

TABLE 2
DEMOGRAPHIC INFORMATION FOR CHOICE BASED AND ADAPTIVE CHOICE BASED CONJOINTS

		CBC n = 777 %	ACBC n = 250 %
Male		23.6	22.8
Female		76.4	77.2
Under 18 years old		0.0	0
18 - 24 years old		15.4	12.8
25 - 29 years old		12.9	12.4
30 - 34 years old		14.2	13.6
35 - 39 years old		9.0	13.2
40 - 44 years old		10.3	8
45 - 49 years old		11.1	6.4
50 - 54 years old		10.7	12.4
55 - 59 years old		8.8	9.6
60 - 64 years old		4.9	6
65 - 69 years old		1.5	3.6
70 years old and older		1.3	2
How often do you consume sour cream	Two or more times per week	21.6	25.6
	Once per week	37.1	33.2
	At least once per month	41.3	41.2
	At least once in the last 3 months	0	0
	At least once in the last 6 months	0	0
	I rarely/never consume sour cream	0	0
What is your involvement with the grocery shopping for your household?	I do all of the grocery shopping	67.3	66
	I do most of the grocery shopping	25.7	28
	I do some of the grocery shopping	6.9	6
	I do none of the grocery shopping	0	0
What is your ethnicity?	American Indian or Alaska Native	0.6	0.8
	Asian	4.4	2.8
	Black or African American	15.7	22
	Hispanic	2.3	1.6
	Latino	0.8	1.2
	Native Hawaiian or other Pacific Islander	0.4	0
	White	77.3	72.4
	Other	0.1	0.8
What is your household income?	Under $20,000 per year	10.6	10
	$20,000 - $34,999 per year	11.6	11.6
	$35,000 - $49,999 per year	18.9	16.4
	$50,000 - $64,999 per year	13.9	16.8
	$65,000 - $79,999 per year	15.8	15.2
	$80,000 - $94,000 per year	11.8	11.2
	More than $95,000 per year	17.4	18.8

TABLE 3
CONSUMER PURCHASE AND SOUR CREAM CONSUMPTION BEHAVIOR RESPONSES

		CBC n = 777	ACBC n = 250
When you purchase sour cream, what size container do you usually purchase?	8oz	41.2	13.0
	16oz	56.8	17.6
	24oz	2.1	1.5
On a typical day, how often would you find sour cream in your refrigerator at home?	Almost always	44.1	12.0
	Most of the time	32.7	13.1
	Sometimes	21.0	6.4
	Very rarely	2.2	0.5
	Never	0.0	0.1
*How often do you use sour cream in the following ways?	As a dip	2.2	2.3
	As a topping	2.8	2.7
	As an ingredient in a main dish	2.4	2.3
	For making a special dish for a party	2.1	2.1
*How important is brand name to you for each of the following product types?	Cereal	2.8	2.6
	Dairy products	2.5	2.5
	Apparel	2.4	3.0
	Skin care	3.0	3.0
	Personal care	2.4	3.0
	Jewelry	3.0	3.0
	Non-alcoholic beverages	2.9	2.0
	Milk	1.9	2.9
	Cured meat	2.6	2.2
	Pasta	2.2	2.6
	Bread	2.6	2.1
	Household cleaners	2.0	2.5
	Detergent	2.4	2.6
How important is it that your sour cream be a brand name as opposed to a generic brand?	Not important	43.2	45.2
	Somewhat important	37.1	30.0
	Important	11.7	14.4
	Very important	6.2	6.8
	Extremely important	1.8	3.6

-Questions marked with an asterisk are presented as overall means; all other questions represent the percentage of respondents that selected those options.
-How often was scored on a 5pt scale where 1 = do not use it this way, 2 = every other week or less, 3 = once a week, 4 = 2-3 times per week, and 5 = more than 3 times per week.
-"How important is brand name?" was scored using a 5pt scale where 1=not important, 2=somewhat important, 3= important, 4 = very important, and 5 = extremely important

TABLE 4

PERCENTAGE OF RESPONDENTS SELECTING EACH OPTION IN THE BUILD YOUR OWN SEQUENCE, MUST HAVES, UNACCEPTABLES, AND APPEARANCE IN THE TOURNAMENT WINNER SELECTION

	Build Your Own	Must Haves	Unacceptables	"Winner" of Tournament Section
Daisy	39.6	0.0	0.0	23.6
Kroger	8.8	0.0	4.8	11.6
Wal-Mart	8.0	0.0	14.0	10.8
Breakstone	30.0	0.0	0.8	24.8
Horizon Organic	13.2	0.0	2.8	22.8
Darigold	0.4	0.0	6.4	6.4
Full Fat	29.2	4.0	22.4	28.4
Reduced Fat	26.4	0.0	5.2	19.6
Light/Lite	10.0	0.0	8.8	14.8
Low Fat	20.4	0.0	8.0	18.8
Fat Free	14.0	0.0	23.2	18.4
8oz	40.0	2.4	3.6	26.4
16oz	54.4	0.8	2.4	55.2
24oz	5.6	0.0	17.2	18.4
Regular	53.6	0.0	1.6	25.6
All Natural	28.4	0.0	0.0	36.0
Organic	18.0	0.0	0.4	38.4
$1.25	NA	0.4	0.8	54.4
$1.75	NA	0.0	1.2	14.4
$2.25	NA	0.0	3.2	6.8
$2.75	NA	0.0	8.0	16.4
$3.25	NA	0.0	26.8	5.2
$3.75	NA	0.0	34.4	2.8

FIGURE 1

PRINCIPAL COMPONENT BIPLOT OF CONSUMER RESPONDENT CLUSTERS FROM CHOICE BASED CONJOINT SURVEY (N=777)

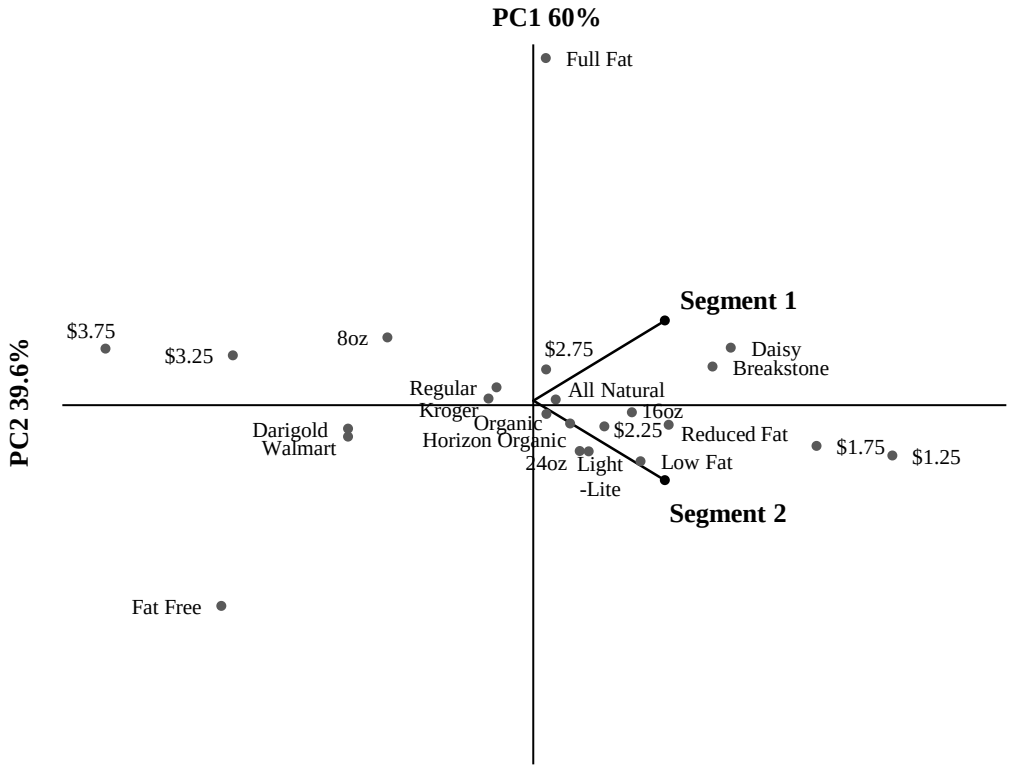

FIGURE 2

PRINCIPAL COMPONENT BIPLOT OF CONSUMER RESPONDENT CLUSTERS FROM ADAPTIVE CHOICE BASED CONJOINT SURVEY WITH ATTRIBUTES AND LEVELS (N=250)

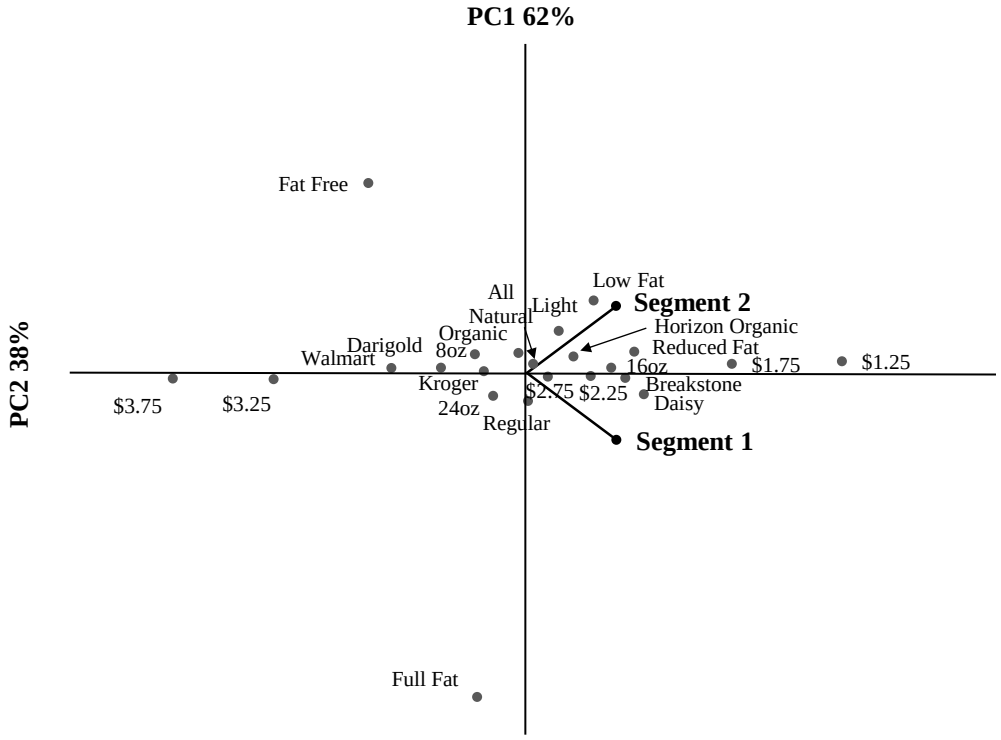

FIGURE 3

ZERO CENTERED AVERAGE UTILITY VALUES FOR ADAPTIVE CHOICE BASED CONJOINT (N=250), CHOICE BASED CONJOINT (N=777), AND CHOICE BASED CONJOINT (N=250)

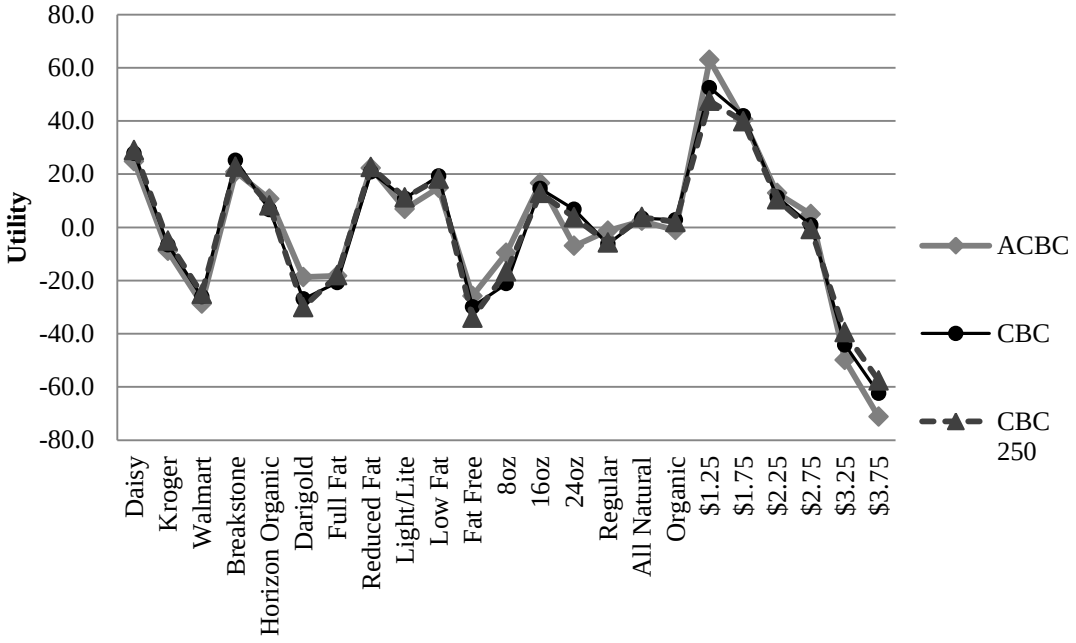

FIGURE 4

AVERAGE STANDARD DEVIATION OF ZERO CENTERED DIFFERENCE UTILITY VALUES FOR ADAPTIVE CHOICE BASED CONJOINT (N=250), CHOICE BASED CONJOINT (N=777), AND CHOICE BASED CONJOINT (N=250)

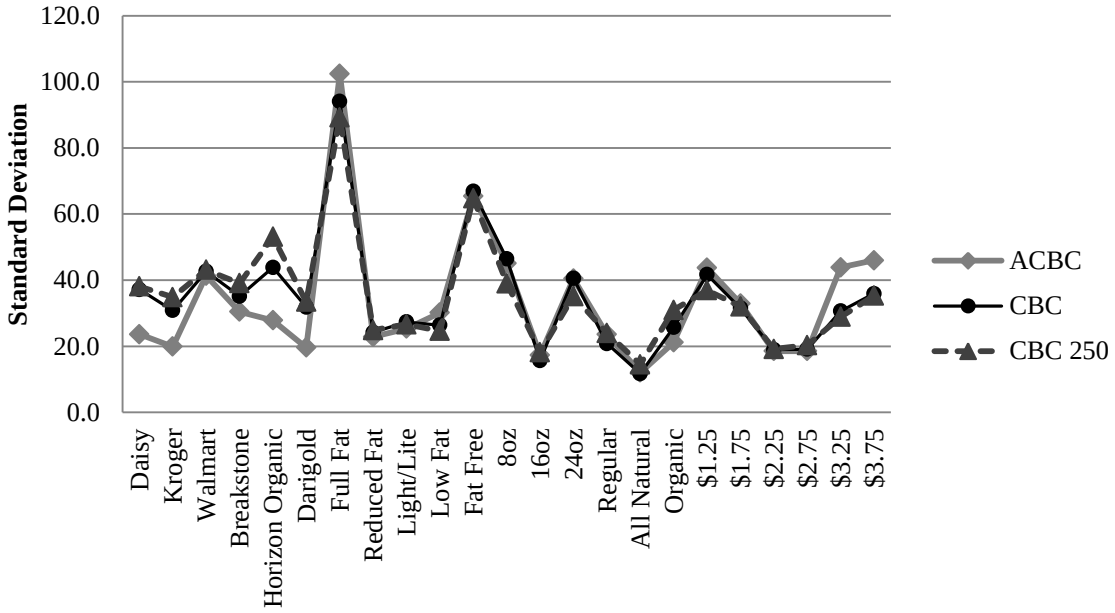

FIGURE 5

OVERALL IMPORTANCE VALUES FOR EACH CONJOINT-TYPE. DIFFERENT LETTERS WITHIN A SURVEY-TYPE ARE SIGNIFICANTLY DIFFERENT (P<0.05)