

## **ABSTRACT**

HARWOOD, WILLIAM SPENCER. Survey-Based Valuation and Temporal Evaluation Methods Applied to Commercial Beverages. (Under the direction of Dr. MaryAnne Drake).

Commercial beverages may be used to satisfy functional consumer needs, as is the case with products such as fluid milk or protein beverages. However, the landscape of commercial beverage offerings also extends to products that are less functional, and instead enjoyed for nuanced flavor profiles, as is the case for beverages such as wine or aged spirits. Investigation into the features of functional beverages consumers value, as well as the nuanced flavors of beverages consumed for enjoyment, is important for guiding product development and meeting consumer needs effectively.

In the first study, consumer perceptions and preferences for fluid milk products were assessed using an adaptive choice-based conjoint (ACBC) survey, as well as other survey-based techniques. The purpose of this study was to identify and understand fluid milk consumer subgroups in terms of the product features they felt most motivating for purchase decisions. Overall, 1163 fluid milk consumers completed the study and four consumer subgroups were identified. For the overall population, the ideal fluid milk product was 2% milkfat, organic, packaged in a plastic jug, conventionally pasteurized, and free from additives or label claims. Of the 1163 total consumers, there were 434 who self-identified as organic dairy users. Organic users were directed to a Maximum Difference (MaxDiff) scaling exercise to understand the primary reasons they chose to consume organic dairy. The belief that organic milk was “healthier” was the leading belief motivating organic dairy purchase, however, “support for local farmers,” “ethical treatment of animals,” and “sustainability” also played a large role in motivating organic purchase. Insights into what specific fluid milk consumer groups value may act as an industry guidance for future product offerings and marketing initiatives.

In the second study, two survey methodologies were administered to the same group of respondents (n=457) to understand the implicit and explicit drivers of preference for commercial protein products. To understand implicit desires, an ACBC survey was conducted, and to investigate explicit desires, a Constant Sum (CS) survey was used. Overall, both surveys agreed on the ideal product build- a chocolate-flavored protein bar with 20-29g of whey protein, all-natural, and sweetened naturally with stevia as the primary sweetener. When compared, the two techniques agreed on the scaling of within-attribute levels, suggesting that consumers are aware of the product details they implicitly prefer. However, significant differences were noted in how consumers assigned importance to the different attribute categories, suggesting that respondents were poor at evaluating the weight certain features ultimately hold in their purchase decisions. Exploring the implicit and explicit desires of protein product consumers can help to address marketing concerns and may highlight areas where consumers would benefit from enhanced education. In a product category where consumer needs and desires are especially diverse, as is the case in the protein product category, understanding these product features from an implicit and explicit consumer perspective is very useful.

In the third study, the temporal flavor profiles of aged rums were evaluated to better understand the role that ethanol concentration plays on the temporal experience of consumption. Trained panelists (n=8) profiled seven commercial rum samples, each at 10%, 20%, 30% and 40% alcohol-by-volume (ABV) dilutions. Evaluations within each ethanol concentration were aggregated so that differences due to ethanol concentration could be identified. Results showed that flavors such as caramel, banana, cherry/almond, cooked apple, and vanilla had detection frequencies at 30% ABV that were the same as those found at 40% ABV (undiluted commercial product). In addition, several significant differences in detection frequency and temporality were

noted between 20% ABV and 40% ABV evaluations. These results suggest that the industry standard of 20% ABV evaluations for descriptive profiling of high-ABV spirits may not be adequate for profiling purposes, although a slight dilution with water may help to enhance the consumer experience as it pertains to temporal flavor profiles of aged rum products.

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Survey-Based Valuation and Temporal Evaluation Methods Applied to Commercial Beverages

by  
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## **BIOGRAPHY**

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**CHAPTER 1:**

**LITERATURE REVIEW. SURVEY-BASED VALUATION AND  
TEMPORAL EVALUATION METHODS APPLIED TO COMMERCIAL  
BEVERAGES**

## **INTRODUCTION**

Understanding sensory qualities, consumer preferences, and consumer beliefs regarding food and beverage products are, at their core, a study of individual evaluations to understand the general partialities of a target population. Administering individual evaluations to garner these insights has traditionally been an expensive and time-consuming process depending on sample size and test complexity; however, advances in computer-based technologies now allow researchers to design and administer complex evaluation techniques on a large scale with a diminished time and finance requirements. This literature review will explain existing sensory analysis methods, and will also review emerging online survey methods and temporal product evaluation methodologies that could conceivably apply to beverage evaluations. In particular, fluid milk, protein beverages, and hard liquor will be products considered for method application in this review due to their varying features and complexities.

## **FLUID MILK AND DAIRY BEVERAGES**

The necessity for understanding the sensory qualities of milk is due, in part, to the widespread familiarity of fluid milk and its typical sensory profile. Sensory evaluation is critical for every application and stage of milk production. Sensory evaluation of the flavor, or at least the aroma of raw milk, can identify handling or production problems before milk is processed. Additionally, during processing and preparation of commercial milk products, fluid milk may be exposed to multiple unit operations at varying temperatures. In turn, sensory evaluation of the finished milk product helps to identify deviations in processing or handling. In many cases, deviations in quality may not be significant day-to-day changes, but rather a drift over time, which require frequent sensory evaluation and strong documentation of evaluations to successfully address areas of concern.

### ***Milk Constituents Relating to Sensory Quality and Acceptance***

The sensory perception of fluid milk is heavily influenced by the balance of its macronutrient components. Milk fat plays a critical role in the sensory perception of fluid milk. Milk fat is preferred by all consumer segments at varying levels, and is considered to be a contributor to creaminess, which is positively correlated with product liking (Richardson-Harman et al., 2000; McCarthy et al., 2017a). However, many consumers purchase skim or reduced-fat milk due to health reasons despite a preference for whole milk, and 2% reduced-fat milk has outsold whole milk every month since January 2005 (Bakke et al., 2016; Economic Research Service, 2014).

Visual, texture, and flavor attributes of milk are all influenced by milk fat (Phillips et al., 1995a; McCarthy et al., 2017a). Descriptive sensory analysis of fluid milks of varying fat percentages demonstrated that opacity, thickness, mouthcoating, viscosity, milk fat flavor, and yellow color increased with fat content (Phillips et al., 1995a; Francis et al., 2005; McCarthy et al., 2017a). Nonfat milk was described as chalkier, less viscous, less sweet, and higher in sour aromatic flavor than whole milk (Francis et al., 2005). When milks were tasted without visual cues, panelists were not able to perceive fat-related texture differences as clearly (Phillips et al., 1995a, McCarthy et al., 2017a). Fortifying milk with nonfat dry milk powder increased the viscosity and mouthcoating of reduced fat milks, but did not increase the visual whiteness and opacity (Phillips et al., 1995b). While texture may play a role in differentiation of milk products at very high fat levels, research suggests that visual cues are most important for determination of fat content at lower fat levels typically encountered by consumers (0-4% fat) (Mela, 1988; Pangborn and Dunkley, 1964a; Pangborn and Dunkley, 1964b; Pangborn and Giovanni, 1984; Pangborn et al., 1985; Phillips et al., 1995b; McCarthy et al., 2017a).

Visual and texture cues may account for much of consumer ability to distinguish between fat contents of milk, but research has also demonstrated that milk fat contributes to flavor (McCarthy et al., 2017a). Milk fat is composed of 98% 26-54 carbon triglycerides, with volatile lactones, ketones, and aldehydes composing the last 2% and contributing most of the flavor (Schaap and Badings, 1990). Creaminess, a desirable consumer attribute for dairy products, including milk, is defined by high fat dairy products with cream aroma, butter aroma, and sweet aromatic/vanilla flavor, indicating that desirable flavor attributes are closely associated with fat content and that fat contributes aromatics, as well as mouthfeel attributes (Richardson-Harman et al., 2000). This association is also observed in dairy products such as sour cream, with full-fat products generally exhibiting higher acceptance scores for overall liking and perception of creaminess (Jervis et al., 2014b). In assessments of fluid milk, consumers rated 1% fat milks thicker and creamier after the addition of vanilla extract (Lawless and Clark, 1992). Milk fat has been reported to improve the aftertaste of milk, which is associated with increased consumer liking as unpleasant aftertaste is a driver of dislike for fluid skim milk (Porubcan and Vickers, 2005; McCarthy et al., 2017a). Higher fat milks had more sweet-related attributes in the aftertaste compared to lower fat milks, as well as fewer cooked flavors (Francis et al., 2005). Tepper and Kuang (1996) used multidimensional scaling techniques to evaluate the effect of addition of natural cream flavor to a skim milk base with fat added as bland vegetable oil, and also reported that the addition of cream flavor provided the sensation of higher fat content. McCarthy et al. (2017a) conducted qualitative interviews with milk consumers. Both skim and 2% fat milk drinkers reported 2% fat milk to be creamier and to have a fuller flavor. In contrast, skim milk was described as watery and having a high aftertaste intensity by these higher fat milk consumers. In general, milk consumers preferred a slightly higher percentage of milk fat than the

milk fat percentage they typically bought, but began to dislike the higher fat milk when the thickness increased too far past that of their typically purchased milk.

Protein also contributes to the flavor of fluid milk. Protein content of fluid milk can be adjusted by using the ultrafiltered permeate and retentate of skim milk. Ultrafiltration separates milk components due to molecular size, with lactose, soluble minerals, and water passing through a membrane to become the permeate while larger sized particles such as casein and whey protein cannot pass through and become the retentate (Yan et al., 1979). Today, ultrafiltration can be used to increase the protein content while decreasing the lactose content of milk products, resulting in dairy beverages which appeal to consumer health concerns without added ingredients. Other types of membrane fractionation such as microfiltration, nanofiltration, and reverse osmosis have been used to fractionate bacteria and spores, somatic cells, proteins, salts, and water in milk (Brans et al., 2004). Adjusting the levels of milk components can have huge effects on the overall flavor of milk and significantly impact consumer liking. As use of these filtration technologies has expanded, so has research on the sensory qualities of filtered fluid milk. The sensory qualities of adjusted protein levels is of particular interest due to growing consumer demand for higher-protein dairy products (Özer and Kirmaci, 2010).

Early research on ultrafiltered fluid milk evaluated the effects of protein content on sensory attributes of milk. Poulsen (1978) noted that fat was standardized for fluid milk products and investigated the feasibility of standardizing fluid milk protein content through ultrafiltration. He found that varying the protein content between 3.1 and 6.4% resulted in no significant sensory differences and that texture and surface gloss alterations were more likely to be impacted than flavor. When protein content was altered using reverse osmosis, the solids not fat content also changed, resulting in significant sensory differences (lower solids not fat samples were

perceived as watery). The author's primary concern, however, was to investigate the feasibility of protein standardization, not its impact on sensory qualities of the milk (Poulsen, 1978). Later studies investigated the effects of altering protein levels on physical properties of fluid milk such as freezing point. Sensory differences between samples were minimal and were primarily driven by visual attributes rather than flavor (Rattray and Jelen, 1996; Quiñones et al., 1997; Quiñones et al., 1998). The vast majority of research on ultrafiltration of milk over the past 50 years has evaluated the resulting effects on milk as an ingredient for other dairy products, such as cheese and yogurt, or investigated technical aspects of milk filtration (Méthot-Hains et al., 2016; Kapsimalis and Zall, 1981; Yan et al., 1979; Covacevich and Kosikowski, 1978; Trachoo and Mistry, 1998). The sensory properties and consumer acceptance of ultrafiltered milk have not been widely documented.

Increased availability of cheaper advanced filtration systems has renewed interest in studies of filtered fluid milk. Recent studies used sophisticated filtration methods to investigate differences in the type of protein in fluid milk and protein beverage products. Misawa et al. (2016) reported that increasing the level of casein as a percentage of true protein in reduced-fat milk had more effects on visual sensory attributes than increasing the percentage of true protein in the milk. Trained panelists detected increased mouthcoating and throat cling in increased casein 2% fat milks even when visual attributes of the samples were masked. As the popularity of protein-enriched products increases and individual protein components of milk increase in value, it is likely that research investigating the sensory changes that result from changing protein levels in milk will increase.

Lactose is the primary carbohydrate component of fluid milk. It is estimated that 25% of U.S. adults, and up to 70% of the world's population are lactose intolerant, creating a large

potential market for commercial lactose-free dairy products (Harrington and Mayberry, 2008; Adhikari et al., 2010). Lactose-hydrolyzed milk products became commercially available in the 1960s and 70s. Enzymatic hydrolysis of lactose via addition of lactase is the process by which lactose reduction is traditionally achieved and has been shown to produce milk with less than 0.01% lactose in modern applications (Jelen and Tossavanien, 2003). Lactose hydrolysis results in a milk that is sweeter than traditional milk since glucose and galactose are sweeter than lactose (Li et al., 2015). In an early study on lactose-hydrolyzed milk, Paige et al. (1975) reported this increased sweet taste, as well as increased staleness and sourness. The authors' main focus, however, was evaluating differences in blood sugar increase and lactose malabsorption when lactose-intolerant panelists consumed lactose-hydrolyzed milk as opposed to regular milk, rather than a specific focus on sensory properties (Paige et al., 1975). The consumers compared the lactose-hydrolyzed milk to fresh whole cow's milk using a 7-point scale in which they could specify only a single attribute in which the lactose-hydrolyzed milk differed from the fresh whole milk. The type of pasteurization used was not specified. The sensory methods used in this study were not validated or repeatable, thus weakening the sensory conclusions of the study. In a more recent study using trained descriptive analysis panelists, Chapman et al. (2001) reported that the increased sweetness of lactose-free milks could be causing a halo effect resulting in a perceived increase in viscosity. In the U.S. today, lactose-free milks are typically ultrapasteurized (UP), resulting in more cooked and sulfurous flavors than traditional HTST milk, which is a confounding factor when comparing the sensory attributes of regular (HTST) and (UP) lactose-free milks (Adhikari et al., 2010). Compared to HTST milks, UP lactose free milks have higher intensities of chalky texture, lack of freshness, light oxidized flavor, and processed flavor, all of which are perceived as negative attributes by consumers (Adhikari et al., 2010). However, these

differences are not necessarily due to lactose hydrolysis, and may be due to the UP pasteurization process, packaging/storage, or a combination of all of these factors (Antunes et al., 2014). There are no recent published studies evaluating the impact of lactose hydrolysis, as an isolated component, on the sensory profile of milk.

### ***Fluid Milk Processing***

Before fluid milk ever reaches the consumer, it is subjected to multiple processing steps to ensure consumer safety and quality standardization. Contact with any surface in processing can noticeably affect flavor of fluid milk, but areas of chief importance in fluid milk processing, in sequential order, are milk fat separation, fat content standardization, pasteurization, homogenization, and packaging (Goff and Griffiths, 2006).

Pasteurization, named for French microbiologist Louis Pasteur, refers to the heating of food or beverage products to kill microbes that would otherwise jeopardize safety or shelf-life. Following government mandates for pasteurization of the U.S. milk supply in the early 1900s, the process of pasteurization has played a large role in dictating the flavor profile of fluid milk. There are a variety of acceptable pasteurization methods for achieving legally pasteurized milk, but those methods are generally separated into the following three groups: Vat Pasteurization, High Temperature Short Time (HTST), and Ultrapasteurization (UP)/ Ultra-High-Temperature (UHT).

Vat Pasteurization is defined under the Pasteurized Milk Ordinance (PMO) (FDA, 2015) as the heat treatment of milk at a minimum of 63°C (145°F) for a minimum hold time of 30 minutes. Vat pasteurization is no longer a major method of commercial pasteurization; however, it is often used by smaller family farms. The minimal heat load of vat pasteurization has been

described as having a notably lower cooked flavor compared to other pasteurization methods (Claeys et al., 2013).

HTST is a continuous flow method of milk pasteurization and is defined under the PMO as the heat treatment of milk at a minimum of 72°C (161°F) for a minimum hold time of 15 seconds, although treatments up to 100°C also meet HTST standards. In experiments comparing different pasteurization temperatures, Gandy et al. (2008) reported that increased cooked flavors in fluid milk due to increased HTST temperatures were associated with a marked decrease in overall consumer liking; however, HTST pasteurization is widely regarded as the most common pasteurization method of milk in the U.S., the flavor of HTST milk is widely accepted, and deviations are generally disliked by U.S. consumers.

Ultrapasteurization is defined under the PMO as the heat treatment of milk at a minimum of 138°C (280°F) for at least two seconds, resulting in a product with extended shelf life. Similarly, UHT pasteurization meets the same thermal standards of UP, with the added features of aseptic transfer and packaging systems post-pasteurization, resulting in a product that is commercially sterile and shelf stable (Burton, 1977; Boor and Murphy, 2002). The flavor of UP and shelf stable milks are typically differentiated from traditional HTST milk by higher cooked, sulfur/eggy and caramelized flavors, lingering aftertaste, stale flavor, and higher viscosity (Lee et al., 2017; Chapman et al., 2001; Clare et al., 2005; Valero et al., 2001; Andersson and Oste, 1995). Blake et al. (1995) reported that the increased cooked and caramelized character of direct steam and indirect plate-exchanged UHT whole milk treatments were generally undesirable to American consumers. Furthermore, subsequent studies by Valero et al. (2001) reported that the extent to which these off flavors were perceived was higher in skim milk compared to reduced-fat milks. In consumer acceptance testing of American children, Chapman and Boor (2001)

reported that traditional HTST milk was significantly preferred over UP and UHT milk. Suggested explanations for the observed preference of HTST milk over UP milk included greater familiarity with HTST milk flavor and the creation of off flavors in the UP process (Chapman and Boor, 2001; Valero et al., 2001). In a recent series of consumer tests (children and adults) comparing HTST skim and 2% fat milks to direct steam and indirect UP milks, Lee et al. (2017) reported that UP milk treatments received significant penalties to overall liking due to having “too much flavor,” and for being “too thick.” Adult U.S. consumers and children still preferred HTST milk over UP milk. In addition, UP milks had significantly higher sulfur/eggy flavors, suggesting that the intensity of cooked flavors in UP milks are likely influential detractors from consumer acceptance.

Besides flavor, a significant point of difference between HTST and UP processed milks is the viscosity or thickness. Chapman et al. (2001) used a trained panel to determine that viscosity of nonfat UP milks was approximately the same as for 1% fat HTST milks. Lee et al. (2017) confirmed this observation, suggesting the differences in viscosity could be due to denaturation of proteins induced after UP pasteurization. Other studies suggest that these results bode well for UP milks in regard to consumer approval because milk consumers prefer the viscosity or thickness of 2% fat milks to those with lower or no fat content, even if the consumers typically drink skim milk (Pangborn et al., 1985; McCarthy et al., 2017a).

### ***Packaging***

Though the use of packaging materials for the final milk product is intended to retard the onset of off-flavors (such as light oxidation) in fluid milk, there are some flavor considerations relating to packaging sensory effects. Due to the direct contact of packaging surface and the fluid milk, there is reasonable likelihood that flavor components from packaging materials may be

transferred to the milk. The oxygen permeability of selected packaging material can present itself as a limiting factor of milk quality over shelf life (Gilbert, 1985). Fluid milk is most commonly packaged in translucent high density polyethylene (HDPE) jugs, although polyethylene-coated paperboard cartons are also extensively used (Potts et al., 2016). In experiments on the sensory effects of polyethylene-coated paperboard cartons, Leong et al. (1992) reported that noticeable packaging flavors were imparted to test milks within one day of filling when analyzed by a trained panel. HDPE containers present minimal risk of flavor leaching; however, several studies have reported that HDPE packages are related to higher risk of light oxidation than other light-shielded package types (Cladman et al., 1998; van Aardt et al., 2001; Amin et al., 2016). Evaluation of packaging modifications by Johnson et al. (2015) suggested that HDPE packaging with greater than 1.3% titanium dioxide was effective in diminishing the light oxidation risk of HDPE packaging.

The role of packaging materials in fluid milk consumption must also be considered from an extrinsic perspective. HDPE jugs have existed as the most popular packaging option in the United States since the 1980's (AMS, 2013), largely due to price and availability; however, evidence of an increasing trend toward sustainability and environmental concern warrants the need for understanding consumer packaging sentiments (Kearney, 2010; Falguera et al., 2012). Outside of brand influence, the perceived value of packaging materials for fluid milk and other similar beverages has not been studied extensively in the modern market. In focus groups of milk consumers in Northern Ireland, Hollywood et al. (2013) reported consumers generally had a positive association with plastic containers due to perceived durability and leak protection. In addition, the focus groups conveyed concerns about paperboard packaging and non-translucent plastic packaging due to the disallowance of visual quality assessment. The general sentiment for

preference of plastic packaging for dairy beverages has also been expressed by U.S. dairy consumers, although the overall importance placed on packaging material is trivial compared to other product attributes (Paterson, 2016). Understanding underlying cultural and social trends and the subsequent consumer opinion on packaging types is an area that requires further investigation to adequately draw conclusions for the fluid milk market and milk producers.

### ***Organic Fluid Milk***

The U.S. organic industry has increased steadily over the last decade, reaching \$47 billion in sales in 2016 (OTA, 2017). Dairy is an important sector of the organic movement, and is currently the second most purchased organic food category, behind only fresh produce. Furthermore, organic dairy purchases have shown continued growth, with an over 10% sales increase in 2016 (OTA, 2017). While organic milk is popular, designation of fluid milk products as “organic” has been shown to coincide with significant premiums compared to non-organic milks (Gulseven and Wohlgenant, 2017); although many studies have found that some consumers exhibit a significantly higher willingness to pay for organic milks (Dhar and Foltz, 2005; Akaichi et al., 2012). Furthermore, Bernard and Bernard (2009) revealed that the difference in price sensitivity for organic milk consumers can be tied to both demographic and belief factors. Due to growing consumer interest in organic fluid milk, it is clearly important to understand the underlying components relating to consumer appeal, as well as the sensory qualities of organic fluid milk and how those attributes compare to conventional fluid milk.

According to the United States Department of Agriculture (USDA) Guidelines for Organic Certification of Dairy Livestock, organic dairy cows are defined by 4 main criteria: origin of cattle, feed, healthcare, and living conditions. To be considered organic cattle, dairy cows themselves must first meet organic standards for one full year. During the one-year organic

transition process, dairy cows must be fed 100% organic feed, which can include foraging from pasture that is under certified organic management or in the third year of organic transition for organic farmland. Regarding pasture-feeding, organically managed livestock must be provided a minimum of 120 grazing days per calendar year, with the goal of pasture-feeding being to provide a minimum of 30% dry matter intake (DMI) during the grazing season. Cattle healthcare requirements are generally related to the application of preventative health measures provided by the producer. These measures include providing appropriate shelter and sanitary living conditions to reduce the risk of disease or parasites in the herd. In the case that diseases or parasites do exist, treatment via antibiotics or parasiticides are required to maintain animal welfare, but nullify the cow's organic certification. When employed correctly, these measures qualify livestock products, such as fluid milk, to be labeled under the designation of "organic" and marketed as such.

Flavor differences between organic and conventional milks are generally feed-related. Feed-related flavors generally appear in fluid milk within 2 to 4 h directly following cow ingestion and have traditionally been explained using defect terms from dairy scorecard grading (Hedrick, 1955); however, modern descriptive analysis techniques have provided more concise and quantifiable sensory profiles for studies focused on milk flavor and the role of cow feed (Lawless and Heymann, 2010; Croissant et al., 2007). Chapman et al. (2001) used descriptive analysis terms such as "malty/grainy" and "metallic" to describe flavors commonly associated with cattle feed in ultrapasteurized milks. More modern studies relating the impact of feed on the flavor of milk have explored the relationship between specific volatile compounds in certain milks and the sensory ramifications. Croissant et al. (2007) examined the sensory properties and volatile compounds of milk from cows fed a pasture-based diet compared to those fed by more

conventional total mixed ration (TMR) diets and reported that milk from pasture-raised cows had higher intensities of grassy and cowy/barny flavors compared to conventional feed milks. Development of grassy flavors resulting from pasture-fed cow's milk have also been widely documented in other dairy products such as dried dairy ingredients and cheeses, with green/grassy flavors commonly coinciding with terpene and sesquiterpene compounds (Drake et al., 2009; Carpino et al., 2004; Mahajan et al., 2004). Differences in feeding practices, and the subsequent differences in flavor profile are often dictated by the country or region of production. For example, grassy flavors are prevalent in several European and Australasian dried dairy ingredients and cheeses due to cattle having more regular access to pasture than currently exists in the United States conventional dairy sector (Drake et al., 2005; Schuppli et al., 2014; Barkema et al., 2015). With heightened demand in the U.S. market for organic, locally farmed, and pasture-raised milk products, continued investigation into the influence of feed on sensory perception of milk will likely be an enhanced area of research (DuPuis, 2000).

### ***Whey Protein Beverages***

With an ever-growing population of health-conscious consumers, protein beverages have emerged as one of the most popular beverage trends (Jacobson, 2015). Protein beverages exist in the market as extremely functional and diverse products that satisfy the needs of multiple consumer populations. Unlike fluid milk, protein products may not be evaluated solely by their flavor, although flavor acceptability is a baseline need (Gruenwald and Paquin, 2009; Oltman et al., 2015). Instead, protein beverages rely heavily on marketing and utility features to drive consumer acceptance (Fuhrman, 2011). While the standard amount of protein required for a beverage to be considered a "protein beverage" is not defined, commercial protein products typically contain 5-40 g protein per serving. Protein load is of chief importance to category

consumers, and is consistently attractive to both physically active and sedentary consumer groups (Childs et al., 2008; Oltman et al., 2015); however, other attributes of protein beverages such as protein type, sweetener type, and health claim/perception have been identified as purchase drivers for certain consumer subgroups (Oltman et al., 2015).

Protein sources used for commercial protein beverages are generally plant-based proteins, such as soy, or milk or whey proteins that are produced during cheese processing (Horne, 1990; Tunick, 2008). Of the potential protein sources, whey protein beverages are among the most pervasive in the sports nutrition market, and consumption is projected to continue to increase (Lagrange et al., 2015). Liquid whey protein may be produced from either rennet-coagulated cheese (sweet whey), or from acid-coagulated cheese production (acid whey) (Tunick, 2008). Following initial production, liquid whey is typically comprised of 7% solids and 93% water, and a total protein content of about 0.6% (Jelen, 2011). Due to low protein concentration, processes to concentrate the liquid whey product are employed for the production of commercial high-protein whey ingredients. This objective is typically achieved through ultrafiltration and results in a product that is roughly 20-80% protein, known as whey protein concentrate (WPC). WPCs are generally concentrated to standard protein concentrations such as 35% or 80% protein and are known as WPC35 and WPC80, respectively (Foegeding and Luck, 2011). To achieve even higher protein concentration, microfiltration in conjunction with diafiltration may be used to remove residual from the liquid whey stream, resulting in a product defined as whey protein isolate (WPI), which is minimum 90% protein (Foegeding and Luck, 2011). The processing of WPI via anion exchange can also be done, but is used less frequently. During the use of anion exchange, whey proteins are separated based on the charge of the proteins (Gernigon et al.,

2011). Following concentration, whey proteins are typically spray dried to extend shelf life and may be packaged and sold as ingredients for food and beverage applications.

The flavor profile of whey protein and its application in commercial beverages has been studied extensively. The reader is directed to review the comprehensive lexicon of dried dairy ingredient flavors developed by Drake et al. (2003). The presence and evolution of these flavors may be dictated by whey source (Tomaino et al., 2004; Whetstine et al., 2003; Whetstine et al., 2005; Smith et al., 2016), processing parameters (Croissant et al., 2009; Park et al., 2014), and storage (Lee et al., 1996; Tomaino et al., 2004; Whitson et al., 2011; Tunick et al., 2016). In addition to flavor, mouthfeel characteristics also play a large part in the consumer acceptance and evaluation of whey beverages. One of the driving mouthfeel characteristics associated with whey beverages is astringency, or the perception of mouth-drying associated with consumption. In whey protein beverages, studies have shown that astringency is largely dependent on pH, with acidic beverages exhibiting significantly higher maximum astringency, compared to beverages at a neutral pH (Beecher et al., 2008). Results of the study by Beecher et al. (2008) also showed that viscosity was not a significant determinant of astringency in whey protein beverages. That said, numerous studies have assessed consumer mouthfeel preferences for protein beverages, with preferences trending toward beverages that are adequately thick and provide a smooth, creamy mouthfeel (Childs et al., 2007).

## **UNDERSTANDING CONSUMER PERCEPTIONS AND DESIRES**

Evaluation of consumer acceptance has been integral to ensuring acceptability of various fluid milk products and treatments since the inception of hedonic scaling methods in the 1940s. Consumer tests may be administered many ways with fluid milk, but central location tests (CLTs) and home usage tests (HUTs) are the most frequently used. True to their title, consumer

evaluations are administered to untrained populations who represent the true consumer base of a product. Early studies on the hedonic qualities of fluid milk attempted to extrapolate consumer acceptance from trained panelists; however, deficiencies in the predictive ability of trained panelists for consumer populations was well documented (Bierman et al., 1956; Ellis, 1969). Practical uses of consumer tests include examining the effects of various processing methodologies (Horner et al., 1980; Gandy et al., 2008; Lee et al., 2017), flavor additions or fortifications (Campbell et al., 2003; Achanta et al., 2007), and shelf life (Hansen et al., 1980) of fluid milks to maintain adequate consumer acceptance and lead new product development.

While quantitative measurements of the consumer experience such as hedonic scaling are the standard for guiding new product development and marketing initiatives, qualitative results may also provide actionable data. Focus groups and one-on-one interviews have been a staple of consumer insights. Using focus group responses, Porubcan and Vickers (2005) were able to link aftertaste as a primary component of dislike for select skim and low-fat fluid milk consumers. In addition, McCarthy et al. (2015) employed the use of one-on-one interviews as a validation for results found from preference testing. Interview results showed that mouthfeel/thickness, color, and “richness” all played a strong role in driving preferences for consumers of different milkfat levels, and those opinions differed based on typical milkfat consumption. Qualitative consumer studies may provide useful data on their own, but many modern applications are used in conjunction with quantitative data collection methods in order to more accurately model consumer sentiment and behavior. For example, qualitative aspects such as free-response comments or check-all-that-apply (CATA) exercises about emotions felt during evaluation may be asked in addition to traditional overall liking questions. Walsh et al. (2015) implemented this emotional CATA approach to better understand consumer sentiments about 2% fluid milks and

the effects of light oxidation. The study found that consumers were able to differentiate samples by liking score, but also by frequency of emotional attributes, with emotions such as happy and safe corresponding with elevated liking scores. Another popular approach in evaluation of foods and beverages that is often used for new product development or product reformulation, is the just-about-right (JAR) scale. The JAR scale is used to categorize specific attributes of a given product by having the consumer determine if they feel the attribute is perceived as “too low,” “just-about-right,” or “too high.” In studies where overall liking is also asked, these JAR scale categorizations may be used to calculate statistics such as mean drops and penalties, which explain the direct effect of an attribute's deviance from JAR as it relates to liking. JAR scales have been used in numerous milk-related studies, including studies on coffee-flavored milks (Li et al., 2014; Li et al., 2015b), pasteurization methods (Lee et al., 2017; Chapman and Boor, 2001), milk desserts (Ares et al., 2009), and functional beverages (Villegas et al., 2010).

Although physical sensory evaluation is often at the forefront of understanding consumer acceptance of food and beverage products, such procedures often fail to adequately elucidate underlying perceptions that drive consumer purchase. Furthermore, these underlying beliefs have been shown to have a significant effect on sensory perception of foods and beverages. In a study by Aaron et al. (1994), the phenomenon of belief-influenced hedonic approval was illustrated in margarine spread consumers. In the study, a constant sample was used and only labeling information on fat content was altered; however, consumers tended to significantly alter their perceptions of the sample to fall in line with the label description and their stated beliefs about health. Similar observations have been observed for numerous other studies (Levin and Gaeth, 1988; Rozin and Tuorila, 1993; Liem et al., 2012; Fernqvist and Ekelund, 2014). To better understand the insights driving consumer acceptability that exist outside sensory evaluation,

survey techniques are among the most popular means, and are particularly effective with the modern ubiquity of internet access and advanced computational capabilities.

In regard to food and beverage evaluation, contemporary survey methodologies range in form from simple concept acceptability/liking, to more advanced techniques such as experimental auctions, or conjoint analysis (Grunert et al., 2009; Allen and Goddard, 2012; McCarthy et al., 2017b). Though the aforementioned survey techniques often provide actionable insights when presented alone, the use of multiple techniques often results in a synergistic effect. For example, Jervis et al. (2014a) used monadic rating questionnaires of bread images in conjunction with an Adaptive Choice-Based Conjoint exercise to understand consumer preferences for bread slice appearance. Results from these surveys were then used to effectively model consumer acceptance in a market simulator and provided contextual evidence for observed conclusions.

### ***Conjoint Analysis***

Conjoint analysis is a survey methodology that applies complex statistical designs to determine what product attributes are attractive to consumers. The conceptual foundation for conjoint analysis was first proposed in the early 1970's by Paul Green as a method for simultaneously estimating the joint effect of multiple variables on the ordering, ranking, or measured value of a dependent variable (Green and Rao, 1971). There are multiple forms of conjoint analysis, as well as analogues that use similar psychological constructs, but the most common types are adaptive conjoint analysis (ACA), choice-based conjoint analysis (CBC), and adaptive choice-based conjoint analysis (ACBC). The response in these conjoint methods generally exist in two forms: direct numeric response (scaled ratings, resource allocation, etc.), or discrete choices. In a conjoint study, a given product is decomposed into a list of attributes

(categories) and within-attribute levels, which represent the potential interchangeable options that could be used to build a product concept. Exercises presenting the possible combinations of attribute/levels are then presented either monadically and rated (traditional conjoint), or multiple product concepts are presented, and respondents choose the most appealing concept(s) (choice-based conjoint). Furthermore, product concepts may appear with all attributes represented (full-profile) or only a subset of the available attributes (partial-profile). The use of full-profile conjoint methods was suggested by Green and Srinivasan (1990) to be ideal for projects with up to about six attributes, although many believe more attributes can be evaluated if surveys are succinctly prepared (Orme and Johnson, 2013). The comparison of assembled product concepts in a conjoint experiment are often referred to as a “trade-off” scenario, and it is this idea of trade-offs and weighted value of certain product aspects that makes conjoint analysis such a powerful tool for marketing and product development.

Based on series of decisions made during a conjoint study, the investigator would typically employ statistical analyses, such as a multiple regression model, with the discrete choice data (dependent variable) to derive estimates of both attribute importance and part-worth utility of within-attribute levels. In the multiple regression model, part-worth utility scores are simply the regression coefficients associated with each level and are practically understood as the relative effect each level has on the likelihood of a consumer choice. Utility scores are interval-scaled data with an arbitrary scale origin for each attribute. Because the scale of part-worth utility scores is arbitrary, it is important to note that negative scores do not necessarily mean a level is disliked and that utility score of one attribute may not be directly compared to the utility scores of another attribute. That said, it is appropriate for the magnitude of difference between utilities to be compared across attributes. Importance scores in conjoint analysis are

scores used to estimate and compare the influence of product attributes. Importance scores for the attributes in the model can be calculated by taking the difference between the largest and smallest part-worth utility scores for each attribute, summing the differences across attributes, and dividing by each attribute's sum (Orme, 2010); an example can be found in figure 3.

Importance scores are reported as percentages and are understood as the weight each attribute holds in the decision-making process for the given project. Calculation of importance scores and part-worth utility scores is often the prerequisite for deriving conclusions during conjoint analysis projects, and sets the framework for more complicated measures of consumer purchase likelihood, such as logistic regression-based market simulations.

Overall, CBC is the most regularly used conjoint method (Orme and Johnson, 2013). CBC, as its name suggests, is a choice-based conjoint method (as opposed to the rating-based method), meaning that consumers are asked to make choices of what products they would choose in hypothetical markets. For example, respondents may be presented with four uniquely assembled product concepts and asked to choose which one they like best. Choice-based conjoint methods have been suggested to be a more realistic representation of typical marketplace situations for consumers (Rao, 2010). Another substantial advantage of CBC and choice-based methods, compared to most other conjoint methods, is the ability to account for interaction effects between attributes. Whereas other conjoint methods generally apply “main effects only” assumptions for model building, choice-based methods are able to account for two-way interactions in across-attribute pairings (Orme and Johnson, 2013). In a CBC experiment on drivers of purchase for latte-style beverages, Jervis et al. (2012a) reported significant interactions between location of purchase and the use of additional flavors in latte-style beverages. Furthermore, the results suggested that consumers associated coffee houses with flavor-added

latte beverages to be more attractive than flavor-added latte beverages at other locations.

Exploration of these interaction effects and their accompanying conclusions can clearly serve to further elucidate underlying consumer beliefs and may help to enhance the ability of conjoint to model and explain otherwise convoluted product markets.

### ***Adaptive Choice Based Conjoint (ACBC)***

Though utility estimations from conjoint methods such as CBC are quite robust, dynamic ballot methodologies within conjoint analysis have gained popularity because of their ability to bolster the stability of part-worth utility estimation and foster better respondent engagement (Chapman et al., 2009; Cunningham et al., 2010). Of these dynamic conjoint methods, Adaptive Choice Based Conjoint (ACBC) analysis is one of the most popular methods. In addition to improved utility estimations, Jervis et al. (2012b) reported that in the application of conjoint analyses to sour cream products, sample size and survey length requirements of ACBC were considerably lower than the requirements of standard CBC analysis.

In practice, an ACBC survey is composed of three main parts: a build-your-own question, screening questions, and a choice tournament. Respondents begin their ACBC survey by first assembling their ideal product via a single build-your-own style question where the ideal product is built for that consumer by choosing a single level from each available attribute category. As respondents continue to the screening portion of the ballot, they are presented with product concepts that differ slightly from their ideal product build and asked to choose which products they find acceptable. During the screening portion, an adaptive algorithm is used to generate concept sets with differences that compare products primarily based on discriminating attribute choices for which the respondent does not clearly have an established choice pattern (Johnson et al., 2005). Product concepts that are chosen as acceptable move forward to the final choice

tournament portion, where the acceptable concept builds are compared to one another in a tournament-style exercise. Following completion of the ballot and discrete choice experiments of product concepts, utility estimation is typically conducted via aggregate methods such as latent class modeling, or individual utility estimation methods such as hierarchical Bayesian (HB) regression (Johnson, 1997).

Individual part-worth utility estimation and subsequent clustering methods provide a substantial advantage for studies with a large population that is especially heterogeneous, or where subgroups are expected to exist. The prime reasoning for exploring these subgroups is explained by Simpson's paradox. Simpson's paradox is a commonly observed phenomenon in mathematical statistics where a significant effect may be observed in subgroups, but that effect is lost or reversed when viewed aggregately (Lindley and Novick, 1981). In the context of conjoint analysis, this phenomenon was observed by Li et al. (2014) when parents were surveyed about their children's preferences for chocolate milk. In the study, overall utility estimations showed that conventional designation of milk products was preferred to designation as organic; however, when results were clustered and consumer clusters were compared, the results revealed a consumer subgroup that preferred organic designation by a significant margin.

In the sphere of beverage evaluation, ACBC and CBC exercises with individual-level part-worth utility estimation have proven to be effective product development and marketing tools for understanding consumer preferences. Using ACBC exercises, McCarthy et al. (2017b) identified key fluid milk attributes for dairy consumers, as well as plant-based milk alternative products for nondairy consumers. Beyond finding the ideal product build for the dairy and nondairy consumer groups, important information about the hierarchy of product details was elucidated, such as sugar content being the primary driver of plant milk purchase instead of plant

source, as might be expected. Conjoint analysis survey methodologies have also been applied to more focused beverage product studies, such as the effects of packaging/branding on chocolate milk products (Kim et al., 2013), understanding beer preferences and market penetration for female consumers (Muggah and McSweeney, 2017), and exploring the effect of landscape/origin on wine choice (Tempesta et al., 2010).

Although the results from conjoint studies offer important consumer insights from a conceptual perspective, it is important to understand that the conclusions from these studies are ultimately incomplete without the consumer truly evaluating and interacting with the product. For example, Oltman et al. (2015) subjected individual part-worth utility estimations from ACBC exercises to cluster analysis, revealing that 3 primary groups existed for protein beverage consumers: taste-driven consumers, health-driven consumers, and consumers driven primarily by protein-load. However, when results of the conjoint were compared to in-person consumer testing results with priming statements, many “advertised” attributes, such as higher protein amount and protein source failed to influence true overall liking following tasting, though concept liking was improved by their disclosure prior to tasting. To assuage this concern, some recent studies have elected to integrate tasting aspects in conjoint exercises (Tempesta et al., 2010; De Pelsmaeker et al., 2013; De Pelsmaeker et al., 2017); however, conflicting results and design limitations have been reported, warranting further research into integrated methodologies (Hoppert et al., 2012; De Pelsmaeker, 2017). When a tasting-integrated conjoint was used in the evaluation of vanilla yoghurt, Hoppert et al. (2012) reported that when intrinsic attributes such as fat or sugar content increased, so did acceptance; yet when increasing contents of fat or sugar were disclosed, acceptance decreased. Although this result is widely observed in several food

products, the validity of simultaneous evaluation of extrinsic and intrinsic value of a single attribute, as well as determination of the practical conclusions, remains unclear.

### ***Maximum Difference Scaling***

As mentioned above, conjoint analysis and its variants are useful tools for understanding consumer sentiments and purchase habits for products consisting of multiple attributes and levels that could conceivably be interchanged; however, the inability to compare attribute utilities across attributes is problematic when drawing study conclusions. To address this issue, one common method that has experienced extensive use is Maximum Difference (MaxDiff) scaling, which was developed by Louviere and Woodsworth (1990) and Finn and Louviere (1992) under the name “Best-Worst Scaling.” Like conjoint analysis, MaxDiff exercises use the concept of trade-off decisions and discrete choice experiments to determine choice patterns of participants; however, in a MaxDiff experiment, the conjoint element of multiattribute model building is lost, and discrete choice exercises are instead presented as a subset from a single master set where the respondent determines the “best” and “worst” option from the subset. The results from MaxDiff experiments are subjected to multinomial logit regression or hierarchical bayes regression modeling to yield ratio-scaled estimates of importance for the tested list items. Several studies have compared the efficacy of MaxDiff experiments compared to other scaling methods. In a comparison of MaxDiff to monadic rating and unstructured line scale rating, Jaeger et al. (2008) reported that MaxDiff scores were more sensitive to differences than the unstructured line scale, and evidence suggested that Maxdiff exercises were perceived as an easier task compared to the other methods. In addition, when compared to conjoint analysis results, MaxDiff has been shown to closely match observed within-attribute trends and produce useful comparisons between attribute categories; however, certain attributes may suffer from the

lack of full-product framing where participants are asked to judge attributes in the context of a fully-assembled product, as is the case in conjoint analysis (Hollin et al., 2015).

MaxDiff scaling has been employed over a wide range of food and beverage studies for developing attribute or belief hierarchies (McLean et al., 2017; Thomson et al., 2010; Lusk and Parker, 2009). Results from these studies are often reported in an overall context to understand general trends, but, like conjoint, MaxDiff results may be subjected to demographic grouping, clustering, or individual score estimation (via hierarchical bayes) to produce comparable hierarchal structures for the determined groups. In a study of beer consumers, MaxDiff scores for light beer consumers and regular beer consumers were directly compared (Chrysouchou, 2014). Results from the study showed that although light beer consumers placed greater importance on perceived health advantages in light beer products, the importance of taste expectations were relatively equal to consumers of regular beer. The conclusions made through comparison of consumer subgroups in this study ultimately helped to establish a direction for marketing efforts specific to the consumer group being evaluated, which would ultimately be lost if results were viewed aggregately. MaxDiff surveys have also been used to evaluate a variety of items, including healthcare systems (Cunningham et al., 2010; Wijnen et al., 2016) and consumer goods/services (Ramaswami and Sailer, 2012; Beck et al., 2017).

In addition, MaxDiff's ease of use and the ability to present MaxDiff projects on a computer interface allows for the development and application of cross-cultural/cross-country studies for identifying trends on a global scale. In a study of emerging ethical and social trends, Auger et al. (2007) used MaxDiff scaling to characterize the relative importance of corporate social responsibilities to respondents in Germany, Spain, Turkey, India, Korea, and the United States. Results from the study showed that underlying beliefs about human rights and labor rights

were generally universal and scaled similarly among different cultures; however, the scaling and magnitude of ratings for animal rights and environmental concerns were unique to each country. Presently, cross-cultural applications of MaxDiff have not been extensively applied to the field of beverage evaluation, but the potential for examination of preferences across cultures certainly exists.

### ***Kano Model Analysis***

Kano Analysis, named for its creator, Dr. Noriaki Kano, is a survey methodology for assessing consumer need and satisfaction for a given product feature (Kano, 1984). The basis for Kano Analysis modeling is the notion that product features do not always exhibit an additive effect on consumer acceptance, nor does approval of a given product feature warrant its inclusion in a product. To assess these features using the Kano model, respondents are asked about their hypothetical satisfaction if a product feature were present (functional question), as well as their satisfaction if the feature were not present (dysfunctional question). Respondents may answer the functional and dysfunctional questions in five ways:

1. I like it that way
2. It must be that way (I expect it that way)
3. I am neutral
4. I can live with it that way.
5. I dislike it that way

Based on the respondent's answers to the functional and dysfunctional presentation of the product feature, the response to the feature is categorized in accordance with Table 1 as being an Attractive attribute, One-Dimensional attribute, Must-Have attribute, Reverse attribute, or an Indifferent attribute (Lofgren and Witell, 2008). Additionally, nonsensical evaluations may be

referred to as Questionable attributes, and may result from poorly worded questions or a lack of consumer understanding for the given feature. A visual representation of each of these possible categories can be found in Figure 1. Following data collection, results from a surveyed population or subpopulations can be tabulated to quantitatively explain consumer trends, preferences, and tendencies for use of a given product and its features. Furthermore, results of a Kano modeling survey may be used in conjunction with simple stated importance for the product features to provide a quantitative and qualitative blueprint for product development purposes (Sauerwein et al., 1996).

The application of Kano modeling has been used in several food and beverage studies to understand product features such as flavor, packaging features, and label claims. Oltman et al. (2015) used the Kano model on protein beverage attributes to add a dimension of understanding to conjoint analysis results and to help corroborate conclusions. In the study, different consumer clusters exhibited different features of interest for protein products, with one cluster placing an emphasis on multiple health claims, while another group showed more interest in the base nutrition and satiety associated with protein beverages. In addition, the Kano model has been used to outline the base consumer needs for staple consumer goods such as eggs, showing that the general consumer population assigns a necessity to features such as freshness and cleanliness, but certain consumer groups may exhibit a need for additional features, such as egg grade and brand (Wardy et al., 2014).

While the use of Kano modeling has shown itself to be a useful tool in food and beverage studies, it should be noted that limitations with product evaluation using the Kano model do exist. For example, the Kano model relies on consumer familiarity with the product and features being evaluated for accurate judgement to take place (Fisher and Schutta, 2003). Another

commonly cited shortcoming of the Kano model is that the Kano model functions solely to identify directional consumer desires, but fails to adequately explain the net magnitude of acceptance change that may occur if a given feature is gained, lost, or altered (McLean, 2016). For that reason, it is advisable to use the Kano model in conjunction with other survey techniques that fully capture the user-product experience.

## **OBJECTIVE SENSORY ANALYSIS METHODS**

### ***Descriptive Analysis***

Descriptive analysis is a widely used sensory technique that allows for a complete and detailed profile of a product, as assessed by a calibrated panel (Murray et al., 2001). Descriptive analysis (DA) techniques are robust methods for quantitatively and objectively profiling the sensory attributes of fluid milk and other beverages. Descriptive analysis requires training of panelists prior to data collection, and typically includes a group of 6-12 trained participants (Chambers et al., 2004). Panel training may be several hours; however, this extensive training is done in the hopes that the panel may produce objective data that is consistent and sensitive, analogous to an instrument. Furthermore, descriptive analysis has been shown to be more sensitive and a better indicator of consumer preference than traditional methods such as dairy judging (Lawless and Claassen, 1993). There has been extensive use of descriptive analysis for the means of differentiating fluid milk and other dairy products (Claassen and Lawless, 1992; Lawless and Claassen 1993; Phillips et al., 1995a; Watson and McEwan 1995; Chapman and Boor 2001; Francis et al., 2005; Chung et al., 2008; McCarthy et al., 2017a; Lee et al., 2017). Furthermore, descriptive analysis data can be paired with consumer panel data in a technique known as preference mapping to better understand drivers of liking in a product (MacFie and Thomson, 1988; Thompson et al., 2004).

### *Temporal Sensory Analysis*

While traditional descriptive analysis techniques are effective for analyzing and differentiating samples based on sensory profiles, dynamic product features may fail to be adequately assessed and reported due to the static nature of typical analyses. Furthermore, the nature of food and beverage consumption (mastication, salivation, etc.) includes inevitable changes in food texture, temperature, and flavor. These changes can greatly change consumer perceptions of a product, which can ultimately dictate product acceptance. For example, Wilson and Brown (1997) reported that during consumer evaluation of model gelatins, products with greater breakdown and lower structural integrity were consistently associated with shorter, but more intense perceptions of flavor, as opposed to model gelatins that required sustained chewing. While that study exemplified physical determinants of temporality in food structures, the chemical structure of food products or ingredients may also influence temporal perception. This phenomenon is commonly seen in non-nutritive sweeteners, which exhibit significantly different peak intensities and durations of sweet taste compared to sucrose (Ott et al., 1991).

Several methods are available for profiling dynamic changes in sensory properties within food and beverages products, and advances in modern technology have made those evaluations convenient and powerful. Some of the most common temporal methods are Time-Intensity (TI), Temporal Dominance of Sensations (TDS), and Temporal Check-All-That-Apply (TCATA). Time Intensity, as the name suggests, evaluates the changes in intensity for a given attribute over the course of continuous evaluation. The result of a time-intensity exercise is a curve that shows the evolution in intensity for a single given attribute during consumption. Temporal Dominance is similar to TI, but instead of continuous measures of attribute intensity, multiple attributes are presented to the panelist and the panelist is simply instructed to choose the most dominant

feature at any given time. The results of a TDS exercise can be aggregated across all panelists and presented as proportion of dominance for each attribute over evaluation time (Pineau et al., 2009). Typically, calculations of significance are determined for TDS proportions and are dependent on the number of attributes being evaluated, with significance being determined based on the binomial test of dominance proportions (Pineau et al., 2009). Though TDS does not report any measures of intensity, the qualitative curves with accompanying validation of significant citation proportions can be used to effectively understand the temporal profile of a product. In addition, differences between products can be evaluated by creating TDS difference curves, where differences in dominance rate between two products is calculated for each attribute (Pineau et al., 2009).

#### ***Temporal Check-All-That-Apply (TCATA)***

For profiling samples that are notably complex, Temporal Check-All-That-Apply (TCATA) has been suggested to be more appropriate than other temporal sensory methods (Ares et al., 2015a; Catura et al., 2016a). TCATA exercises are an extension of static Check-All-That-Apply (CATA) methodologies, which have been employed in numerous beverage-related studies for understanding beverage attributes (Ares et al., 2010; Ares et al., 2011; Dooley et al., 2010). In a CATA exercise, consumers are given a set list of attributes, and simply instructed to choose all attributes that apply to the given product. Traditional CATA questions are often a useful way of providing rapid profiles of products and have been widely considered a clear and facile exercise for naive consumers (Jaeger et al., 2013; Ares et al., 2014a). In a series of studies, Jaeger et al. (2013) reported that results from naive consumers using CATA questions to profile dairy desserts were generally reliable, and even comparable to trained panelists, although trained panelists have shown to be consistently more sensitive to sample differences as might be

expected (Ares et al., 2015b). Furthermore, the number of consumers required for reliable CATA data are relatively small compared to the recommended amount for traditional consumer acceptance tests with hedonic rating exercises (Ares et al., 2014b; Hough et al., 2006). While CATA methods are indeed useful for quick product profiling, there is very little information collected to explain relative intensities of observed attributes. For that reason, some modern studies have employed a secondary step to CATA product evaluations where panelists first identify all applicable attributes present in a traditional CATA question, and are then asked the corresponding intensities of those attributes (Ares et al., 2014a). This method is generally referred to as Rate-All-That-Apply (RATA). Results from RATA questions add the dimension of intensity to a product evaluation while maintaining the versatility of CATA methodologies, and in some cases, RATA formats have shown to be superior to CATA without a reported increase in exercise difficulty (Ares et al., 2014a). Still, these static methods of rapid product characterization fail to take the aforementioned temporal aspects of a product adequately into account.

Just like traditional CATA exercises, during TCATA product evaluation, panelists are presented with a set list of attributes they may choose from; however, TCATA allows for the continuous selection and deselection of the attributes during a set evaluation time, thus resulting in a dynamic sensory profile given product (Castura et al., 2016a). TCATA exercises are presented on a computer or tablet interface, and generally use a maximum of about 10 attributes, although use of up to 15 attributes has recently been shown not to be detrimental to sample evaluation and product discrimination (Castura et al., 2016a; Jaeger et al., 2017). That said, careful selection of available attributes must be done to ensure that there are no competing or ambiguous attributes. Once evaluations are complete, results from TCATA evaluations are

stored as binary responses for each attribute at each second of evaluation, resulting in a multivariate binary series data (Castura et al., 2016a). Using TCATA methodologies, McMahon et al. (2017) used proportion of panelists who cited attribute presence over evaluation time to graphically display the temporal changes for each attribute in sparkling wine samples (Figure 4). Castura et al. (2016b) also reported that dynamic profiles may be shown using data compression techniques such as correspondence analysis (CA) or principal components analysis (PCA), resulting in animated representations of products and differences between product profiles (Figure 6). Due to the novelty of TCATA methodologies, advances in technology, as well as guidelines for application, recommendations for valid statistical analysis are avenues expected to be explored and studied in the near future.

### **OBJECTIVES**

The objectives of this thesis are to evaluate the drivers of purchase for fluid milk, protein beverages, and the temporal properties of rums, to better understand consumer attitudes and ideal product builds. This information directs the formulation and posturing of market products so evaluation of sensory profiles of complex beverages, with a focus on temporal evaluation via TCATA, will be employed to set groundwork for understanding how different formulations of market products affect the consumer experience from a temporal sensory perspective.

## REFERENCES

- Aaron, J. I., D. J. Mela, and R. E. Evans. 1994. The influence of attitudes, beliefs and label information on perception of reduced-fat spreads. *Appetite*. 22:25–37.
- Achanta, K., Boeneke, C.A. and Aryana, K.J., 2007. Characteristics of reduced fat milks as influenced by the incorporation of folic acid. *J. Dairy Sci.* 90:90-98.
- Adhikari K, L.M. Dooley, Chambers IV E, N. Bhumiratana. 2010. Sensory characteristics of commercial lactose-free milks manufactured in the United States. *LWT – Food Sci. Technol.* 43:113-118.
- Akaichi, F., R.M. Nayga Jr, and J.M. Gil. 2012. Assessing consumers' willingness to pay for different units of organic milk: evidence from multiunit auctions. *Can. J. Agr. Econ.* 60:469-494.
- Allen, S. and E. Goddard, 2012. Consumer preferences for milk and yogurt attributes: How health beliefs and attitudes affect choices. Pages 1-45 at the Agricultural & Applied Economics Association's 2012 Annual Meeting.
- Amin, K.N., M.L. Johnson, J.B. Phillips, S. Duncan, H. Potts, S.F. O'Keef, J.E. Marcy and K. Mallikarjunan. 2016. Differences in high-density polyethylene milk packaging performance under light emitting diode and fluorescent retail storage. *J. Anim. Sci.* 94:338-338.
- AMS (Agricultural Marketing Service). 2013. Packaged fluid milk sales in federal milk order markets: By size and type of container and distribution method during November 2013. U.S. Department of Agriculture, Agricultural Marketing Service (AMS). Washington, DC. [https://www.fmmcentral.com/packaged\\_fluid\\_milk\\_sales.html](https://www.fmmcentral.com/packaged_fluid_milk_sales.html)
- Andersson, L., and R. Ôste. 1995. Sensory quality of UHT milk. Pages 318-330 in *Heat-induced Changes in Milk*. IDF Special Issue 9501. International Dairy Federation, Brussels, Belgium.
- Antunes, A.E.C., A.T.S. Alves, D.A. Gallina, F.K.H.S. Trento, P.B. Zacarchenco, A.G.F. Van Dender, I. Moreno, R.C.S.C. Ormenes, and L.M. Spadoti. 2014. Development and shelf-life determination of pasteurized, microfiltered, lactose hydrolyzed skim milk. *J. Dairy Sci.* 97:5337-5344.
- Ares, G., C. Barreiro, and A.N.A. Giménez. 2009. Comparison of attribute liking and JAR scales to evaluate the adequacy of sensory attributes of milk desserts. *J. Sens. Stud.* 24:664-676.
- Ares, G., C. Barreiro, R. Deliza, A.N.A. Giménez, and A. Gambaro. 2010. Application of a check-all-that-apply question to the development of chocolate milk desserts. *J. Sens. Stud.* 25:67-86.

- Ares, G., P. Varela, G. Rado, and A. Giménez. 2011. Are consumer profiling techniques equivalent for some product categories? The case of orange-flavoured powdered drinks. *Int. J. Food Sci. Tech.* 46:1600-1608.
- Ares, G., F. Bruzzone, L. Vidal, R.S. Cadena, A. Giménez, B. Pineau, D.C. Hunter, A.G. Paisley, and S.R. Jaeger. 2014a. Evaluation of a rating-based variant of check-all-that-apply questions: Rate-all-that-apply (RATA). *Food Qual. Pref.* 36:87-95.
- Ares, G., A. Tárrega, L. Izquierdo, and S.R. Jaeger. 2014b. Investigation of the number of consumers necessary to obtain stable sample and descriptor configurations from check-all-that-apply (CATA) questions. *Food Qual. Pref.* 31:135-141.
- Ares, G., S.R. Jaeger, L. Antúnez, L. Vidal, A. Giménez, B. Coste, A. Picallo, and J.C. Castura. 2015a. Comparison of TCATA and TDS for dynamic sensory characterization of food products. *Food Res. Inter.* 78:148-158.
- Ares, G., L. Antúnez, F. Bruzzone, L. Vidal, A. Giménez, B. Pineau, M.K. Beresford, D. Jin, A.G. Paisley, S.L. Chheang, and C.M. Roigard. 2015b. Comparison of sensory product profiles generated by trained assessors and consumers using CATA questions: Four case studies with complex and/or similar samples. *Food Qual. Pref.* 45:75-86.
- Auger, P., T.M. Devinney, and J.J. Louviere. 2007. Using best–worst scaling methodology to investigate consumer ethical beliefs across countries. *J. Bus. Ethics.* 70:299-326.
- Bakke, A.J., C.V. Shehan, and J.E. Hayes. 2016. Type of milk typically consumed, and stated preference, but not health consciousness affect revealed preferences for fat in milk. *Food Qual. Pref.* 49:92-99.
- Barkema, H.W., M.A.G. Von Keyserlingk, J.P. Kastelic, T.J.G.M. Lam, C. Luby, J.P. Roy, S.J. LeBlanc, G.P. Keefe, and D.F. Kelton. 2015. Invited review: Changes in the dairy industry affecting dairy cattle health and welfare. *J. Dairy Sci.* 98:7426-7445.
- Beck, M.J., J.M. Rose, and S.P. Greaves. 2017. I can't believe your attitude: a joint estimation of best worst attitudes and electric vehicle choice. *Transportation.* 44:753-772.
- Beecher, J.W., M.A. Drake, P.J. Luck, and E.A. Foegeding. 2008. Factors regulating astringency of whey protein beverages. *J. Dairy Sci.* 91:2553-2560.
- Bernard, J.C. and D.J. Bernard. 2009. What is it about organic milk? An experimental analysis. *Am. J. Agr. Econ.* 91:826-836.
- Bierman, G.W., B.E. Proctor and S.A. Goldblith. 1956. Radiation preservation of milk and milk products. II. Off flavors in milk and cream induced by ionizing radiations as judged by organoleptic tests. *J. Dairy Sci.* 39:379- 390.

- Blake, M., B. Weimer, D.J. McMahon, P. Savello. 1995. Sensory and microbial quality of milk processed for extended shelf life by direct steam injection. *J. Food Prot.* 58:1007-1013.
- Boor, K.J., and S.C. Murphy. 2002. Microbiology of market milks. 3<sup>rd</sup> ed. Pages 91-122 in *Dairy Microbiology Handbook: The Microbiology of Milk and Milk Products*. R.K. Robinson, ed. Wiley-Interscience, New York, NY.
- Brans, G., C.G.P.H. Schroë, R.G.M. van der Sman, and R.M. Boom. 2004. Membrane fractionation of milk: state of the art and challenges. *J. Membrane Sci.* 243:263-272.
- Burton, H., 1977. Subject: The review of UHT treatment and aseptic packaging in the dairy industry. *Int. J. Dairy Technol.*, 30:135-142.
- Campbell, W., M.A. Drake, and D.K. Larick. 2003. The impact of fortification with conjugated linoleic acid (CLA) on the quality of fluid milk. *J. Dairy Sci.* 86:43-51.
- Carpino, S., J. Horne, C. Melilli, G. Licitra, D.M. Barbano, and P.J. Van Soest. 2004. Contribution of native pasture to the sensory properties of Ragusano cheese. *J. Dairy Sci.* 87:308-315.
- Castura, J.C., L. Antúnez, A. Giménez, and G. Ares. 2016a. Temporal Check-All-That-Apply (TCATA): A novel dynamic method for characterizing products. *Food Qual. Pref.* 47:79-90.
- Castura, J.C., A.K. Baker, and C.F. Ross. 2016b. Using contrails and animated sequences to visualize uncertainty in dynamic sensory profiles obtained from temporal check-all-that-apply (TCATA) data. *Food Qual. Pref.* 54:90-100.
- Chambers, D.H., A.A. Allison, and E. Chambers. 2004. Training effects on performance of descriptive panelists. *J. Sens. Stud.* 19:486-499.
- Chapman, K.W., H.T. Lawless, and K.J. Boor. 2001. Quantitative descriptive analysis and principal component analysis for sensory characteristics of ultrapasteurized milk. *J. Dairy Sci.* 84:12-20.
- Chapman, K.W., and K.J. Boor. 2001. Acceptance of 2% ultra-pasteurized milk by consumers, 6 to 11 years old. *J. Dairy Sci.* 84:951-954.
- Chapman, K.W., H.T. Lawless, and K.J. Boor. 2001. Quantitative descriptive analysis and principal component analysis for sensory characteristics of ultrapasteurized milk. *J. Dairy Sci.* 84:12-20.
- Chapman, C.N., J.L. Alford, C. Johnson, R. Weidemann, and M. Lahav. 2009. CBC vs. ACBC: Comparing results with real product selection. Pages 199-206 in *Sawtooth Software Inc. 2009 Sawtooth Software Conference Proceedings*, Mar 25-27; Delray Beach, FL.

- Chen, C.C. and M.C. Chuang. 2008. Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design. *Int. J. Prod. Econ.* 114:667-681.
- Childs, J.L., M.D. Yates, and M.A. Drake. 2007. Sensory properties of meal replacement bars and beverages made from whey and soy proteins. *J. Food Sci.* 72:S425-S434.
- Childs, J.L., J.L. Thompson, J.S. Lillard, T.K. Berry, and M.A. Drake. 2008. Consumer perception of whey and soy protein in meal replacement products. *J. Sens. Stud.* 23:320-339.
- Chrysochou, P. 2014. Drink to get drunk or stay healthy? Exploring consumers' perceptions, motives and preferences for light beer. *Food Qual. Pref.* 31:156-163.
- Chung, S.J., C.R. Lim. and B.S. Noh. 2008. Understanding the sensory characteristics of various types of milk using descriptive analysis and electronic nose. *Korean J. Food Sci. Technol.* 40:47-55.
- Claassen, M., and H.T. Lawless. 1992. Comparison of descriptive terminology systems for sensory evaluation of milk. *J. Food Sci.* 57:596-621.
- Cladman, W., S. Scheffer, N. Goodrich, and M. W. Griffiths. 1998. Shelf-life of milk packaged in plastic containers with and without treatment to reduce light transmission. *Int. Dairy J.* 8:629-636.
- Claeys, W.L., S. Cardoen, G. Daube, J. De Block, K. Dewettinck, K. Dierick, L. De Zutter, A. Huyghebaert, H. Imberechts, P. Thiange, and Y. Vandenplas. 2013. Raw or heated cow milk consumption: review of risks and benefits. *Food Control.* 31:251-262.
- Clare, D.A., W.S. Bang, G. Cartwright, M.A. Drake, P. Coronel, and J. Simunovic. 2005. Comparison of sensory, microbiological, and biochemical parameters of microwave versus indirect UHT fluid skim milk during storage. *J. Dairy Sci.* 88:4172-4182.
- Covacevich, H.R., and F.V. Kosikowski. 1978. Mozzarella and cheddar cheese manufacture by ultrafiltration principles. *J. Dairy Sci.* 61:701-709.
- Croissant, A.E., S.P. Washburn, L.L. Dean, and M.A. Drake. 2007. Chemical properties and consumer perception of fluid milk from conventional and pasture-based production systems. *J. Dairy Sci.* 90:4942-4953.
- Croissant A.E., E.J. Kang, R.E. Campbell, E. Bastian, and M.A. Drake. 2009. The effect of bleaching agent on the flavor of liquid whey and whey protein concentrate. *J. Dairy. Sci.* 92:5917-5927.
- Cunningham, C. E., K. Deal, and Y. Chen, 2010. Adaptive choice-based conjoint analysis: A new patient-centered approach to the assessment of health service preferences. *Patient.* 3: 257-273.

- De Pelsmaeker, S., K. Dewettinck, and X. Gellynck. 2013. The possibility of using tasting as a presentation method for sensory stimuli in conjoint analysis. *Trends Food Sci. Technol.* 29:108-115.
- De Pelsmaeker, S., Schouteten, J.J., Lagast, S., Dewettinck, K. and Gellynck, X., 2017. Is taste the key driver for consumer preference? A conjoint analysis study. *Food Qual. Pref.* 62:323-331.
- Dhar, T. and J.D. Foltz. 2005. Milk by any other name... consumer benefits from labeled milk. *Am. J. Ag. Econ.* 87:214-228.
- Dijksterhuis, G.B., and J.R. Piggott. 2000. Dynamic methods of sensory analysis. *Trends Food Sci. Technol.* 11:284-290.
- Dooley, L., Y.S. Lee, and J.F. Meullenet. 2010. The application of check-all-that-apply (CATA) consumer profiling to preference mapping of vanilla ice cream and its comparison to classical external preference mapping. *Food Qual. Pref.* 21:394-401.
- Drake, M.A., Y. Karagul-Yuceer, K.R. Cadwallader, G.V. Civille, and P.S. Tong. 2003. Determination of the sensory attributes of dried milk powders and dairy ingredients. *J. Sens. Stud.* 18:199-216.
- Drake, M.A., M.D. Yates, P.D. Gerard, C.M. Delahunty, E.M. Sheehan, R.P. Turnbull, and T.M. Dodds. 2005. Comparison of differences between lexicons for descriptive analysis of Cheddar cheese flavour in Ireland, New Zealand, and the United States of America. *Int. Dairy J.* 15:473-483.
- Drake, M.A., J.M. Wright, M.E. Whitson, and M.A. Lloyd. 2009. Impact of dairy ingredients on the flavor profiles of foods. Pages 442-466 in *Dairy-Derived Ingredients: Food and Nutraceutical Uses*. Woodhead Publishing, Great Abington, Cambridge, UK.
- DuPuis, M. 2000. Not in my body: rBGH and the rise of organic milk. *Agric. Hum. Values* 17:285-295.
- Economic Research Service. 2014. Data files: Dairy Products: Per capita consumption, United States (Annually). Accessed February 20th, 2017.  
<http://www.ams.usda.gov/AMSV1.0/ams.fetchTemplateData.do?startIndex=1&template=TemplateV&navID=IndustryMarketingandPromotion&leftNav=IndustryMarketingandPromotion&page=FluidMilkSalesDataMonthlyandYeartoDate&acct=dmktord>.
- Ellis, B.H., 1969. Acceptance and consumer preference testing. *J. Dairy Sci.* 52:823-831.
- Falguera, V., Aliguer, N. and Falguera, M., 2012. An integrated approach to current trends in food consumption: Moving toward functional and organic products? *Food Control.* 26:274-281.

- Fernqvist, F. and L. Ekelund. 2014. Credence and the effect on consumer liking of food – a review. *Food Qual. Pref.* 32:340-353.
- Finn, A., and J.J. Louviere. 1992. Determining the appropriate response to evidence of public concern: The case of food safety. *J. Public Policy Mark.* 11:12-25.
- Fisher, C., and J.T. Schutta. 2003. Voice of the Customer. Pages 28-36 in *Developing New Services*. American Society for Quality. Quality Press. Milwaukee, WI.
- Foegeding, E.A., and P. Luck. 2011. Whey protein products. Pages 873-878 in *Encyclopedia of Dairy Sciences*. J.W. Fuquay, P.F. Fox, and P.L.H. McSweeney, ed. Academic Press.
- Francis, L.L., D.H. Chambers, S.H. Kong, G.A. Milliken, I.J. Jeon, and K.A. Schmidt. 2005. Serving temperature effects on milk flavor, milk aftertaste, and volatile compound quantification in nonfat and whole milk. *J. Food Sci.* 70:S413–S418.
- Fuhrman E. 2011. Whey protein builds on success. *Beverage Industry.* 102:62.
- Gandy, A.L., M. Schilling, P. Coggins, C. White, Y. Yoon, and Kamadia, V. 2008. The effect of pasteurization temperature on consumer acceptability, sensory characteristics, volatile compound composition, and shelf-life of fluid milk. *J. Dairy Sci.* 91:1769-1777.
- Gernigon, G., P. Schuck, and R. Jeantet. 2011. Demineralization. Pages 738-743 in *Encyclopedia of Dairy Sciences*. J.W. Fuquay, P.F. Fox, and P.L.H. McSweeney, ed. Academic Press.
- Gilbert, S.G. 1985. Food/package compatibility. *Food Technol.* 39:54-56.
- Goff, H.D. and M.W. Griffiths. 2006. Major advances in fresh milk and milk products: fluid milk products and frozen desserts. *J. Dairy Sci.*, 89:1163-1173.
- Green, P.E. and V.R. Rao. 1971. Conjoint measurement for quantifying judgmental data. *J. Mark. Res.* 8:355-363.
- Green, P.E., and V.Srinivasan. 1990. Conjoint analysis in marketing: new developments with implications for research and practice. *J. Mark.* 54:3-19.
- Gruenwald, J. and P. Paquin 2009. Fortification of beverages with products other than vitamins and minerals. Pages 92-106 in *Functional and speciality beverage technology*. Elsevier.
- Grunert, K.G., H.J. Juhl, , L. Esbjerg, B.B. Jensen, T. Bech-Larsen , K. Brunsø, and C.Ø. Madsen. 2009. Comparing methods for measuring consumer willingness to pay for a basic and an improved ready made soup product. *Food Qual. Pref.* 20:607-619.
- Gulseven, O. and M. Wohlgenant. 2017. What are the factors affecting the consumers' milk choices? *J. Agric. Econ.* 63:271-282.

- Hansen, A.P., K.R. Swartzel, and F.G. Giesbrecht. 1980. Effect of temperature and time of processing and storage on consumer acceptability of ultra-high-temperature steam injected whole milk. *J. Dairy Sci.* 63:187-192.
- Harrington L.K. and J.F. Mayberry. 2008. A re-appraisal of lactose intolerance. *Int. J. Clin. Pract.* 62:1541-1546.
- Hedrick, R.R. 1955. Feed flavor transmission to milk. MS Thesis. Montana State Univ., Bozeman.
- Hollin, I.L., H.L. Peay, and J.F. Bridges. 2015. Caregiver preferences for emerging duchenne muscular dystrophy treatments: a comparison of best-worst scaling and conjoint analysis. *Patient.* 8:19-27.
- Hollywood, L., L. Wells, G. Armstrong, and H. Farley. 2013. Thinking outside the carton: attitudes towards milk packaging. *Brit. Food J.* 115:899-912.
- Hoppert, K., R. Mai, S. Zahn, S.Hoffmann, and H.Rohm. 2012. Integrating sensory evaluation in adaptive conjoint analysis to elaborate the conflicting influence of intrinsic and extrinsic attributes on food choice. *Appetite.* 59:949-955.
- Horne, D.S. 1990. Whey proteins. *Int. J. Dairy Technol.* 43:1-4.
- Horner, S.A., S.E. Wallen, and F. Caporaso. 1980. Sensory aspects of UHT milk combined with whole pasteurized milk. *J. Food Prot.* 43:54-57.
- Hough, G., I. Wakeling, A. Mucci, E. Chambers, I.M. Gallardo, and L.R. Alves. 2006. Number of consumers necessary for sensory acceptability tests. *Food Qual. Pref.* 17:522-526.
- Jacobson, J. 2015. Beverage survey finds 'high protein,' 'natural' are top trends. Pages 16-17 in *Dairy Foods*. BNP Media, Troy, MI.
- Jaeger, S.R., Jørgensen, A.S. Aaslyng, M.D. and Bredie, W.L., 2008. Best-worst scaling: An introduction and initial comparison with monadic rating for preference elicitation with food products. *Food Qual. Pref.* 19:579-588.
- Jaeger, S.R., S.L. Chheang, J. Yin, C.M. Bava, A. Gimenez, L. Vidal, and G. Ares. 2013. Check-all-that-apply (CATA) responses elicited by consumers: Within-assessor reproducibility and stability of sensory product characterizations. *Food Qual. Pref.* 30:56-67.
- Jaeger, S.R., F. Alcaire, D.C. Hunter, D. Jin, J.C. Castura, and G. Ares. 2017. Number of terms to use in temporal check-all-that-apply studies (TCATA and TCATA Fading) for sensory product characterization by consumers. *Food Qual. Pref.* 64:154-159.

- Jelen, P., and O. Tossavanien. 2003. Low lactose and lactose-free milk and dairy products – prospects, technologies and applications. *Aust. J. Dairy Technol.* 58:161-165.
- Jelen, P. 2011. Utilization and Products. Pages 731-737 in *Encyclopedia of Dairy Sciences*. W. Fuquay, P.F. Fox, and P.L.H. McSweeney, ed. Academic Press.
- Jervis, S.M., K. Lopetcharat, and M.A. Drake. 2012a. Application of ethnography and conjoint analysis to determine key consumer attributes for latte-style coffee beverages. *J. Sens. Stud.* 27:48-58.
- Jervis, S. M., J. M. Ennis, and M.A. Drake. 2012b. A comparison of adaptive choice-based conjoint and choice-based conjoint to determine key choice attributes of sour cream with limited sample size. *J. Sens. Stud.* 27:451-462.
- Jervis, S.M., Jervis, M.G., Guthrie, B. and Drake, M.A., 2014a. The Efficacy of Using Photographs to represent attributes of sliced sandwich bread in an adaptive choice-based conjoint. *J. Sens. Stud.* 29:64-73.
- Jervis, S.M., P. Gerard, S. Drake, K. Lopetcharat, and M.A. Drake. 2014b. The perception of creaminess in sour cream. *J. Sens. Stud.* 29:248-257.
- Johnson, D.S., S.E. Duncan, L.M. Bianchi, H.H. Chang, W.N. Eigel, and S.F. O’Keefe. 2015. Packaging modifications for protecting flavor of extended-shelf-life milk from light. *J. Dairy Sci.* 98:2205-2214.
- Johnson, R.M. 1997. Individual Utilities from Choice Data: A New Method. Pages 191-208 in *Sawtooth Software Inc. 1997 Conference Proceedings*; Aug; Seattle, WA.
- Johnson, R. M., B. Orme, J. Huber, and J. Pinnell. 2005. Testing adaptive choice-based conjoint designs. Pages 1-14 in *2005 Sawtooth Software Research Paper Series*.
- Kano, N., N. Seraku, F. Takahashi, and S. Tsuji. 1984. Attractive quality and must be quality. *J. Jpn. Soc. Qual. Control.* 14:147-156.
- Kapsimalis, D.J. and R.R. Zall. 1981. Ultrafiltration of skim milk at refrigerated temperatures. *J. Dairy Sci.* 64:1945-1950.
- Kearney, J., 2010. Food consumption trends and drivers. *Philos. Trans. Royal Soc. B. Biol. Sci.* 365:2793-2807.
- Kim, M.K., K. Lopetcharat, and M.A. Drake. 2013. Influence of packaging information on consumer liking of chocolate milk. *J. Dairy Sci.* 96:4843-4856.
- Lagrange, V., D. Whitsett, and C. Burriss. 2015. Global market for dairy proteins. *J. Food Sci.* 80:A16-A22.

- Lawless, H.T., and C.C. Clark. 1992. Psychological biases in time-intensity scaling. *Food Technol.* 11:81-90.
- Lawless, H. T., and M. R. Claassen. 1993. Validity of descriptive and defect-oriented terminology systems for sensory analysis of fluid milk. *J. Food Sci.* 58:108–112, 119.
- Lawless, H. T., and H. Heymann. 2010. Pages 79-100, 227-257 in *Sensory Evaluation of Food: Principles and Practices*. 2nd ed. Chapman and Hall, New York, NY.
- Lee, Y.B., I. Laye, Y.D. Kim, and C.V. Morr. 1996. Formation of volatile compounds in whey protein concentrate during elevated temperature storage as a function of water activity. *Int. Dairy J.* 6:485-496.
- Lee, A.P., D.M. Barbano and M.A. Drake, 2017. The influence of ultra-pasteurization by indirect heating versus direct steam injection on skim and 2% fat milks. *J. Dairy Sci.* 100:1688-1701.
- Leong, C.M.O, B.R. Harte, J.A. Partridge, D.B. Ott, and T.W. Downes. 1992. Off-flavor development in milk packaged in polyethylene-coated paperboard cartons. *J. Dairy Sci.* 75:2105-2111.
- Levin, I.P. and G.J. Gaeth. 1988. How consumers are affected by the framing of attribute information before and after consuming the product. *J. Consumer Res.* 15:374-378.
- Li, X.E., K. Lopetcharat, and M.A. Drake. 2014. Extrinsic attributes that influence parents' purchase of chocolate milk for their children. *J. Food Sci.* 79:S1407-S1415.
- Li, X.E., K. Lopetcharat, Y. Qiu, and M.A. Drake. 2015a. Sugar reduction of skim chocolate milk and viability of alternative sweetening through lactose hydrolysis. *J. Dairy Sci.* 98:1455-1466.
- Li, B., J.E. Hayes, and G.R.Ziegler. 2015b. Maximizing overall liking results in a superior product to minimizing deviations from ideal ratings: an optimization case study with coffee-flavored milk. *Food Qual. Prefer.* 42:27-36.
- Liem, D.G., A.N, Toraman, E.H. Zandstra. 2012. Effects of health labels on expected and actual taste perception of soup. *Food Qual. Pref.* 25:192-197.
- Lindley, D.V. and M.R. Novick. 1981. The role of exchangeability in inference. *Ann. Stat.* 9:45-58.
- Louviere, J. J., and G. G. Woodworth. 1990. Best-worst scaling: A model for largest difference judgments. Working Paper, Department of Marketing and Economic Analysis. Univ. of Alberta, Canada.

- Lusk, J. L., and N. Parker. 2009. Consumer preferences for amount and type of fat in ground beef. *J. of Agr. App. Econ.* 41:75-90.
- Lofgren, M. and L. Witell. 2008 Two decades of using Kano's theory of attractive quality: A literature review. *Quality Management Journal.* 15:59-75.
- MacFie, H. J. H., and D.M.H. Thomson. 1988. Preference mapping and multidimensional scaling. In: J. R. Piggott, *Sensory analysis of foods.* New York: Elsevier Applied Science.
- Mahajan, S.S., L. Goddik, and M.C. Qian. 2004. Aroma compounds in sweet whey powder. *J. Dairy Sci.* 87:4057-4063.
- McCarthy, K.S., K. Lopetcharat, and M.A. Drake. 2017a. Milk fat threshold determination and the effect of milk fat content on consumer preference for fluid milk. *J. Dairy Sci.* 100:1702-1711.
- McCarthy, K.S., M. Parker, A. Ameerally, S.L. Drake, and M.A. Drake. 2017b. Drivers of choice for fluid milk versus plant based alternatives: what are consumer perceptions of fluid milk? *J. Dairy Sci.* 100:6125-6138.
- McLean, K.G., 2016. Alternative sensory methods for evaluation of consumer liking. MS Thesis. North Carolina State University. Raleigh, NC.
- McLean, K. G., D. J. Hanson, S. M. Jervis, and M. A. Drake. 2017. Consumer perception of retail pork bacon attributes using adaptive choice-based conjoint analysis and maximum differential scaling. *J. Food Sci.* 82:2659-2668.
- McMahon, K.M., C. Culver, J.C. Castura, and C.F. Ross. 2017. Perception of carbonation in sparkling wines using descriptive analysis (DA) and temporal check-all-that-apply (TCATA). *Food Qual. Pref.* 59:14-26.
- Mela, D. J. 1988. Sensory assessment of fat content in fluid dairy products. *Appetite* 10:37-44.
- Méhot-Hains, S., S. Benoit, C. Bouchard, A. Doyen, L. Bazinet, and Y. Pouliot. 2016. Effect of transmembrane pressure control on energy efficiency during skim milk concentration by ultrafiltration at 10 and 50°C. *J. Dairy Sci.* 99:8655-8664.
- Misawa, N., D.M. Barbano, and M.A. Drake. 2016. Influence of casein as a percentage of true protein and protein level on color and texture of milks containing 1 and 2% fat. *J. Dairy Sci.* 99:5284-5304.
- Muggah, E.M. and M.B. McSweeney. 2017. Females' attitude and preference for beer: a conjoint analysis study. *Int. J. Food Sci. Tech.* 52:808-816.
- Murray, J. M., C. M. Delahunty, and I. A. Baxter. 2001. Descriptive sensory analysis: past, present and future. *Food Res. Inter.* 34:461-471.

- Oltman, A. E., K. Lopetcharat, E. Bastian, and M. A. Drake. 2015. Identifying key attributes for protein beverages. *J. Food Sci.* 80:S1383–S1390.
- Orme, B. 2010. Interpreting the results of conjoint analysis. Pages 77-88 in *Getting Started with Conjoint Analysis: Strategies for Product Design and Pricing Research*. Research Publishers. Madison, WI.
- Orme, B. and R.M. Johnson. 2013. *The CBC System for Choice-Based Conjoint Analysis*. Technical Paper Series. Sawtooth Software.
- OTA. 2017. *U.S. Organic Industry Survey 2017*. Organic Trade Association. Washington, DC.
- Ott, D.B., C.L. Edwards, and S.J. Palmer. 1991. Perceived taste intensity and duration of nutritive and non-nutritive sweeteners in water using time-intensity (T-I) evaluations. *J. Food Sci.* 56:535-542.
- Özer, B.H., and H.A. Kirmaci. 2010. Functional milks and dairy beverages. *Int. J. Dairy Sci.* 63:1-12.
- Paige, D.M., T.M. Bayless, S. Huang, and R. Wexler. 1975. Lactose hydrolyzed milk. *Am. J. Clin. Nutr.* 28:818-822.
- Pangborn, R. M., K.E.O. Bos, and J.S. Stern. 1985. Dietary fat intake and taste responses to fat in milk by under, normal, and overweight women. *Appetite* 6:25-40.
- Pangborn, R.M., and W. L. Dunkley. 1964a. Difference-preference evaluation of milk by trained judges. *J. Dairy Sci.* 47:1414-1416.
- Pangborn, R. M., and W. L. Dunkley. 1964b. Sensory discrimination of fat and solids-not-fat in milk. *J. Dairy Sci.* 47:719-726.
- Pangborn, R. M., and M. E. Giovanni. 1984. Dietary intake of sweet foods and of dairy fats and resultant gustatory responses to sugar in lemonade and to fat in milk. *Appetite* 5:317-327.
- Park, C.W., E. Bastian, B. Farkas, and M.A. Drake. 2014. The effect of feed solids concentration and inlet temperature on the flavor of spray dried whey protein concentrate. *J. Food Sci.* 79:C19-C24.
- Paterson, M.E., 2016. Assessment of consumers' perceptions, preferences, behaviors and values with fluid milk packaging, code date and new product concepts. Doctoral dissertation. Iowa State University. Ames, IA.
- Phillips, L. G., M.L. McGiff, D.M. Barbano, and H.T. Lawless. 1995a. The influence of fat on the sensory properties, viscosity, and color of lowfat milk. *J. Dairy Sci.* 78:1258-1266.

- Phillips, L. G., M.L. McGiff, D.M. Barbano, and H.T. Lawless. 1995b. The influence of nonfat dry milk on the sensory properties, viscosity, and color of lowfat milk. *J. Dairy Sci.* 78:2113-2118.
- Pineau, N., P. Schlich, S. Cordelle, C. Mathonniere, S. Issanchou, A. Imbert, M. Rogeaux, P. Etievant, and E. Koster. 2009. Temporal dominance of sensations: construction of the TDS curves and comparison with time-intensity. *Food Qual. Pref.* 20:450-455.
- Porubcan, A. R., and Z. M. Vickers. 2005. Characterizing milk aftertaste: The effects of salivation rate, PROP taster status, or small changes in acidity, fat, or sucrose on acceptability of milk to milk dislikers. *Food Qual. Pref.* 16:608–620.
- Pouliot, F. 1993. Theoretical parallels between Kano's and Herzberg's theories. *Center for Quality of Management Journal.* 2:28-36.
- Poulsen, P. R. 1978. Feasibility of ultrafiltration for standardizing protein in milk. *J. Dairy Sci.* 61:807–814.
- Potts, H.L., K.N. Amin, and S.E. Duncan. 2016. Retail lighting and packaging influence consumer acceptance of fluid milk. *J. Dairy Sci.* 100:146-156.
- Public Health Service/Food and Drug Administration. 2015. Grade “A” Pasteurized Milk Ordinance. US Government Printing Office, Washington, DC.
- Quiñones, H. J., D. M. Barbano, and L. G. Phillips. 1997. Influence of protein standardization by ultrafiltration on the viscosity, color, and sensory properties of skim and 1% milk. *J. Dairy Sci.* 80:3142–3151.
- Quiñones, H. J., D. M. Barbano, and L. G. Phillips. 1998. Influence of protein standardization by ultrafiltration on the viscosity, color, and sensory properties of 2% and 3.3% milks. *J. Dairy Sci.* 81:884-894.
- Ramaswami, K., and A. Sailer. 2012. How to assess and customize service value for IT cloud services clients. Pages 676-678 in 2012 IEEE Ninth International Conference on Services Computing. June, 2012.
- Rao, V.R., 2010. Conjoint analysis. *Wiley International Encyclopedia of Marketing.*
- Rattray, W., and P. Jelen. 1996. Freezing point and sensory quality of skim milk as affected by addition of ultrafiltration permeates for protein standardization. *Int. Dairy J.* 1:569-579.
- Richardson-Harman, N.J, R. Stevens. S. Walker. J. Gamble, M. Miller, and A. McPherson. 2000. Mapping consumer perceptions of creaminess and liking for liquid dairy products. *Food Qual. Pref.* 11:239–246.

- Rozin, P. and H. Tuorila. 1993. Simultaneous and temporal contextual influences on food acceptance. *Food Qual. Pref.* 4:11-20.
- Sauerwein, E., F. Bailom, K. Matzler and H.H. Hinterhuber. 1996, February. The Kano model: How to delight your customers. In *International Working Seminar on Production Economics* (Vol. 1, No. 4, pp. 313-327).
- Schaap, J.E., and H.T. Badings. 1990. Extraction of flavors from milk fat with supercritical carbon dioxide. *J. Supercrit. Fluid.* 3:15-19.
- Schuppli, C.A., M.A.G. Von Keyserlingk, and D.M. Weary. 2014. Access to pasture for dairy cows: Responses from an online engagement. *J. Animal Sci.* 92:5185-5192.
- Smith, T.J., E.A. Foegeding, and M.A. Drake. 2016. Flavor and functional characteristics of whey protein isolates from different whey sources. *J. Food Sci.* 81:C849-C857.
- Tempesta, T., R.A. Giancristofaro, L. Corain, L. Salmaso, D. Tomasi, and V. Boatto. 2010. The importance of landscape in wine quality perception: An integrated approach using choice-based conjoint analysis and combination-based permutation tests. *Food Qual. Pref.* 21:827-836.
- Tepper, B. J., and T. Kuang. 1996. Perception of fat in a milk model system using multidimensional scaling. *J. Sens. Stud.* 11:175–190.
- Thompson, J.L., M.A. Drake, K. Lopetcharat, and M.D. Yates. 2004. Preference mapping of commercial chocolate milks. *J. Food Sci.* 69:S406-S413.
- Thomson, D. M., C. Crocker, and C.G. Marketo. 2010. Linking sensory characteristics to emotions: An example using dark chocolate. *Food Qual. Pref.* 21:1117-1125.
- Tomaino, R.M., L.G. Turner, and D.K. Larick. 2004. The effect of *Lactococcus lactis* starter cultures on the oxidative stability of liquid whey. *J. Dairy Sci.* 87:300-307.
- Trachoo, N. and V.V. Mistry. 1998. Application of ultrafiltered sweet buttermilk and sweet buttermilk powder in the manufacture of nonfat and lowfat yogurts. *J. Dairy Sci.* 81:3163-3171.
- Tunick, M.H. 2008. Whey protein production and utilization: a brief history. Pages 1-13 in *Whey Processing, Functionality, and Health Benefits*. C. Onwulata, and P.J. Huth, ed. Wiley-Blackwell.
- Tunick, M.H., A. Thomas-Gahring, D.L. Van Hekken, S.K. Iandola, M. Singh, P.X Qi, D.O. Ukuku, S. Mukhopadhyay, C.I. Onwulata, and P.M. Tomasula. 2016. Physical and chemical changes in whey protein concentrate stored at elevated temperature and humidity. *J. Dairy Sci.* 99:2372-2383.

- U.S. Dairy Export Council. 2006. Reference manual for U.S. whey and lactose products. U.S. Dairy Export Council. Arlington, VA.
- Valero, E., M. Villamiel, B. Miralles, J. Sanz, and I. Martinez-Castro. 2001. Changes in flavour and volatile components during storage of whole and skimmed UHT milk. *Food Chem.* 72: 51-58.
- Van Aardt, M., S.E. Duncan, J.E. Marcy, T.E. Long, and C.R. Hackney. 2001. Effectiveness of poly (ethylene terephthalate) and high-density polyethylene in protection of milk flavor. *J. Dairy Sci.* 84:1341-1347.
- Villegas, B., A. Tárrega and E. Costell. 2010. Optimizing acceptability of new prebiotic low-fat milk beverages. *Food Qual. Pref.* 21:234-242.
- Walsh, A.M., S.E. Duncan, H. Potts, and D.L. Gallagher. 2015. Comparing quality and emotional responses as related to acceptability of light-induced oxidation flavor in milk. *Food Res. Inter.* 76:293-300.
- Wardy, W., B. Mena, S. Nongtaodum, H.K. No, and W. Prinyawiwatkul. 2014. Exploring the drivers of purchase intent and consumer satisfaction of chicken eggs using principal component analysis and the Kano model. *J. Sens. Stud.* 29:463-473.
- Watson M.P., J.A. McEwan. 1995. Sensory changes in liquid milk during storage and the effect on consumer acceptance. *J. Soc. Dairy Technol.* 48:1-8.
- Wijnen, B.F.M., K.L. Cheung, I.L. Hollin, A.J. Colon, E.M. Janssen, J.F. Bridges, S.M.A.A. Evers, and M. Hiligsmann. 2016. Using best-worst scaling to investigate preferences in health care. *PharmacoEconomics.* 34:1195-1209.
- Whetstine, M.C., J.D. Parker, M.A. Drake, and D.K. Larick. 2003. Determining flavor and flavor variability in commercially produced liquid Cheddar whey. *J. Dairy Sci.* 86:439-448.
- Whetstine, M.C., A.E. Croissant, and M.A. Drake. 2005. Characterization of dried whey protein concentrate and isolate flavor. *J. Dairy Sci.* 88:3826-3839.
- Whitson, M., R.E. Miracle, E. Bastian, and M.A. Drake. 2011. Effect of liquid retentate storage on flavor of spray-dried whey protein concentrate and isolate. *J. Dairy Sci.* 94:3747-3760.
- Wilson, C.E., and W.E. Brown. 1997. Influence of food matrix structure and oral breakdown during mastication on temporal perception of flavor. *J. Sens. Stud.* 12:69-86.
- Yan, S.H., C.G. Hill, and C.H. Amundson. 1979. Ultrafiltration of white milk. *J. Dairy Sci.* 62:23-40.

## FIGURES

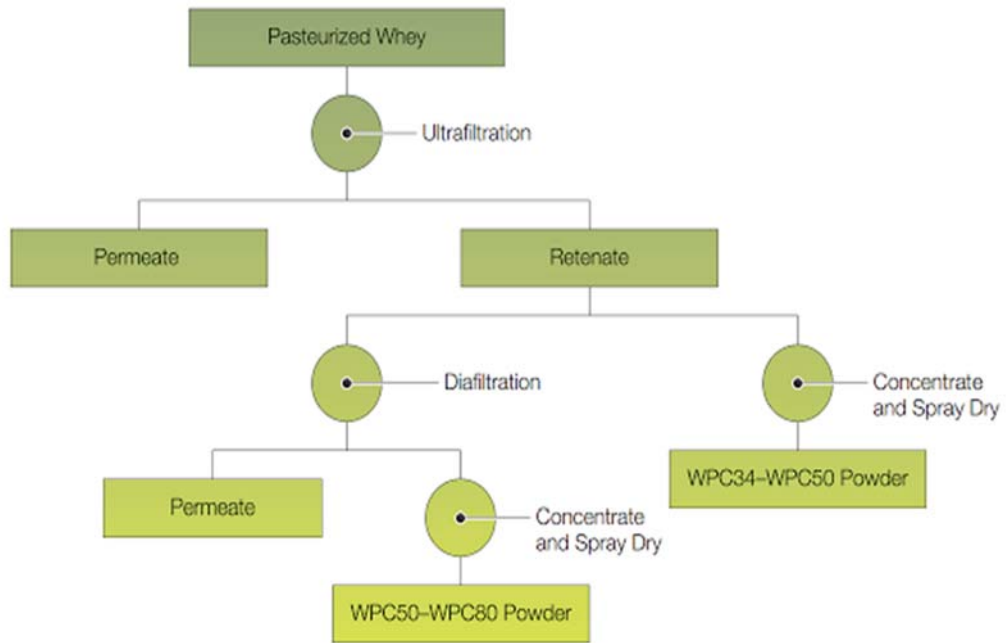


Figure 1. WPC processing overview (Taken from USDEC, 2006)

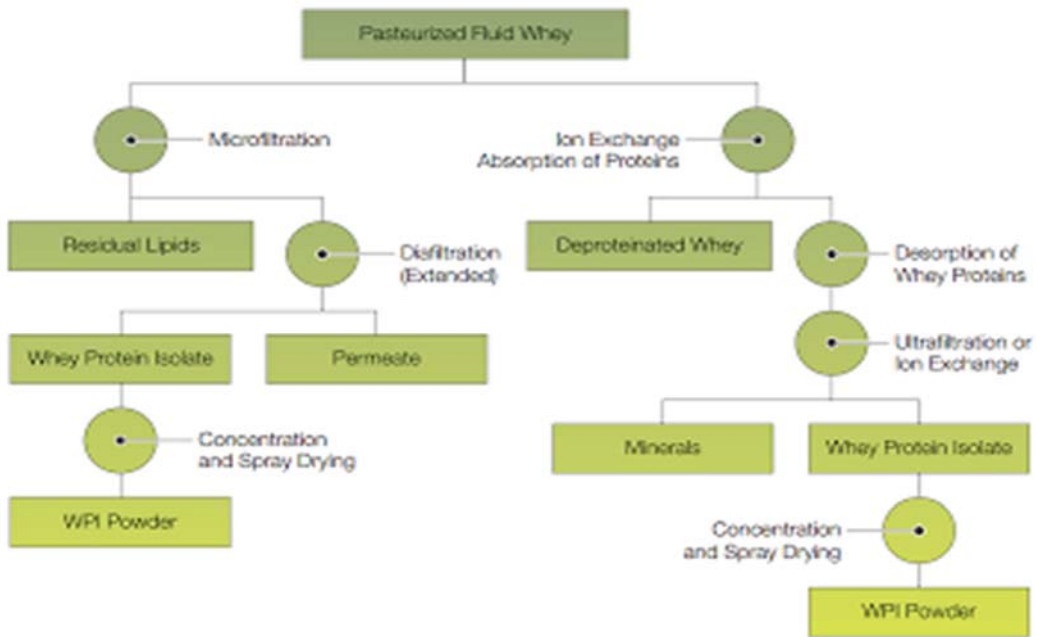


Figure 2. WPI processing overview (Taken from USDEC, 2006)

<i>Attribute</i>	<i>Level</i>	<i>Part-Worth Utility</i>	<i>Attribute Utility Range</i>	<i>Attribute Importance</i>
Brand	A	30	60 - 20 = 40	$(40/150) \times 100\% = 26.7\%$
	B	60		
	C	20		
Price	\$50	90	90 - 0 = 90	$(90/150) \times 100\% = 60.0\%$
	\$75	50		
	\$100	0		
Color	Red	20	20 - 0 = 20	$(20/150) \times 100\% = 13.3\%$
	Pink	0		
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <i>Utility Range Total</i>            40 + 90 + 20 = 150         </div>				

Figure 3. Calculating relative importance of attributes (Taken from Orme, 2010)

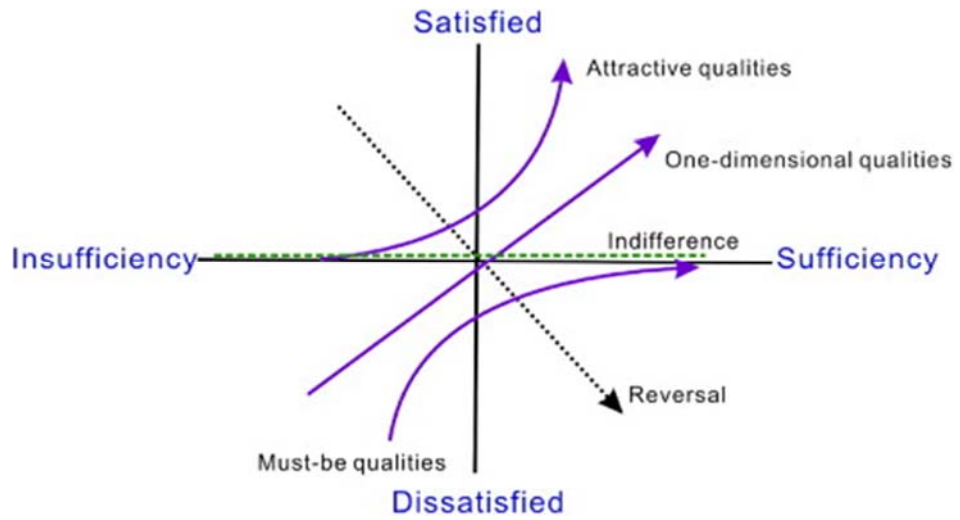


Figure 4. Kano model of customer satisfaction (Taken from Chen and Chuang, 2008).

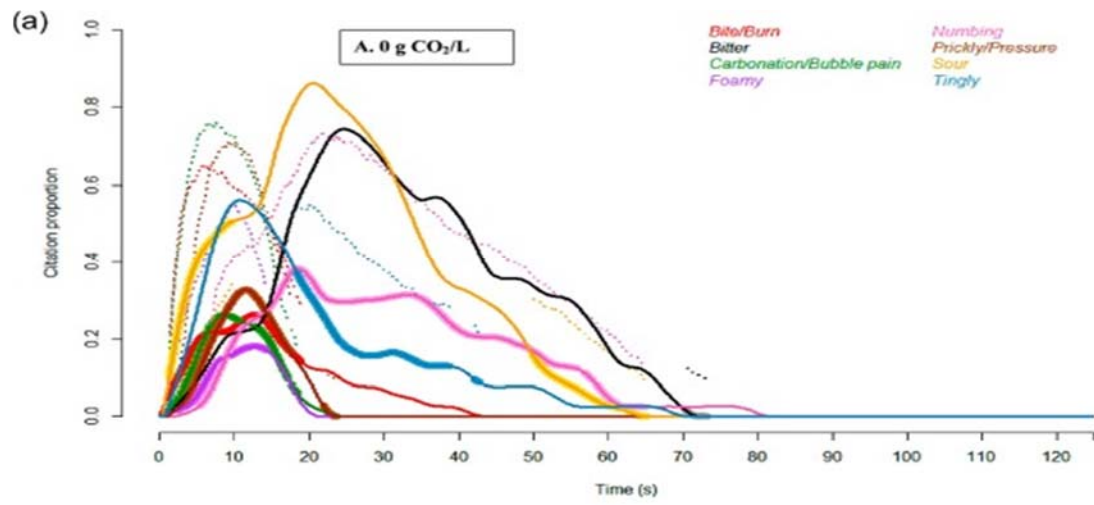


Figure 5. TCATA profile of sparkling wine sample (Taken from McMahon et al., 2017)

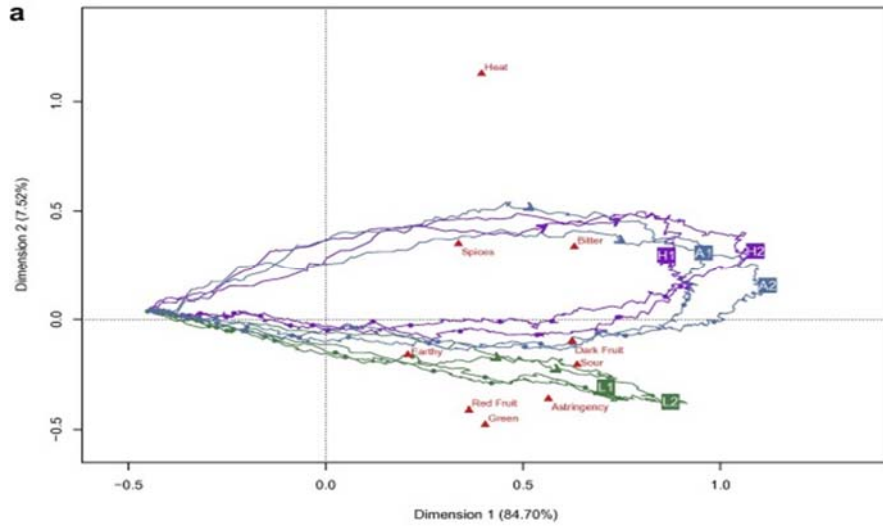


Figure 6. PCA trajectories of wine samples following TCATA analysis (Taken from Castura et al., 2016b)

## TABLES

Table 1. Kano model answer categorization guide (Taken from Pouliot, 1993)

Customer Requirements ↓		Dysfunctional				
		1. like	2. must-be	3. neutral	4. live with	5. dislike
Func- tional	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Customer Requirement is:

A: Attractive

M: Must-be

R: Reverse

O: One-dimensional

Q: Questionable result

I: Indifferent

**CHAPTER 2:**  
**IDENTIFICATION AND CHARACTERIZATION OF FLUID MILK**  
**CONSUMER GROUPS**

## **Identification and Characterization of Fluid Milk Consumer Groups**

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## **INTERPRETIVE SUMMARY**

Fluid milk is a staple product in the American household. Emerging trends and changing consumer ideals are changing the landscape of the fluid milk industry and the commercial products offered. This study investigated the attributes that fluid milk consumers find attractive and identified the reasons for purchase of organic fluid milk. Better insight into the preferences and motivating factors of purchase will enable fluid milk manufacturers to better target groups of consumers and better allocate their resources and efforts in the future market.

## ABSTRACT

Consumption of fluid milk has steadily declined over the last few decades. Understanding the attributes of fluid milk products that are attractive to specific consumer groups may provide a sound basis for education and marketing to encourage increased dairy consumption and reverse the downward trend. The objective of this study was to identify the attributes that specific consumer groups find attractive and attributes that suggest a higher purchase likelihood. An Adaptive Choice Based Conjoint (ACBC) survey was designed to assess attributes of fluid milk. The ACBC survey included Kano, importance, labeling identification, and emotions questions to determine the key attributes that dictated consumer purchase and consumption. Self-reported purchase habits and attitudes for organic food products were also collected. Attributes in the ACBC exercise included fat content, package type, shelf life, and label claims. Maximum Difference scaling (MaxDiff) was used to rank the importance of attributes in fluid milk that affected purchase. MaxDiff was also used to rank qualities and issues associated with organic milk that were most motivating for those who identified as organic milk consumers. Results were analyzed by univariate and multivariate statistics. A total of 1163 fluid milk consumers completed the survey and of those, 434 were regular purchasers of organic milk. The ideal fluid milk from conjoint analysis was 2% milkfat, organic, packaged in a plastic jug, conventionally pasteurized, and contained no additives or label claims. The belief that “organic milk is healthier” was the most important motivator for purchases of organic milk, followed by the beliefs that “organic milk production encourages ethical treatment of animals,” and “organic milk production supports local farms and farmers.” Conjoint importance scores of all fluid milk consumers showed that milkfat content was the most important attribute, followed by flavor, package size, and price. For all milk consumers, designation as “organic” was ranked as the 8<sup>th</sup>

most important of 14 attributes. Evaluation of these results on both aggregate and individual levels suggest that fluid milk consumers are not a homogeneous consumer group, and that underlying consumer groups are led to purchase decisions by specific product features or expectations.

Key Words: milk, organic milk, conjoint analysis, Kano, MaxDiff

## INTRODUCTION

Fluid milk is a product that is often treated as a dietary staple. However, fluid milk sales have decreased significantly in recent years, with a 2.6% decline observed in 2016 (DMI, 2017). Several reasons for the decline have been proposed, such as the growing popularity of milk alternatives, flavor concerns, and shelf life concerns (McCarthy et al., 2017a). While sales within the fluid milk category are generally in decline, sales of organic milk continue to climb. The U.S. organic industry has increased steadily over the last decade, reaching \$47 billion in sales in 2016 (OTA, 2017). Dairy is an important part of this movement and is currently the second most purchased organic food category, behind only fruits and vegetables (OTA, 2017). There have been relatively few studies that have sought to identify and profile the typical organic dairy user. McCarthy et al. (2017a) identified that some consumer groups had preference for organic designation relative to other label claims in fluid milk products. Similarly, consumer choice exercises have identified consumer segments with preference for organic designation in flavored milk products and other dairy beverages (Kim et al., 2013; Li et al., 2014; Oltman et al., 2015). The preference for organic designation in fluid milk is typically linked to increased willingness to pay a premium price (Smith et al., 2009; Schott and Bernard, 2015). Fluid milk label claims such as pasture-raised and rBST-free designations have been similarly associated with greater willingness to pay by certain consumer groups (Kolodinsky, 2008). With evidence of consumer interest in mind, further investigation and appropriate valuation of different features in commercially-offered fluid milk products is essential for milk producers in the modern market.

Multiple survey and auction methods have been suggested to be useful for understanding and measuring consumer perceptions relating to commercial products. Conjoint analysis is one such method that is particularly useful because it mimics the real-life trade-off scenarios that

consumers encounter in everyday life (Orme, 2010a). Conjoint analysis is a survey-based market research technique that uses complex statistical designs to derive the importance of product features using simple rating or choice exercises on randomly assembled product profiles. There are multiple types of conjoint analysis, such as menu-based choice (MBC), choice-based conjoint (CBC), and adaptive choice-based conjoint (ACBC), as well as many specific methodological applications for each type. For evaluation of commercial consumer goods, the most commonly used conjoint method is CBC. CBC surveys are conducted by comparing multiple product profiles at once and simply asking consumers to simulate a typical shopping experience by choosing one of the products from a set. This process is repeated multiple times until trends in consumer choice behavior can be effectively mapped and subjected to utility estimation (Orme, 2010a). While CBC surveys are effectively used market research initiatives, CBC surveys require price to be handled as a discrete level, making realistic price estimation difficult. Furthermore, sizeable CBC surveys may require large amounts of respondents which can be expensive and demanding of time and resources.

ACBC surveys are useful because they effectively engage respondents and assuage the concerns associated with CBC because they require fewer responses to estimate utility values (Chapman et al., 2009; Cunningham et al., 2010; Jervis et al., 2012). ACBC, like CBC, simulates a realistic consumer experience using discrete choice exercises. However, the ACBC software operates by utilizing an algorithm to analyze consumer responses during the survey and adapts upcoming exercises to best investigate the motivators behind consumer choice. In addition to lower sample size requirements, ACBC has been shown to be superior to CBC in evaluations including pricing attributes (Cunningham et al., 2010; Jervis et al., 2012). ACBC surveys have been effectively used to profile consumer desires for several food products such as sour cream

and bacon, and provided stable estimates of valuation for product features that were tested (Jervis et al., 2012; McLean et al., 2017). Using an ACBC survey, Kim et al. (2013) effectively investigated the effect of brand, packaging, and label claims for commercial chocolate milk products. In this way, ACBC shows its value because it can simultaneously estimate features that are intrinsic to a product such as size or flavor, as well as extrinsic features such as label claims.

Other effective methods for assessing consumer perceptions include Kano model analysis and Maximum Difference (MaxDiff) Scaling. Similar to conjoint analysis, MaxDiff employs the use of trade-off scenarios to determine consumer choice patterns, but lacks the multiattribute model that is used in conjoint. MaxDiff exercises are useful in research applications because they are easy to administer, easy for respondents to understand, and provide concise rankings and ratings for a list of items. In a MaxDiff experiment, subsets from a master list of items are presented and the respondent is asked to choose the “best” and “worst” option from the set (Louviere and Woodworth, 1990). Following several evaluations, and statistical analysis via multinomial logit or hierarchical Bayesian regression, an easy-to-understand ratio-scaled list of importance for the given attributes is produced. MaxDiff analysis has been applied in several food studies, including applications for products such as beer, wine, and ground beef (Lusk and Parker, 2009; Goodman et al., 2005; Chrysochou, 2014). McLean et al. (2017) also used MaxDiff exercises to better understand how consumers visually assessed lean-to-fat ratios in commercial bacon products. Unlike MaxDiff and conjoint exercises, Kano model analysis seeks to describe consumer sentiments about product features through assessment of their usefulness or function in response to the degree to which they are implemented (Kano et al., 1984). In practice, questions in the Kano model ask about the consumer’s feelings if a product feature is present versus how the how the consumer would feel if the feature was missing. The joint answers from

the functional and dysfunctional questions are then used to categorize the utility of the feature in question (Lofgren and Witell, 2008). Categorized Kano results provide valuable data on their own merits, but are particularly useful as a means for complementing and explaining the calculations from methods like conjoint analysis from a more qualitative perspective. Kim et al. (2013) used the Kano model in conjunction with conjoint analysis to understand consumer perspectives for chocolate milk and found that there was agreement between positive Kano classifiers and higher utility values. Kano model analysis has also been applied to numerous other food and beverage products including black beans, eggs, and cottage cheese (Kuo et al., 2014; Wardy et al., 2014; Hubbard et al., 2016).

The utilization of the aforementioned survey methodologies, whether administered on their own, or conjunctively with other methods, have been shown to be useful for profiling and understanding food and beverage consumers. While many studies on fluid milk have addressed features that are attractive in fluid milk, there is limited understanding on how exactly these sentiments are linked to the consumer. Furthermore, there has been no holistic assessment of consumers who purchase organic fluid milk that explains purchase behavior, preferences, and belief systems concurrently. The objectives of this study were to identify the unique drivers of liking for fluid milk products, explain motivations for purchase outside of convention, and to compare the differences among different consumer groups.

## **MATERIALS AND METHODS**

### **Experimental Overview**

An online survey using Adaptive Choice-Based Conjoint (ACBC), Maximum Difference (MaxDiff) scaling, and Kano analysis was conducted. Estimation of attribute values were determined using multinomial regression techniques and were subjected to cluster analysis for

elucidating purchase motivations in unique consumer groups. Participants who completed the entire survey were entered into a drawing to receive one of 15 \$25 gift certificates to a local store. All survey procedures were conducted in compliance with North Carolina State University Institutional Review Board (NCSU IRB) regulations.

## **Survey**

An online survey was developed using Lighthouse Studio (Sawtooth Software version 9.5.3, Orem, UT). The survey was uploaded to a database maintained by the North Carolina State University Sensory Service Center, which consists of over 10,000 consumers. Survey participants (n=1407) who were 18 years of age or older were able to enter the survey. Participants who reported consumption/purchase of fluid milk at least once a month (n=1163) were directed to participate in the conjoint analysis exercise and subsequent survey sections. In addition, participants who reported they were at least “occasional” organic consumers, and specifically reported purchase and consumption of organic milk (n=434) were directed to a supplemental MaxDiff exercise for understanding the principles that motivated organic milk purchase.

An adaptive choice-based conjoint (ACBC) was used. The attributes and levels for this survey (Table 1) were designed to be easily understood by consumers. The ACBC exercise consisted of 6 total attributes with two to five levels per attribute. The attributes examined in the survey included fat content, milk type, package type, shelf life, label claim, and price. Within fat content, the levels used were skim, 1% milkfat, 2% milkfat, and whole milk. Within the milk type attribute, the levels used were conventional, organic, locally farmed, pasture-raised, and organic pasture-raised. Within the package type attribute, the levels used were plastic jug and cardboard carton packaging. Within the shelf life attribute, the levels were identified and defined

as conventional pasteurization (18-21 days of refrigerated shelf life), ultrapasteurization (50-65 days refrigerated shelf life), and shelf-stable (no refrigeration). Within the label claims attribute, the levels used were rBST-free, DHA-fortified, rBST-free & DHA-fortified, and “none”. The survey was designed with a single build-your-own (BYO) task, followed by eight choice tasks with four product concepts per task and available responses of “a possibility” or “won’t work for me” for each product concept. All product concepts were displayed and compared as half-gallon fluid milk products.

To assess the price attribute in this study, summed pricing was used to account for levels that warranted a price premium. Summed pricing within ACBC surveys has been suggested to generate more realistic product concepts (Cunningham et al., 2010). Level components that were given a price premium in this study were the following: organic, locally farmed, pasture-raised, organic pasture-raised, rBST-free, DHA fortified, and rBST-free and DHA fortified. Base price of a fluid milk product and level-specific price premiums were determined heuristically from a survey of fluid milk prices at grocery stores located in Raleigh, NC. Redundant product features, such as organic and rBST-free, were not counted doubly in price calculation for the product concepts. Within the conjoint exercise, each price premium was figured into the overall price displayed at +/- 30% of the determined price. The sum of base price and all applicable price premiums was presented as the displayed price for each product concept. Component prices were shown during the BYO exercise to encourage realistic product builds, but component prices were not shown in the screening or choice-tournament exercises. Each product concept in the 8 choice tasks was a random generation of levels within each attribute that differed from the participant’s BYO product build by three attributes. To refine available levels and tailor subsequent portions of the conjoint survey to each participant, five unacceptable and four must-have questions were

built in to the screening portion of the survey, in accordance with recommendations built in to the software (Orme, 2009). The screening task was followed by a 10-question choice task tournament section. A maximum of 20 product concepts were brought into the tournament section, with three concepts per choice task.

Two MaxDiff exercises were implemented in the survey following the conjoint exercise. The first MaxDiff consisted of 14 fluid milk attributes and was asked to all fluid milk consumer respondents (n=1163). While conjoint results effectively characterize consumer choice between levels within the same attribute and compare attributes via calculated importance scores, MaxDiff scaling was employed with the goal of providing direct comparisons across attributes. These MaxDiff scores were analyzed within the conjoint-determined clusters to help further characterize unique consumer groups. The exercise was designed as eight sets of best-worst questions, with five randomly displayed attributes per set. Respondents were asked to choose a single attribute as “most important” and a single attribute as “least important” for each set. In addition, a second MaxDiff exercise was administered to respondents who self-reported themselves as organic milk purchasers/consumers (n=434) to better understand the underlying motivations for organic purchase of milk and dairy products. This task was asked at the end of the survey and involved 12 qualities/issues related to organic dairy purchase. The design of the second MaxDiff exercise matched the parameters of the first MaxDiff exercise.

Kano questions were asked after the first MaxDiff exercise; questions contained the same elements as the conjoint survey, with questions about all-natural, GMO-free, humanely raised, branded, protein-fortified, lactose-free, and vitamin fortified milks added. All fluid milk survey respondents (n=1163) participated in Kano analysis questions. Respondents were asked about milk attributes in both a constructive (for example, “A fluid milk product that is organic”) and a

reductive form (for example, “A fluid milk product that is not organic”). Response options for each question included ‘I will like it’, ‘I must have it’, ‘I do not care’, ‘I can live with it’ and ‘I will dislike it’ and were used to determine classification for the given attribute (Xu et al., 2009). Kano classifications included: **Attractive**: typically unexpected by consumer and result in increased satisfaction when fulfilled; **Must-Have**: expected by consumer and lead to dissatisfaction if not fulfilled; **One-Dimensional**: a linear relationship exists between fulfillment and satisfaction; **Rejecter**: consumers are indifferent if the feature is not present and dissatisfied if it is present; **Indifferent**: consumer is not interested or affected by the feature, whether it is present or absent.

### **Statistical Analysis**

Individual utility scores from the conjoint survey, as well as MaxDiff scores were determined via hierarchical Bayesian (HB) regression. Additionally, root likelihood (RLH) values were determined for each respondent from the conjoint survey and respondents that received an RLH value of 0.333 or lower were removed to ensure quality data was collected and reported. To analyze mean values and test for significant differences between utility scores and importance scores, a one-way analysis of variance with Fisher’s least significant difference (95% confidence) was applied. Cluster analysis of individual utility scores was performed with XLSTAT (version 19.5.2018, Addisoft, Paris, France) using Euclidean distances and Wards linkage to categorize similar respondents into groups. Kano questions were evaluated according to the model proposed by Kano et al. (1984). Utilization of correspondence analysis (CA) was suggested by Lillestøl (1991) as a viable method for analysis of categorized Kano model results for elucidating product sentiments not captured by traditional Kano model characterization and was applied to Kano results. Count data from Kano analysis was subjected to CA in XLSTAT to

further characterize the consumer clusters derived from the conjoint exercise. All analyses were performed at 95% confidence ( $p < 0.05$ ).

## **RESULTS AND DISCUSSION**

### **Conjoint Survey**

No respondents from the conjoint exercise had a root likelihood value below 0.333, so all responses were used in HB regression analysis. Utility estimates from HB analysis are reported as zero-centered differences and higher scores indicate relatively more appealing levels within an attribute (Orme, 2010a). Based on average utility estimations, the ideal fluid milk build for the milk consumers surveyed ( $n=1163$ ) was a 2% organic milk that was conventionally pasteurized, had no label claims, and was packaged in a plastic jug (Table 2). Price was the most important attribute ( $p < 0.05$ ), followed by fat content ( $p < 0.05$ ), milk type and shelf life, which were at parity ( $p > 0.05$ ), and finally, label claims and packaging, which were at parity ( $p > 0.05$ ) (Figure 1). Within the fat content attribute, a preference for reduced-fat milks was observed in the overall population, with 2% milkfat receiving the highest utility ( $p < 0.05$ ), followed by 1% milkfat. Skim milk and whole milk received lower utility scores by a significant margin ( $p < 0.05$ ) (Figure 1). Consumer preference for reduced-fat fluid milks mirrors the breakdown of current market volume shares by fat content in the commercial fluid milk category (DMI, 2017). Consumer sentiments regarding packaging type were of low importance overall; however, the overall population gave a higher average utility to plastic jug packaging than for cardboard cartons ( $p < 0.05$ ). Regarding milk type levels, respondents displayed generally higher utilities towards products outside of the convention fluid milk option; specifically, organic milk received the highest utility score ( $p < 0.05$ ), followed by locally farmed milk. Conventional milk received the lowest utility score within the milk type attribute ( $p < 0.05$ ). Consumer interest for locally farmed

milk is likely due to the fact that “local” designation is often associated with environmental benefit or support for the local economy (Zepeda and Leviten-Reid, 2004). In addition, McCarthy et al. (2017a) showed that environmental concerns were a primary reason consumers chose plant-based milk alternatives instead of fluid milk. Results from that study, coupled with the relatively high utility for local designation found in this study, suggest that promotion of local designation in fluid milk may be important in dissuading some consumers from exploring fluid milk alternatives. Regarding pasteurization method, conventional pasteurization (~18-21 day shelf life) received the highest utility score ( $p < 0.05$ ), followed by ultrapasteurization. For the label claims attribute, the overall population gave the “none” option the highest utility ( $p < 0.05$ ), indicating minimal interest in added components such as DHA or rBST-free status. Although rBST-free labeling had a significantly lower utility than the “none” option, it should be noted that the preference for organic milk expressed by the overall population may have been influenced by the understanding that organic designation includes rBST-free as a component. These sentiments were reported by Bernard and Bernard (2009), who showed that many fluid milk consumers do find an added value from rBST-free designation, but often opt to pay the premium for organic instead because of perceived added value from other aspects related to organic labeling.

Raw utility scores derived from the ACBC survey were subjected to k-means clustering and four distinct consumer groups were identified (Figure 2). Clusters were given the following names heuristically based on their results from the exercises throughout the study: the Premium Cluster ( $n=352$ ), Opportunistic Cluster ( $n=393$ ), Value Cluster ( $n=234$ ), and the Basics Cluster ( $n=184$ ). Overall, each cluster showed similar trends in allotted importance for fluid milk attributes, with an increased price importance corresponding with a proportional decrease in

importance for all other attributes (Figure 3). Several studies have suggested that price sensitivity for fluid milk primarily mirrors consumer disposable income (Jones et al., 2003; Alviola and Capps, 2010). While there appeared to be a slight trend between income and price sensitivity for consumer clusters in this survey, there was no observed difference in proportion of respondents that fell into each income bracket within the clusters ( $p>0.05$ ). These results suggest that factors outside of price such as consumer demographics, fluid milk product availability, past experience, and belief systems may play a part in purchase habits for consumer subgroups (Zepeda et al., 2003; McCarthy et al., 2017a). Premium Cluster ( $n=352$ ) respondents placed significantly higher importance on all attributes outside of price ( $p<0.05$ ) and were least price sensitive, compared to other groups (Figure 4). In addition, Premium respondents were defined by a preference for fat-containing fluid milk products (relative aversion to skim milk), high utility for organic/pasture-raised products, and preference for conventionally pasteurized fluid milk products. Opportunistic Cluster ( $n=393$ ) respondents were primarily driven by price and showed minimal discrimination between different fluid milk products and options, although a preference for locally-farmed milk was expressed. Value Cluster ( $n=234$ ) respondents were defined by high price sensitivity, a relative aversion to whole milk, and preference for locally-farmed milk. Basics Cluster ( $n=184$ ) respondents showed high price sensitivity, the highest approval for conventional milk ( $p<0.05$ ), and were significantly more likely ( $p<0.05$ ) than other groups to choose the “none” option for label claims.

The utilities derived from the conjoint analysis exercise successfully identified unique purchase habits for the identified clusters; however, assessment of the demographic and usage data further explained the motivations and restrictions experienced by those groups (Figure 2). Evaluation of demographic information by cluster revealed that respondents in the Premium

Cluster were defined by relatively high annual income, high education, and a greater likelihood of reporting a lifestyle that includes frequent exercise and a healthy diet. Furthermore, the Premium Cluster had a high frequency of respondents who self-reported as organic consumers. This might explain why the Premium Cluster was the least price sensitive and most likely to explore purchase of organic and other value-added fluid milk products. Similar demographic breakdown and increased willingness to pay for organic fluid milks was also observed by Bernard and Bernard (2009) during auction-style experiments of fluid milk consumers. The Opportunistic Cluster was demographically similar to the Premium Cluster in terms of income, organic use, and education, but was more diverse in respects to gender, race, and exercise/dietary habits. The combination of demographic qualities and conjoint analysis results from the Opportunistic Cluster suggest that this group (the largest identified cluster in this study) consists of consumers who have an income that allows them to explore added-value product features, but generally maintain a sense of price-sensitivity and lean toward convention in regards to fluid milk purchase. The Value and Basics Clusters had similar purchase habits in the conjoint exercise, and were defined by high price sensitivity. In addition, both clusters had a significantly lower percentage of consumers who self-identified as organic consumers compared to the Premium and Opportunistic Clusters. Compared to Basics Cluster respondents, the Value Cluster had more ( $p < 0.05$ ) Caucasian respondents and more ( $p < 0.05$ ) female respondents; conversely, the Basics Cluster had more ( $p < 0.05$ ) non-Caucasian respondents than any other group. Furthermore, the Basics Cluster was characterized by respondents who reported a generally lower income, lower age, and less focus on diet and exercise compared to other groups. The similarities between the Value and Basics Clusters in respect to their conjoint results suggest that

demographics may not be an effective determinant of fluid milk purchase for all consumer groups (Zepeda et al., 2003; Chang et al., 2011).

### **Maximum Difference Scaling**

In the survey design, all fluid milk consumers (n=1163) were asked to participate in a MaxDiff exercise for scaling fluid milk product components (Table 3). Overall, MaxDiff scores for the general population matched very closely with the overall conclusions drawn from the conjoint exercise, suggesting stable consumer sentiments exist. The top three attributes in MaxDiff scaling for the overall population (n=1163) were, in order: Milk that has the fat content I usually buy, milk that tastes good, and milk that is low in price. One notable difference from conjoint results was that “Milk that is low price” was rated as only the 3<sup>rd</sup> most attractive feature, suggesting that fluid milk consumers either overstated the importance of price in the conjoint exercise, or have a reactionary response to explicitly listed price. An additional explanation may be that consumers do not associate fat content or taste with a price premium, and therefore feel price is a secondary concern to the more direct goal of buying a product that meets their tastes. Results in this study agree with previous literature which has shown that fluid milk consumers are typically rigid in their purchase of specific fat contents, although consumers often show preference for fluid milks with different fat contents than those they typically purchase in blinded tastings (Bakke et al., 2016; McCarthy et al., 2017a, McCarthy et al., 2017b). Of the 14 listed attributes, organic designation was rated as the 8<sup>th</sup> overall attribute, receiving a 4.95% MaxDiff score. While this seems at odds with the conjoint results that identified organic designation as an ideal product feature, it should be noted that the importance of organic is being compared to product-defining features such as fat content and acceptable flavor in the MaxDiff exercise.

Within the conjoint results, similar conclusions can be drawn, with the milk type attribute being ranked 3<sup>rd</sup> in importance behind price and fat content.

When analyzed by cluster, distinct similarities and differences were observed. For each cluster, the top two fluid milk features were fat content and flavor, respectively, and were followed by either package size or low price to round out the top 4 features. The Premium Cluster differentiated itself from other clusters with the rating of organic in the fifth position, receiving a MaxDiff score of 8.5%, which was significantly higher ( $p < 0.05$ ) than any other group; additionally, Premium Cluster respondents gave significantly more importance to pasture-raised and GMO-free designation compared to other groups, and put less importance on low price ( $p < 0.05$ ). The Opportunistic Cluster's MaxDiff scores were less directional than other groups. Save for vitamin content, the Opportunistic Cluster did not exhibit the highest or lowest score for any fluid milk feature. While ultimately unclear, these results suggest consumers in the Opportunistic Cluster may be interested in product details outside of conventional store-brand fluid milks, but only on a situational basis. The Value and Basics Clusters allotted the greatest importance to price ( $p < 0.05$ ), corroborating the conjoint analysis results. They also placed a significantly higher importance than the Premium and Opportunistic Clusters on features such as package size and long shelf life, suggesting a singular focus on low price and satisfaction of only basic utility for their fluid milk purchases. Interestingly, the interest in long shelf life determined by the MaxDiff exercise was not reflected in the conjoint results. Low utility of ultrapasteurized milk products is likely due to a lack of familiarity with ultrapasteurized fluid milk products, or from lack of understanding of the flavor impact imparted by ultrapasteurization (Oupadissakoon et al., 2009; Lee et al., 2017). In addition, the Basics Cluster had the highest MaxDiff score for milk that was store brand. This, in conjunction with the low score for organic, might suggest that

some consumers associate store brand fluid milk products with a lower likelihood of value-added inclusion and an associated price mark-up.

Consumers who reported at least occasional purchase/consumption of organic milk and dairy products were directed to an additional MaxDiff exercise with the goal of understanding the underlying motivations for organic dairy purchases (Table 4). Demographically, respondents who self-classified as organic milk and dairy users (n=434) showed marked differences from non-organic consumers (n=729). In terms of age, there was a higher proportion ( $p<0.05$ ) of respondents between 25 and 40 years of age, and a lower proportion ( $p<0.05$ ) of respondents aged 56 years or older in the organic user group compared to the non-organic group. There was also evidence that there were trends in ethnicity regarding organic use, with a higher proportion ( $p<0.05$ ) of non-Caucasian respondents and a lower proportion of Caucasian respondents within the organic user group compared to the non-organic group. The trend of non-Caucasian dairy consumers showing increased interest in organic products agrees with nationwide trends for Asian, Hispanic, and “other” ethnic groups to be more likely purchasers of organic fluid milk (Alviola and Capps, 2010). Age has been found to be unrelated to organic purchase likelihood and purchase frequency (Paul and Rana, 2012); however, results in this study suggest age may play a part in organic dairy purchase. No other demographic factors significantly differentiated organic and non-organic respondents, although questions about respondents’ personal beliefs and habits showed that organic respondents were more likely ( $p<0.05$ ) to report that they felt they consumed a “healthy” diet, whereas non-organic consumers were more likely ( $p<0.05$ ) to report “balanced” dietary habits.

Overall, the top motivating concepts reported by organic users were, in order, “Organic milk is healthier for me,” “Organic milk encourages the ethical treatment of animals,” and

“Organic milk production supports local farms and farmers.” The notion of organic milk being a healthier option (compared to conventional milk) was rated as the leading reason for organic purchase and mirrored the self-reported dietary habits of the organic user group; however, it is arguably the most misled conclusion, as the nutritional equivalence of organic and conventional milk has been addressed extensively (Woese et al., 1997; Kouba, 2003). Interestingly, the idea of organic milk purchase as a passively benevolent act (ethical animal treatment, local farm/farmer support, environmental sustainability) was reported as a highly motivating factor behind organic purchase, accounting for 35.1% of the purchase reasoning on average. Beliefs concerning animal welfare and the environment have consistently been cited as motivations for consumers to explore substitutes to conventional fluid milk, such as plant-based alternatives (McCarthy et al., 2017a). However, for fluid milk, it is hypothesized that some consumers equate organic designation with practices such as free-range farming and or rBST-free, and are willing to pay a price premium to assuage these concerns (Harper and Makatouni, 2002; Hill and Lynchehaun, 2002; Connor and Oppenheim, 2008). In addition, sentiments regarding desire to support local farms were particularly strong among organic consumers, accounting for 12.08% of organic dairy purchase reasoning among tested issues or beliefs. Outside of willingness-to-pay and valuation studies, very little is known about the perception of local designation as it relates to fluid milk. Choice experiments on blackberry preserves by Meas et al. (2014) suggest that consumer opinions of local products typically overlap with organic designation. Furthermore, conjoint experiments by Darby et al. (2008) suggest that consumers typically believe “local” to be interchangeable with terms such as “nearby” or “in-state” for produce products. Although it is likely similar overlap and understanding of local products may exist for fluid milk, the subject is largely unknown and is an area that requires further investigation. Overall, results of this

MaxDiff analysis suggest that although the idea of health/nutritional promotion is the leading reason for organic milk purchase, appeals to ideals outside of nutrition are also effective motivators. Furthermore, it is important to note that the ideals of animal welfare, local farm support, and environmental consciousness are not exclusive to organic fluid milk products alone and may impart a perceived added value on their own merits. Consumer education and effective product positioning may provide further benefits to the fluid milk industry.

### **Kano Model**

Kano analysis results were analyzed within the clusters derived from conjoint utility scores (Figures 5a-d). Overall, each cluster defined the majority of fluid milk features as being “Indifferent” attributes, with the exception of “Milk that tastes good,” which was chosen as an “One-Dimensional” attribute by each cluster. To further understand underlying trends that defined each cluster, CA was applied to each cluster Kano analysis count data. CA was utilized due to the fact that the Kano model is susceptible to having products described by multiple similar categorizations, which may result in misclassification (Sauerwein et al., 1996). Because the full spectrum of Kano categorizations is figured into CA biplots, a more clear representation of consumer sentiments is preserved. Results showed that Premium Cluster respondents (Figure 5a) strongly associated low price and humanely raised cows with must-have or one-dimensional classification, which was not shown in classical Kano categorization alone. In addition, attributes such as lactose-free, whole milk, and skim milk, were associated strongly with rejecter classification, and attributes such as organic, GMO-free, high protein, and pasture-raised showed modest classification as attractive. For the Opportunistic Cluster (Figure 5b), there was a strong association observed between must-have/one-dimensional characterization and features such as low price and humanely raised cows, similar to the Premium Cluster. Like the Premium Cluster,

the Opportunistic Cluster also exhibited strong association between rejecter attribute characterization and features such as whole milk and lactose-free. The sentiment of whole milk as a rejecter attribute is in line with current market standings, however, the universal dislike of lactose-free milk is likely because lactose-free milk products violate “all-natural” classification, which is a leading motivator for fluid milk purchase (McCarthy et al., 2017a). The Opportunistic Cluster differentiated itself from the Premium Cluster by associating attributes such as organic and GMO-free with relatively greater indifference. Evaluation of Kano results from the Value Cluster (Figure 5c) was characterized by strong rejection for whole milk, indifference for skim milk relative to Premium and Opportunistic Cluster respondents, and a strong association between price and one-dimensional characterization. Furthermore, Value Cluster members showed little differentiation in attribute characterization as indifferent or attractive, suggesting they felt no attributes warranted sentiment of added value. This included “all-natural” designation, which was perceived as more of a one-dimensional/must-have attribute in the Premium and Opportunistic Clusters. Value Cluster respondents exhibit a modest association of attractive characterization with pasture-raised and high protein features. Results from the Basics Cluster (Figure 5d) showed similar tendencies to the Value Cluster. The Basics Cluster was differentiated from other clusters by associating label claim features, such as GMO-free, pasture-raised, DHA-fortified, rBST-free, all-natural, and organic, with relatively more indifference and less attractive characterization. In general, these results validated conjoint utility estimation of price by cluster (Figure 4), with the Premium and Opportunistic Clusters showing less indifference to value-added features, and Value and Basics Clusters associating value-added features that may suggest higher prices, with indifference. In addition, Value and Basics Cluster respondents were relatively more interested in long shelf-life, compared to Premium and

Opportunistic Cluster members, although they assigned a lower importance score for the shelf-life attribute in the conjoint exercise. This inconsistency suggests that some consumer clusters may be unfamiliar with non-conventional pasteurization techniques and the shelf-life benefits they convey and indicates that further education of fluid milk consumers is warranted.

## **CONCLUSION**

Fluid milk is primarily viewed as a staple product, meaning its value is typically derivative of its utility. This belief is reflected in the overall population disproportional emphasis on attributes such as milkfat (nutrition) and price; however, unique attribute levels are clearly differentiators of purchase for certain consumer clusters. Premium Cluster respondents expressed interest in milk categories outside of convention such as organic and pasture-raised, the Opportunistic Cluster was characterized by interest in locally-farmed milk and moderate interest in added-value attributes, the Value Cluster expressed interest in locally-farmed milk, but was ultimately very price sensitive, and the Basics Cluster was almost entirely price-focused except for a slight interest in product details such as taste, size, and brand. Evaluation of demographics by cluster also suggested that factors such as income, education, and lifestyle habits may be significant indicators of ultimate purchase habits.

For organic fluid milk consumers, there are several different factors that motivate purchase of organic milk and dairy products. Many of the issues influencing organic consumers are rooted in the idea of enhanced nutrition/well-being, or beliefs of benevolence, such as environmental sustainability, ethical animal treatment, or local farm support. Utilization of sentiments from organic fluid milk consumers may act as guidance for marketing and education initiatives and may help product developers and fluid milk producers to better meet the needs of consumers in today's market.

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## REFERENCES

- Alviola, P.A. and O. Capps. 2010. Household demand analysis of organic and conventional fluid milk in the United States based on the 2004 Nielsen Homescan panel. *Agribusiness*, 26:369-388.
- Bakke, A.J., C.V. Shehan, and J.E. Hayes. 2016. Type of milk typically consumed, and stated preference, but not health consciousness affect revealed preferences for fat in milk. *Food Qual. Pref.* 49:92-99.
- Bernard, J.C. and D.J. Bernard. 2009. What is it about organic milk? An experimental analysis. *Am. J. Agric. Econ.* 91:826-836.
- Chang, C.H., N.H. Hooker, E. Jones, and A. Sam. 2011. Organic and conventional milk purchase behaviors in Central Ohio. *Agribusiness*, 27:311-326.
- Chapman, C.N., J.L. Alford, C. Johnson, R. Weidemann, and M. Lahav. 2009. CBC vs. ACBC: Comparing results with real product selection. Pages 199-206 in Sawtooth Software Inc. 2009 Sawtooth Software Conference Proceedings; Mar 25–27; Delray Beach, FL.
- Chrysochou, P. 2014. Drink to get drunk or stay healthy? Exploring consumers' perceptions, motives and preferences for light beer. *Food Qual. Pref.* 31:156-163.
- Conner, D.S. and D. Oppenheim. 2008. Demand for pasture-raised livestock products: Results from Michigan retail surveys. *J. Agribusiness*. 26:1-20.
- Cunningham, C. E., K. Deal, and Y. Chen. 2010. Adaptive choice-based conjoint analysis: A new patient-centered approach to the assessment of health service preferences. *Patient.* 3:257-273.
- Darby, K., M.T. Batte, S. Ernst, and B. Roe. 2008. Decomposing local: a conjoint analysis of locally produced foods. *Am. J. Agric. Econ.* 90:476-486.
- DMI. 2017. DMI Quarterly Retail Snapshot: Milk Q2 2017. Dairy Management Inc. Rosemont, IL.
- Goodman, S., Lockshin, L., and Cohen, E. 2005. Best-worst scaling: a simple method to determine drinks and wine style preferences. *International Wine Marketing Symposium 2005 Proceedings*; July 8-9; Sonoma, CA.
- Harper, G.C. and A. Makatouni. 2002. Consumer perception of organic food production and farm animal welfare. *Brit. Food J.* 104:287-299.
- Hill, H. and F. Lynchehaun. 2002. Organic milk: attitudes and consumption patterns. *Brit Food J.* 104:526-542.
- Hubbard, E.M., S.M. Jervis, and M.A. Drake. 2016. The effect of extrinsic attributes on liking of cottage cheese. *J. Dairy Sci.* 99:183-193.

- Jervis, S. M., J. M. Ennis, and M.A. Drake. 2012. A comparison of adaptive choice-based conjoint and choice-based conjoint to determine key choice attributes of sour cream with limited sample size. *J. of Sens. Stud.* 27:451-462.
- Jones, E., C. Akbay, B. Roe, and W.S. Chern. 2003. Analyses of consumers' dietary behavior: An application of the AIDS model to supermarket scanner data. *Agribusiness*, 19:203-221.
- Kano, N., N. Seraku, F. Takahashi, and S. Tsuji. 1984. Attractive quality and must be quality. *J. Jpn. Soc. Qual. Control.* 14:147-156.
- Kim, M.K., K. Lopetcharat, and M.A. Drake. 2013. Influence of packaging information on consumer liking of chocolate milk. *J. Dairy Sci.* 96:4843-4856.
- Kolodinsky, J., 2008. Affect or information? Labeling policy and consumer valuation of rBST free and organic characteristics of milk. *Food Policy.* 33:616-623.
- Kouba, M. 2003. Quality of organic animal products. *Livest. Sci.* 80:33-40.
- Kuo, C.M., S.H. You, and C.Y. Lu. 2014. Integration of the Kano and QFD model in health food development: using black beans as examples. *Qual. Quant.* 48:225-242.
- Lee, A.P., D.M. Barbano, and M.A. Drake. 2017. The influence of ultra-pasteurization by indirect heating versus direct steam injection on skim and 2% fat milks. *J. Dairy Sci.* 100:1688-1701.
- Li, X.E., K. Lopetcharat, and M.A. Drake. 2014. Extrinsic attributes that influence parents' purchase of chocolate milk for their children. *J. Food Sci.* 79:S1407-S1415.
- Lillestøl, J. 1991. Multivariate statistical methods for quality creation: a review. *Total Qual. Manag. Bus.* 2:291-304.
- Lofgren, M. and L. Witell. 2008 Two decades of using Kano's theory of attractive quality: A literature review. *Qual. Manag. J.* 15:59-75.
- Louviere, J. J., and G. G. Woodworth. 1990. Best-worst scaling: A model for largest difference judgments. Working Paper, Department of Marketing and Economic Analysis. Univ. of Alberta, Canada.
- Lusk, J. L., and N. Parker. 2009. Consumer preferences for amount and type of fat in ground beef. *J. of Agr. App. Econ.* 41:75-90.
- McCarthy, K.S., M. Parker, A. Ameerally, S.L. Drake, and M.A. Drake. 2017a. Drivers of choice for fluid milk versus plant-based alternatives: What are consumer perceptions of fluid milk? *J. Dairy Sci.* 100:6125-6138.

- McCarthy, K.S., K. Lopetcharat, and M.A. Drake. 2017b. Milk fat threshold determination and the effect of milk fat content on consumer preference for fluid milk. *J. Dairy Sci.* 100:1702-1711.
- McLean, K. G., D. J. Hanson, S. M. Jervis, and M. A. Drake. 2017. Consumer perception of retail pork bacon attributes using adaptive choice-based conjoint analysis and maximum differential scaling. *J. Food Sci.* 82:2659-2668.
- Meas, T., W. Hu, M.T. Batte, T.A. Woods, and S. Ernst. 2014. Substitutes or complements? Consumer preference for local and organic food attributes. *Am. J. Agric. Econ.* 97:1044-1071.
- Oltman, A.E., K. Lopetcharat, E. Bastian, and M.A. Drake. 2015. Identifying key attributes for protein beverages. *J. Food Sci.* 80:S1383-S1390.
- Orme, B.K. 2009. Fine-tuning CBC and adaptive CBC questionnaires. Sawtooth Software Research Paper Series. Sawtooth Software. Sequim, WA.
- Orme, B.K. 2010a. Pages 19-50 in *Getting started with conjoint analysis: strategies for product design and pricing research*. Research Publishers, LLC. Madison, WI.
- Orme, B.K. 2010b. Menu-based choice modeling using traditional tools. In *Sawtooth Software Conference Proceedings*, Sequim, WA.
- OTA. 2017. *U.S. Organic Industry Survey 2017*. Organic Trade Association. Washington, DC.
- Oupadissakoon, G., D.H. Chambers, and E. Chambers IV. 2009. Comparison of the sensory properties of ultra-high temperature (UHT) milk from different countries. *J. Sens. Stud.* 24:427-440.
- Paul, J. and J. Rana. 2012. Consumer behavior and purchase intention for organic food. *J. Consum. Market.* 29:412-422.
- Sauerwein, E., F. Bailom, K. Matzler, and H.H. Hinterhuber. 1996. The Kano model: How to delight your customers. *International Working Seminar on Production Economics*. 1: 313-327.
- Schott, L. and J. Bernard. 2015. Comparing consumer's willingness to pay for conventional, non-certified organic and organic milk from small and large farms. *J. Food Dist. Res.* 46:186-205.
- Smith, T.A., C.L. Huang, and B.H. Lin. 2009. Estimating organic premiums in the US fluid milk market. *Renew. Agr. Food Syst.* 24:197-204.
- Wardy, W., Mena, B., Nongtaodum, S., No, H.K., and Prinyawiwatkul, W. 2014. Exploring the drivers of purchase intent and consumer satisfaction of chicken eggs using principal component analysis and the Kano model. *J. Sens. Stud.* 29:463-473.

- Woese, K., D. Lange, C. Boess, and K.W. Bögl. 1997. A comparison of organically and conventionally grown foods—results of a review of the relevant literature. *J. Sci. Food Agric.* 74:281-293.
- Wolf, C.A., G.T. Tonsor, and N.J. Olynk. 2011. Understanding US consumer demand for milk production attributes. *J. Agr. Resour. Econ.* 36:326-342.
- Xu, Q., R.J. Jiao, X. Yang, M. Helander, H.M. Khalid, and A. Opperud. 2009. An analytical Kano model for customer need analysis. *Des. Stud.* 30:87-110.
- Zepeda, L., R. Douthitt, and S.Y. You. 2003. Consumer risk perceptions toward agricultural biotechnology, self-protection, and food demand: the case of milk in the United States. *Risk Analysis.* 23:973-984.
- Zepeda, L. and C. Leviten-Reid. 2004. Consumers' views on local food. *J. Food Dist. Res.* 35:1-6.

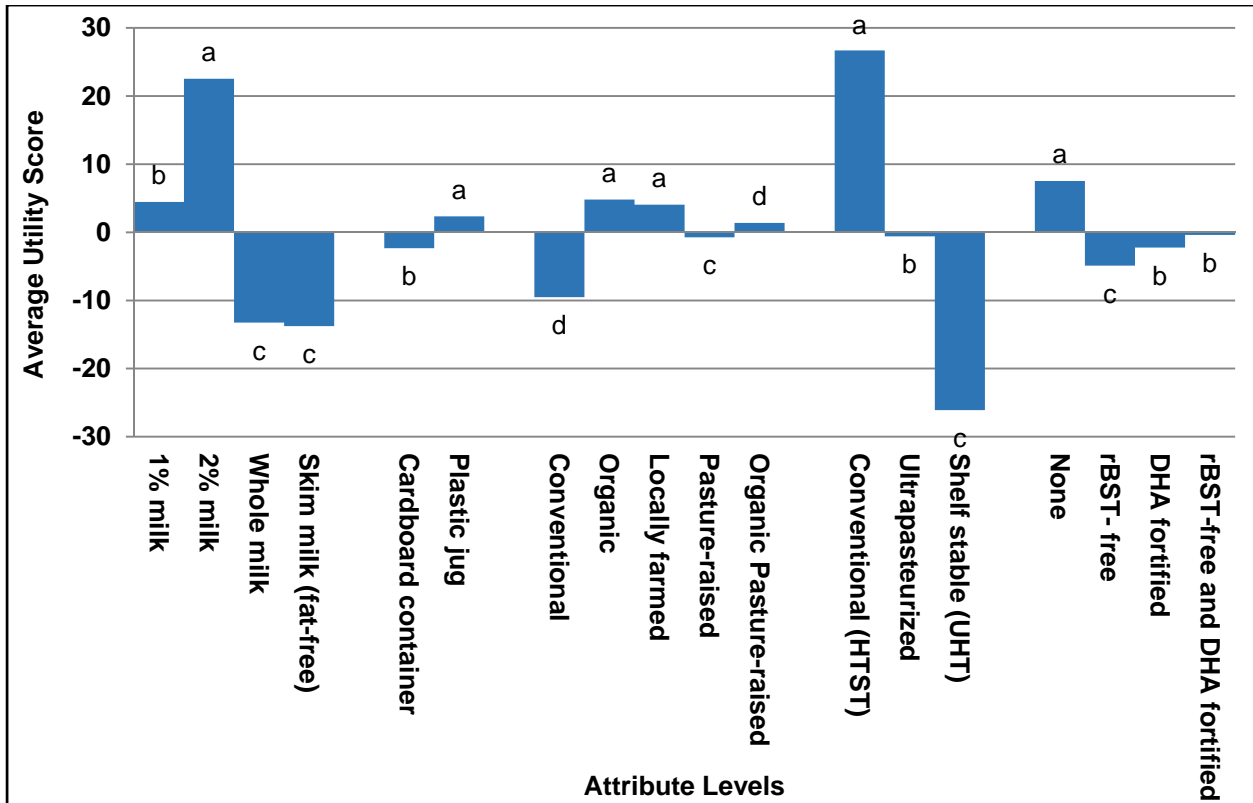


Figure 1. Utility scores for attribute levels for the total population (n=1163) from the fluid milk conjoint survey. Zero-centered utility values for levels within attributes. Letters (a-d) indicate significant differences ( $p < 0.05$ ) within each attribute for the total population.

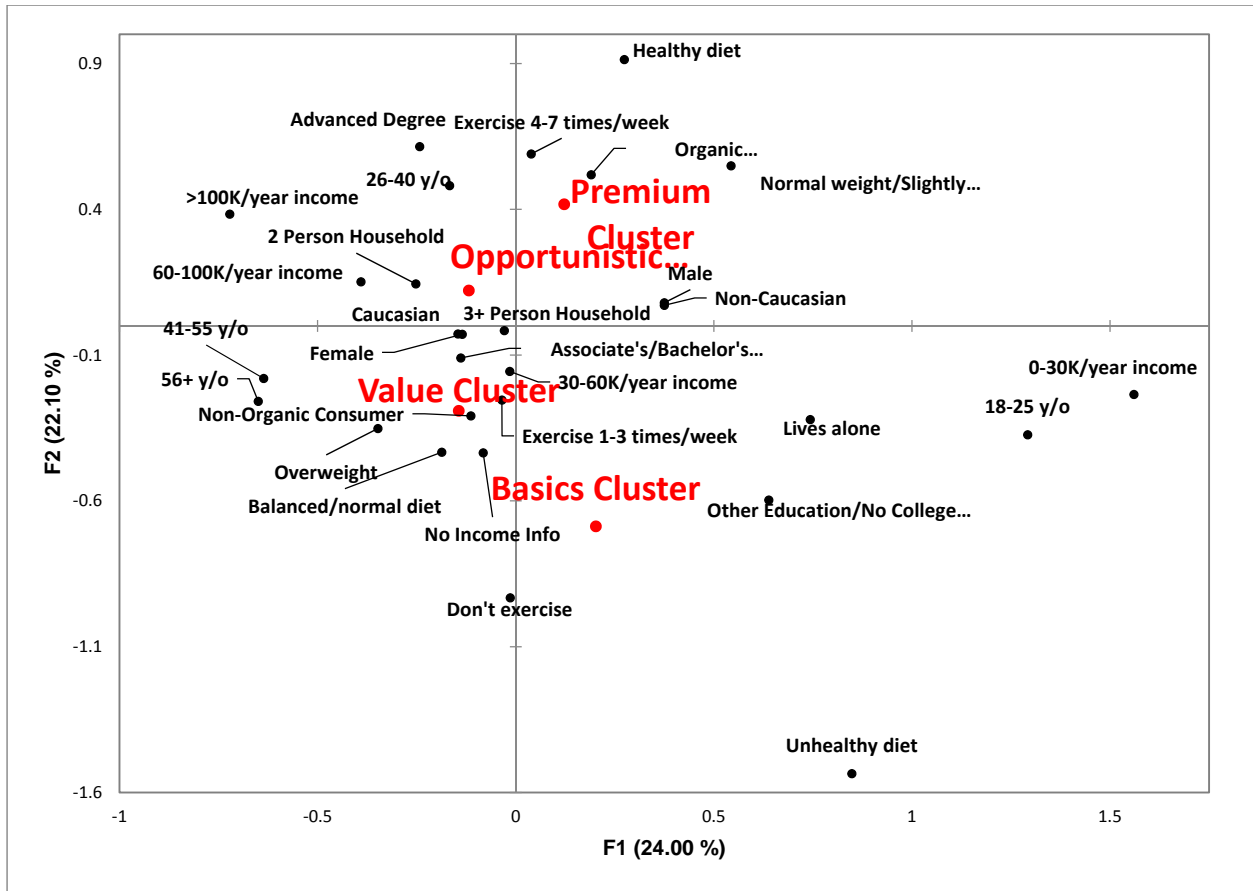


Figure 2. Multiple Correspondence Analysis (MCA) of demographic features for fluid milk consumer clusters (n=1163 total) derived from k-means clustering of individual utility scores. Household income is expressed numerically in thousands of U.S. dollars earned per year (K). Age group is expressed in years old (y/o).

Table 1. Attributes and levels used in fluid milk conjoint survey

Attribute	Fat Content	Milk Type	Package Type	Shelf Life*	Label Claims	Price
<b>Levels</b>	Skim	Conventional	Plastic jug	Conventional pasteurization (HTST) (~18-21 days)	None	Summed pricing
	1% Milkfat	Organic (\$2.37)	Cardboard carton	Ultrapasteurized (UP) (~30-65 days)	rBST-free (\$0.24)	
	2% Milkfat	Locally Farmed (\$1.00)		Shelf-stable (does not have to be refrigerated until opened)	DHA fortified (\$0.48)	
	Whole	Pasture-raised (\$1.76)			rBST-free and DHA fortified (\$0.72)	
		Organic pasture-raised (\$4.14)				

\*Definitions were explained in terms of refrigerated shelf life

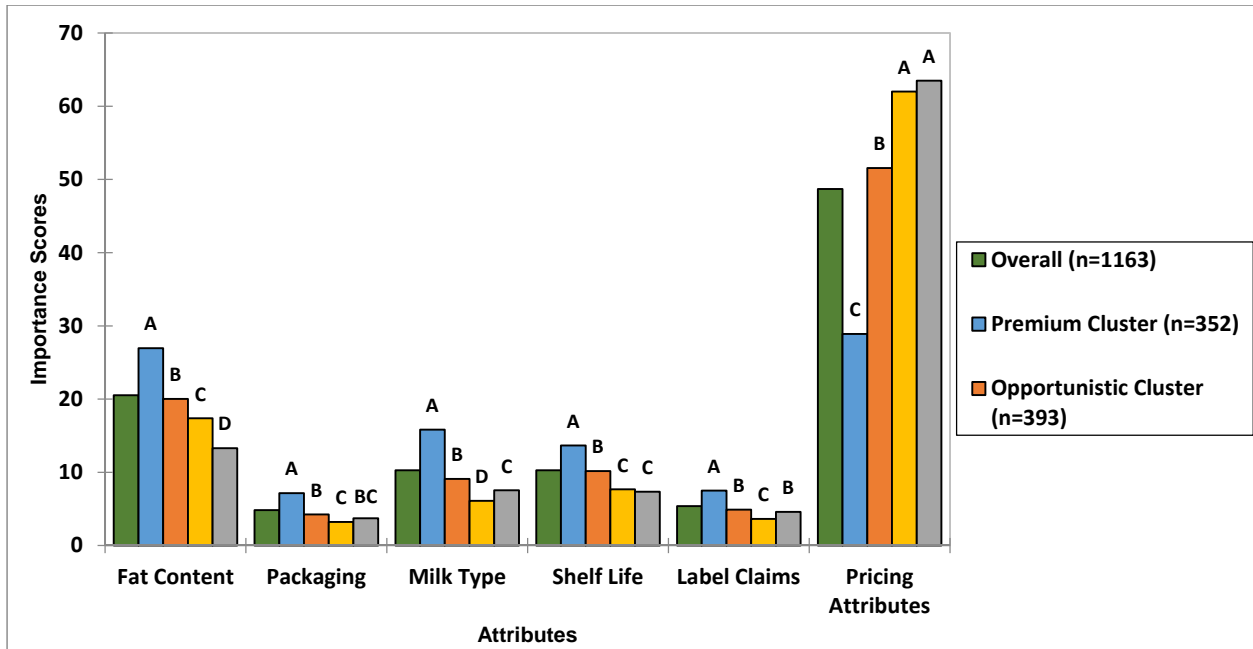


Figure 3. Attribute importance scores from fluid milk conjoint survey for segmented consumer clusters. Letters within attributes (a-d) indicate significant differences between clusters ( $p < 0.05$ ). \*Sum of importance score values for each cluster is 100 points total and scores are interpreted as ratio-scaled values.

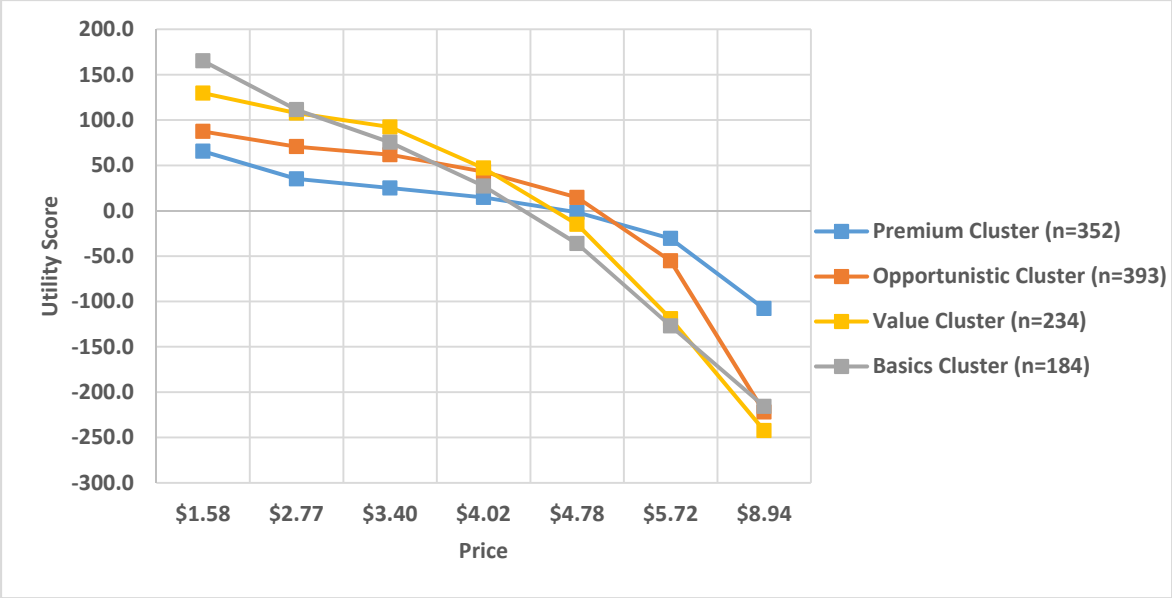


Figure 4. Price sensitivity for fluid milk products by segmented consumer cluster

Table 2. Ideal fluid milk product builds for the total population (n=1163) and for segmented consumer clusters

<b>Attribute</b>	<b>Fat Content</b>	<b>Milk Type</b>	<b>Package Type</b>	<b>Shelf Life</b>	<b>Label Claims</b>
<b>Overall</b>	2% Milkfat	Organic	Plastic jug	Conventional pasteurization (18-21 days)	None
<b>Premium Cluster (n=352)</b>	2% Milkfat	Organic pasture-raised	Cardboard carton	Conventional pasteurization (18-21 days)	None
<b>Opportunistic Cluster (n=393)</b>	2% Milkfat	Locally farmed	Plastic jug	Conventional pasteurization (18-21 days)	None
<b>Value Cluster (n=234)</b>	2% Milkfat	Locally farmed	Plastic jug	Conventional pasteurization (18-21 days)	None
<b>Basics Cluster (n=184)</b>	2% Milkfat	Conventional	Plastic jug	Conventional pasteurization (18-21 days)	None

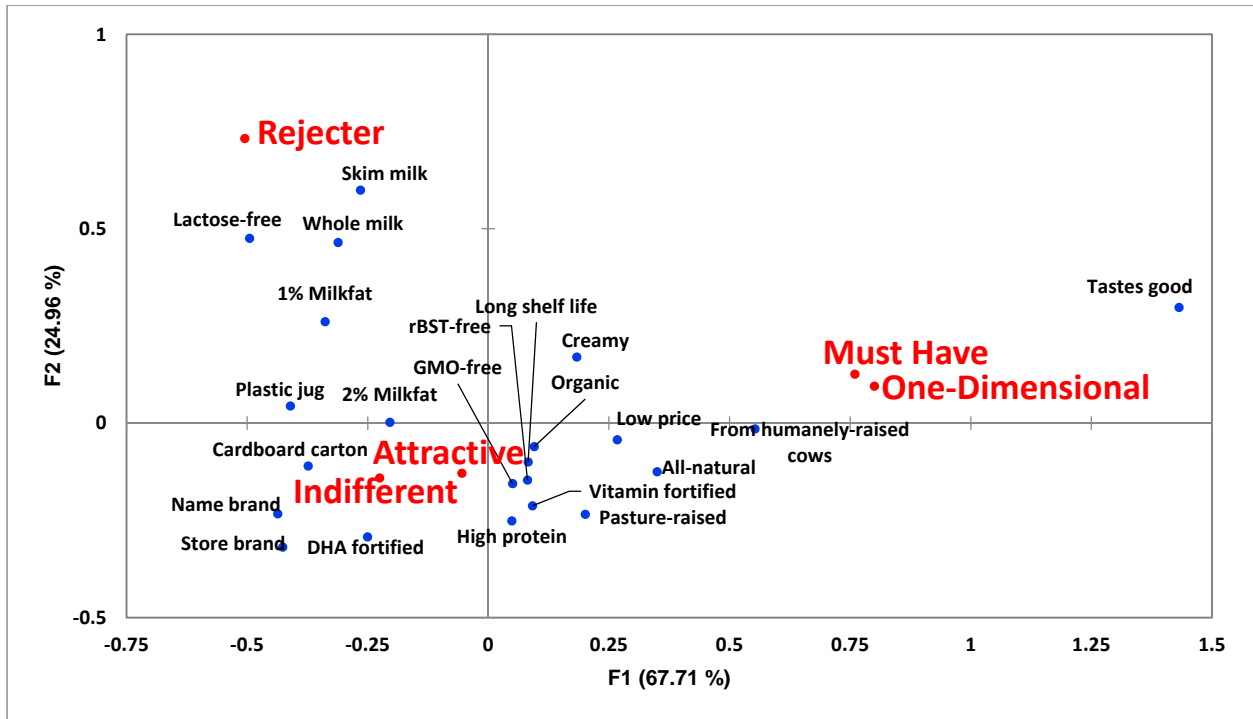


Figure 5a. Correspondence analysis biplot of Kano analysis counts for Premium Cluster (n=352) of fluid milk consumers.

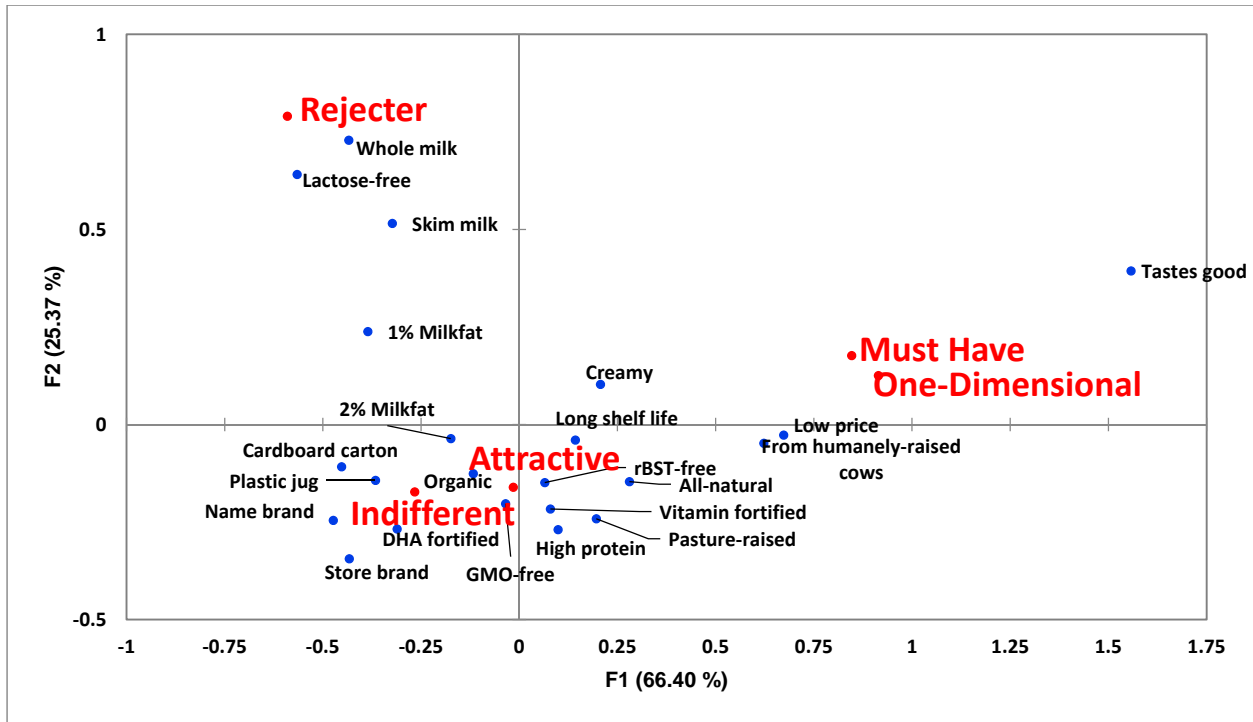


Figure 5b. Correspondence analysis biplot of Kano analysis counts for Opportunistic Cluster (n=393) of fluid milk consumers.

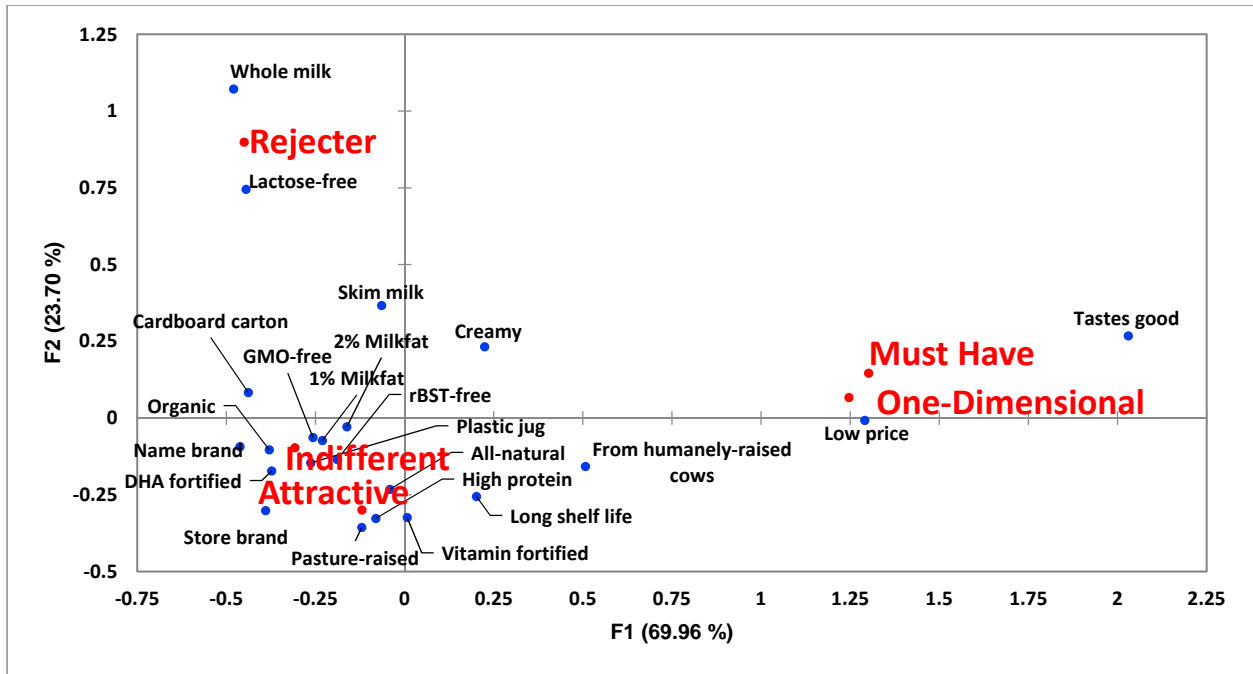


Figure 5c. Correspondence analysis biplot of Kano analysis counts for Value Cluster (n=234) of fluid milk consumers.

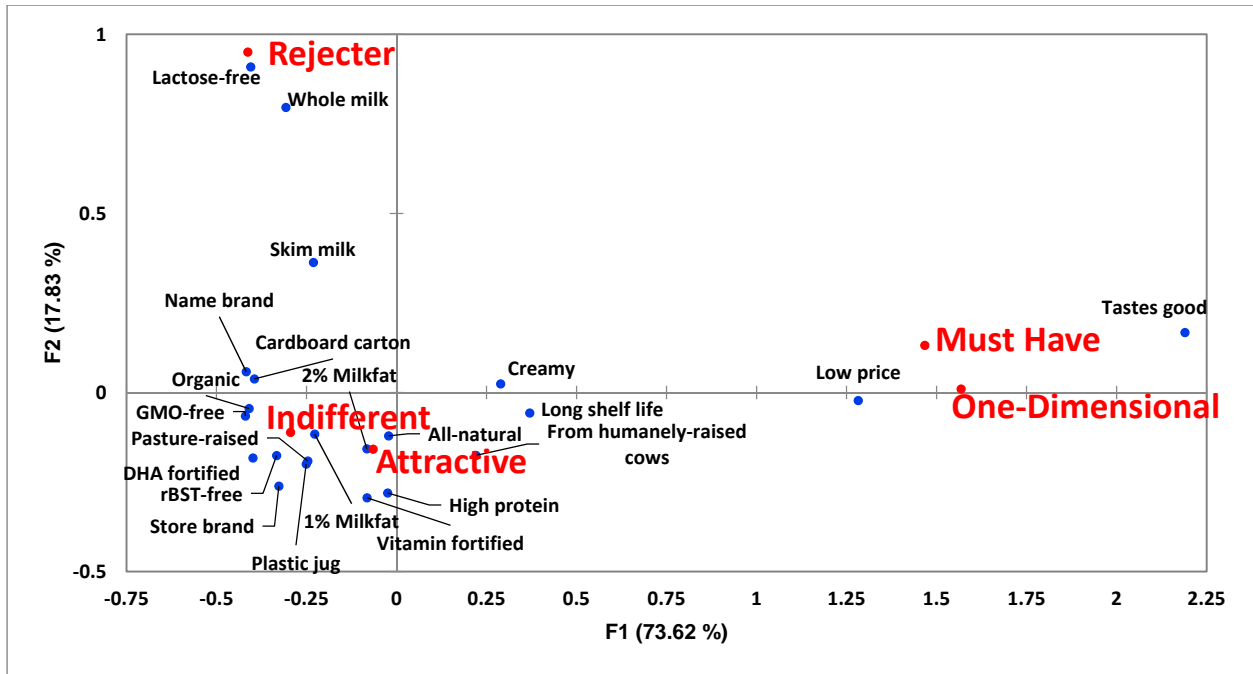


Figure 5d. Correspondence analysis biplot of Kano analysis counts for Basics Cluster (n=184) of fluid milk consumers.

Table 3. Maximum Difference (MaxDiff) scaling of fluid milk attributes by cluster

Label	Overall (n=1163)	Premium Cluster (n=352)	Opportunistic Cluster (n=393)	Value Cluster (n=234)	Basics Cluster (n=184)
Milk that is organic	4.95	8.32a	5.44b	2.00c	1.23c
Milk that is rBST/rBGH-free	3.73	5.25a	4.56a	1.91b	1.35b
Milk that is GMO-free	3.25	4.89a	3.85b	1.60c	0.91c
Milk that has the fat content I usually buy (skim, 1%, 2%, whole)	16.55	15.04c	16.30b	18.19a	17.90a
Milk that comes in the package size I usually buy (gallon, half gallon, etc.)	12.07	9.10c	11.61b	14.98a	15.03a
Milk that has a long shelf life (>18 days in refrigerator)	9.17	7.92b	8.35b	11.01a	10.98a
Milk that is low in price	12.07	8.50c	11.17b	15.42a	16.56a
Milk that tastes good	15.86	14.91c	15.68b	16.78a	16.88a
Milk fortified with vitamins/minerals	6.98	7.15ab	7.30a	6.44b	6.68ab
Milk that is lactose-free	1.63	1.97a	1.86ab	1.12c	1.16bc
Milk that is name brand	1.13	1.57a	0.97b	0.82b	1.02b
Milk that is store brand	1.98	1.69c	1.77bc	2.19b	2.71a
Milk that has a higher protein and calcium content	6.54	7.25a	6.61ab	5.61c	6.24bc
Milk that comes from pasture-raised cows	4.08	6.44a	4.53b	1.94c	1.34c

\*Sum of values in each column is 100 total points and results are interpreted as ratio-scaled values

\*\*Means in a row followed by a different letter are different (p<0.05)

Table 4. Maximum Difference (MaxDiff) scaling of reasons for organic milk purchase by organic milk users (n=434)

<b>Label</b>	<b>Average</b>
Organic milk is healthier for me	16.83a
Organic milk production encourages the ethical treatment of animals	12.47b
Organic milk production supports local farms and farmers	12.08b
Organic milk is all-natural	11.81bc
Organic milk production promotes environmental sustainability	10.55c
Organic milk is a higher quality product than conventional milk	9.07d
Organic milk tastes better	7.76d
Organic milk is rBST-free	6.37e
Organic milk is non-GMO	5.30e
Organic milk is a premium product	3.35f
Organic milk is part of my dietary habits (I always eat organic)	3.01f
Organic milk is more available than other types of milk	1.40g

\*Sum of column values is 100 total points and results are interpreted as ratio-scaled values

\*\*Means in a row followed by a different letter are different (p<0.05)

**CHAPTER 3:**  
**UNDERSTANDING IMPLICIT AND EXPLICIT CONSUMER DESIRES**  
**FOR PROTEIN BARS, POWDERS, AND BEVERAGES**

# **Understanding Implicit and Explicit Consumer Desires for Protein Bars, Powders, and Beverages**

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## **ABSTRACT**

The objective of this study was to assess the implicit and explicit qualities of protein products that consumers find attractive. To do so, an Adaptive Choice-Based Conjoint (ACBC) survey and a Constant Sum (CS) survey were conducted. Participants (n=457) were the same for both studies and results were compared on both aggregate and individual levels. Additionally, ACBC utility scores were used to calculate “Share of Preference” scores so that each attribute level could be directly compared to CS. Attribute importance scores were relatively similar between methods, with the exception of the platform, sweetener claim, and sweetener type, which were different ( $p < 0.05$ ) between surveys. Overall, both techniques agreed that the ideal protein product was a chocolate-flavored protein bar with 20-29g of primarily whey protein, all-natural, and naturally sweetened by stevia. Additionally, both methods agreed on relative scaling of levels within each attribute. ACBC resulted in smaller standard deviations for shares of preference ratings than the CS survey. Differences in results between the surveys suggest that protein product consumers have differences in implicit and explicit preferences. Exploration of where these preferences disagree may provide insight on product development initiatives for select consumers.

## **PRACTICAL APPLICATIONS**

This study found that there are subgroups of protein product consumers who express different ideals and desires. Furthermore, these preferences exist both explicitly and implicitly within individual consumers, and differences in those preferences may influence subsequent segmentation of consumer groups. Understanding the benefits and shortcomings of these different survey methods, and reviewing the sentiments each method captures, may help manufacturers and product developers reach new consumer groups and satisfy existing consumers to a greater extent.

Key Words: protein, whey, conjoint analysis, constant sum

## **INTRODUCTION**

In recent years, protein products have established as a staple in the diets of bodybuilders and athletes. However, a growing group of U.S. consumers express interest in incorporating more protein into their diet (Nielsen 2015). This, in turn, has extended the market for protein products past the sports nutrition category alone. Commercial protein products exist primarily as ready-to-mix (RTM) powders, ready-to-drink (RTD) beverages, or single-serve bars, but are offered in a variety of flavors and incorporate several different label or health claims. To continue the expansion of the protein product category, it is important to understand the preferences and desires that consumers place on these products. In a study of protein beverage attributes, Oltman *et al.* (2015) identified that the needs of protein beverage consumers were diverse, with different consumer segments expressing different drivers of preference. While consumers clearly express different desires, there is also evidence that those desires are driven both explicitly and implicitly (Friese *et al.* 2006). Explicit preferences refer to attitudes that are consciously expressed or verbalized in regards to choice, whereas implicit preferences are

defined as underlying, subconscious, or otherwise unknown belief systems (Friese *et al.* 2006; De Houwer 2006). Identification of explicit measures is commonly resultant from methods such as rating scales or constant sum scaling. On the other hand, implicit desires are typically derived from market research methods such as conjoint analysis, maximum difference scaling, or Kano model analysis. In studies comparing explicit and implicit consumer preferences for pizza and fruit juice products, Louviere and Islam (2008) noted instances where these desires were not in agreement. Comparison of the mentioned survey methodologies may be an effective means for profiling consumer desires and preferences for commercial protein product offerings.

Conjoint analysis is an established market research tool for understanding consumer behaviors and preferences for specific attributes in commercial products or services. In practice, conjoint analysis functions by presenting product concepts that are constructed from a determined set of attributes and within-attribute levels. Respondents are then instructed to perform multiple choice tasks, eventually allowing for the researcher to derive utility values for the component elements. Caruso *et al.* (2009) noted that while conjoint is based on a series of deliberate behavior, it is ultimately an implicit measure for understanding consumer preferences. Furthermore, conjoint is flexible enough to emulate real-life trade-off scenarios that consumers experience while shopping, which is critical for market research applications (Orme 2010). With advances in computing technology, adaptable features and designs that are tailored to the respondent have become possible as well. One of the most popular conjoint methods is adaptive choice-based conjoint (ACBC). The adaptive nature of ACBC uses consumer responses to identify within-attribute levels that fail to differentiate user implicit preferences and removes them from the test design, enhancing predictive ability on an individual level and reducing redundant measures. Furthermore, ACBC has been adopted as a popular market research method

because it is interactive in nature and requires fewer respondents overall for stable utility estimations (Cunningham *et al.* 2010; Jervis *et al.* 2012). In the realm of food-related studies, ACBC has been used for multiple products including fluid milk and plant-based alternatives (McCarthy *et al.* 2017), bread (Jervis *et al.* 2014), tomatoes (Oltman *et al.* 2014) and protein beverages (Oltman *et al.* 2015).

Maximum Difference scaling (MaxDiff) is another commonly used method for understanding the implicit and explicit hierarchies consumers ascribe to product attributes. MaxDiff is conceptually a similar task to conjoint analysis in terms of the trade-off decisions it uses to derive attribute values, but has been suggested to be comprised of simpler tasks (Orme 2005). In a MaxDiff study, respondents are presented with consecutive subsets of a master list and simply asked to choose the options they deem the “best” and “worst” within each set (Louviere and Woodworth 1990). The number of tasks in a MaxDiff exercise is determined by the overall number of attributes being evaluated and the number of attributes within the subset presented in each task. Following completion of the exercise, there are multiple analysis methods that may be employed, although statistical analyses such as hierarchical Bayesian regression are commonly used because they produced easily-understood ratio-scaled data on an individual level (Orme 2009). MaxDiff studies have been shown to produce robust results for understanding consumer preferences in food products such as ground beef (Chrysochou 2014) and olive oil (Dekhili *et al.* 2011). In addition, MaxDiff may be used with photographs or other media instead of text descriptions to understand consumer perceptions of packaging displays or product visible attributes (Jervis *et al.* 2014; McLean *et al.* 2017).

While deriving implicit consumer desires has been shown to be an effective model of consumer choice, it has been argued that different variables may influence consumers to make

purchase decisions that are more in-line with their explicit preferences (Friese *et al.* 2006). Methods for measuring explicit consumer preferences and desires are generally straightforward rating procedures such as Likert or semantic differential scales, but may also include exercises such as check-all-that-apply (CATA) or free-response comment questions (Albaum 1997; De Pelsmaeker *et al.* 2013). Rating methodologies are standard for understanding consumer sentiments and comparing products or product concepts, but there are several shortcomings related to their ability to distinguish consumer groups and their preferences. Among the most noted issues related to misuse of these scales are cross-cultural differences and “dumping” ratings toward the center of the scale (Chen *et al.* 1995; Kulas *et al.* 2008). Constant sum (CS), also commonly known as chip allocation, is a rating method that has been suggested to alleviate these usage concerns (Cohen 2003). In addition to usage concerns, CS has been suggested as a superior method for explaining explicit consumer preferences because the implementation of trade-off perspective dissuades respondents from poor rating response habits such as “yea-saying” (Hughes 1971). Chip allocations exercises have been used for various food items including soft drinks and fast-food (Woodside and Wilson 1985), juice products, and pizza (Louviere and Islam 2008). In addition, Mai and Hoffmann (2012) used constant sum scaling to understand consumer desires for health-conscious food products, which were subsequently compared to conjoint survey results. The study reported that some respondents closely matched results between the two methods, but others showed marked differences. Exploration of the product-specific instances where explicit and implicit measures of consumer preference agree or disagree is necessary for the identification and explanation of this phenomenon.

The continued growth of the protein product category, and ever-changing consumer sentiments related to supplementing their daily health have facilitated a need for understanding

how users feel about the products they purchase and consume. Additionally, the ubiquity of the internet has provided the opportunity for reaching large numbers of consumers and profiling their beliefs and preferences through the above-mentioned survey methodologies. Previous studies have provided actionable insights into consumer perceptions of certain protein product offerings, however, there is a lack of published research which has investigated the drivers of purchase for the entire protein product category (bars, RTD beverages, and RTM powders) simultaneously. Additionally, previous studies on protein products have failed to explain how consumer explicit and implicit preferences compare. The primary objective of this study was to investigate consumer implicit and explicit desires for commercial protein products. Product features where implicit and explicit sentiments showed convergence or divergence were further investigated.

## **MATERIALS AND METHODS**

### **Adaptive Choice-Based Conjoint (ACBC) Survey**

An online survey was developed using Lighthouse Studio (Sawtooth Software version 9.5.3, Orem, UT). The survey was uploaded to a database of over 10,000 consumers, maintained by the North Carolina State University Sensory Service Center. Survey participants (n=457) who were 18 years of age or older were able to participate in the survey. Participants were required to report that the frequency of their purchase/consumption of commercial protein products was once every three months or more often. Respondents who reported that they consumed protein items less than once every three months were disqualified from the test and no further results were collected.

An adaptive choice-based conjoint (ACBC) survey was the first survey sent out to potential respondents. The attributes and levels for this survey (Table 1) were designed to be

easily understood by respondents and familiar to protein product consumers. The survey was comprised of 8 attributes, each with 3-7 available levels. The survey design included a single build-your-own (BYO) task, 10 screening choice tasks, and a concept “tournament” where a maximum of 20 acceptable product concepts were compared to find the most desired products and features. In the BYO task, respondents were asked to assemble their ideal protein product by choosing a single level from each attribute category. Within each of the 8 screening tasks, 4 randomly assembled product concepts were presented and respondents were given available responses of each product being “a possibility” or a product that “won’t work for me.” Each product concept in the screening tasks differed from the participant’s BYO assembly by 2-4 attributes. Products chosen as “a possibility” in the screening tasks were brought into the subsequent concept tournament. During the screening tasks, available levels were refined through the use of 6 possible “unacceptable” and 6 possible “must-have” questions where essential product levels were preserved and unacceptable features were removed within the test design.

Kano questions were asked to all respondents following the ACBC exercise in the first survey. Questions were asked about the same features used in the conjoint survey, with questions about vegan protein and non-soy plant protein alternatives added. Questions for the Kano exercise were posed in both a constructive (for example, “A protein product sweetened with stevia”) and reductive (for example, “A protein product not sweetened with stevia”) fashion. The following responses were available for both the constructive and reductive questions: ‘I will like it’, ‘I must have it’, ‘I do not care’, ‘I can live with it’, and ‘I will dislike it.’ Attribute categorization within the Kano model exercise was determined from the two responses according to the classification method proposed by Kano (1984) and refined by Berger *et al.* (1993).

A single MaxDiff exercise was included following the Kano model analysis exercise in the first survey. The MaxDiff design was created using the Lighthouse Studio survey hosting tool for Maximum Difference Scaling and was directly implemented into the survey. In this exercise, attributes of protein products were directly compared to one another without the limitations based on attribute type. The purpose was to seek support for the other analyses, while also providing perspective on cross-attribute levels. Because the ACBC exercise is not able to make these comparisons, MaxDiff was intended to serve as a definitive way of scaling importance of individual product features. In all, 32 protein product features were analyzed by MaxDiff. All features from the ACBC exercise, except for flavor were included in the MaxDiff exercise; in addition, non-soy plant proteins and “vegan” as a label claim were included. Respondents were asked to complete 16 best-worst questions, with “Most Appealing” and “Least Appealing” serving as the decision anchors. Each of the 16 questions contained 6 random product features and asked respondents the following question: “Considering only these 6 protein product features, which do you find MOST appealing and which do you find LEAST appealing?”

### **Constant Sum (Chip Allocation) Survey**

Following a 3-month waiting period to discourage learned behavior, respondents from the ACBC survey were contacted and asked to participate in another survey. The survey was also designed using Lighthouse Studio. Available attributes and levels within the survey were the same as those used within the ACBC survey. The constant sum exercises were posed as 100-chip allocation exercises where respondents were asked to allocate their resources according to the following statement template: “If you were to purchase 100 protein products and the products were the same, save for the [attribute] options shown, how many times would you purchase each

option?” In addition, importance scores for the available attributes were found using a similar 100-chip allocation exercise that asked respondents to allot importance to the 8 attribute categories. Participants who participated in both surveys were entered into a drawing to receive 1 of 15 \$25 gift certificates to a local store.

### **Statistical Analysis**

Individual utility scores from the conjoint survey, as well as MaxDiff scores in the MaxDiff exercises were determined via hierarchical Bayesian (HB) estimation (Sawtooth Software Lighthouse Studio, Orem, UT). Antilog transformations of the raw utility scores derived from the conjoint were used to calculate shares of preference for the levels within each attribute category. Additionally, importance scores were derived from utility scores in the ACBC survey, and were derived from an attribute-only constant sum exercise in the CS survey. Comparison of importance scores and shares of preference were conducted via one-way analysis of variance with Fisher’s least significant difference (95% confidence). Cluster analysis of individual share of preference scores from the conjoint exercise was performed with XLSTAT version 19.5.2018 (Addisoft, Paris, France) using Euclidean distances and Wards linkage to categorize similar respondents into groups. Kano questions were evaluated according to the model proposed by Kano (1984). In addition, count data from Kano analysis was subjected to correspondence analysis (CA) with Hellinger distances (XLSTAT) to characterize the consumer clusters derived from the conjoint exercise. All analyses were performed at 95% confidence ( $p < 0.05$ ).

## RESULTS AND DISCUSSION

### Survey Comparison

The same consumer population (n=457) participated in both the ACBC and CS surveys. Comparison of overall importance scores and level shares of preference are presented in Fig. 1 and Fig. 2, respectively. Overall, within-attribute trends in levels were the same for the ACBC and constant sum surveys, with almost full agreement on relative scaling of the levels. Both methods agreed that overall, the ideal protein product build was a chocolate-flavored protein bar formulated with 20-29g/serving of whey protein, all-natural, low carb, and naturally sweetened with stevia as the primary sweetener (Table 2). Importance score calculations from the surveys showed that protein type, protein amount, and carbohydrate content were similarly scored, but significant differences were observed in platform, flavor, label claim, sweetener claim, and sweetener type attributes. Furthermore, the two survey methods were inconsistent in describing what attributes were most important to consumers, but relatively agreed that label claims, carb content, and sweetener claims were among the least important attributes. The magnitude of difference between the two surveys was greatest in the platform and sweetener type categories, with scores for sweetener type importance higher by ACBC compared to CS, and scores for platform importance higher by CS compared to ACBC. While some of the discrepancies may be due to scale usage or allocation exaggerations within the constant sum exercise, as described by Böckenholt and Dillon (1997), there is ample evidence that explicit preferences and underlying preferences are often at odds (Cervellon *et al.* 2007; Finlayson *et al.* 2008). This may explain why respondents in the CS survey placed disproportionate importance on a single level they found appealing (such as bars), in lieu of appropriate scoring for less eye-catching product details such as sweetener type.

While relative scaling of levels was similar between the two test methods, differences in share of preference scores were found for select levels, with most significant differences found within the flavor, protein type, label claim, and sweetener type categories. Within the flavor attribute, vanilla scored significantly lower and peanut butter scored significantly higher in the ACBC survey compared to the CS survey. Within the protein type attribute, milk protein and soy protein scored significantly lower in the ACBC survey compared to the CS survey, while “other” scored significantly higher. High implicit value of the “other” attribute by ACBC analysis is particularly interesting because it suggests that consumers have no aversion to exploring “other” protein options, but are unwilling to actively allot value to an unknown option when well-defined options exist, as evidenced by the CS exercise. Ambiguity in choice exercises was described by Louviere and Islam (2008) to be a possible source of difference across measures, and this possibility cannot be ruled out within this study. Within the label claim attribute, all-natural and organic scored significantly lower in the ACBC survey compared to the CS survey and gluten-free and lactose-free scored significantly higher. Within the sweetener type attribute, fructose and sucralose scored significantly lower in the ACBC survey compared to the CS survey, and monk fruit scored significantly higher.

Variances in the magnitude of share of preference ratings (Fig. 2) suggests that there are differences in how consumers make comparisons implicitly and explicitly. To understand these differences, the standard deviation (SD) for the shares of preference ratings was calculated for each level within each test (Fig. 3). It should be noted that areas where SDs were high indicate heterogeneity, meaning attributes with high SDs were more likely to differentiate underlying consumer groups. Overall, trends relating to SDs were similar from test to test, particularly in the platform, flavor, protein type, protein amount, and primary sweetener type attributes. These

similarities suggest that respondent implicit and explicit preferences converge on well-defined product-defining attributes. Conversely, label claim, sweetener claim, and carbohydrate claim showed the largest gap in SDs between the two survey methods, with each attribute showing a much higher SD in the CS survey, compared to the ACBC results. These results indicate that respondents were differentiated strongly in the CS survey by attributes that implied a belief or attributes that were more ambiguous. These discrepancies, at least in part, may be attributed to the framing of surveys for understanding explicit preferences, which force consumers to assign ratings or predict future behavior. Studies by Kahneman and Snell (1990, 1992) have suggested that consumers are poor predictors of their future behavior and tastes. However, ambiguity may also be a root cause for the observed differences in explicitly measured preference. Ambiguous product attributes that showed large SD values, such as the “no claim” label claim option or low carbohydrate designation required respondents to both interpret the attribute, and assign value. Louviere and Islam (2008) suggest that explicit measures of value will inherently suffer in these situations because respondents assign value based on personal reference ranges they apply to the ambiguous features. For example, some respondents may interpret “no claim” to simply mean no explicit claim is made on the packaging of the hypothetical product concept (neutral reaction), whereas others may interpret it to mean that the product concept is deficient in some capacity that would typically warrant an advertised claim (negative reaction). In these cases, results from explicit valuation methods, such as the CS survey, may result in exaggerated variation, and lead to improper respondent segmentation that has been biased by these ambiguous features.

### **Cluster Analysis**

To better understand the underlying consumer groups present, k-means clustering was performed on the share of preference scores from each test. Derived clusters were compared

between the ACBC and CS surveys so that similarities and differences of implicit and explicit preferences could be identified within specific consumer groups. In addition, demographic profiles of the consumer clusters were described (Table 3). Each method identified 3 clusters from the share of preference score patterns, however, there were marked differences in how variation between the groups was explained. Differentiation of groups in the CS survey (Fig. 4) was primarily dominated by 3 levels: all-natural label claim (CS cluster 1), naturally sweetened (CS cluster 2), and no label claim (CS cluster 3). Preference within select consumer subgroups for protein products that are all-natural or naturally sweetened is consistent with findings reported by Oltman *et al.* (2015) and Parker *et al.* (2018). Product attribute categories such as protein amount, protein type, and platform failed to define specific groups. Demographically, CS cluster 1 had a greatest proportion of non-Caucasian respondents, compared to the other groups. CS Cluster 1 explicitly reported that their ideal protein product included all-natural as a label claim, and stevia, a non-nutritive/all-natural sweetener, as the primary sweetener type. These results similarly mirror the findings reported by Smith *et al.* (2009), which showed that non-Caucasian consumers were more likely to purchase and consume organic or all-natural products. CS cluster 2 had the highest proportion of consumers who reported infrequent protein product consumption, but was otherwise similar to the other CS clusters. While self-reported consumption frequency was low, CS cluster 2 showed singular focus on products that were all-natural, naturally sweetened with either sucrose or fructose, and in bar form. These results indicate that CS cluster 2 consumers hold strong explicit beliefs about sweetener type in their products, and are led to a preference for bar products, likely due to bars having increased shelf stability, which compliments their infrequent consumption pattern. CS cluster 3 was primarily defined by a preference for products that had no added claims. Furthermore, CS cluster 3 was

demographically different from the other CS clusters in terms of annual income, with significantly less respondents earning \$79,999-\$99,999/year. Disposable income has been widely viewed as a factor that dictates consumer willingness-to-pay for products with organic or other label claims, although several exceptions have been noted (Govindasamy and Italia 1999).

Compared to the CS survey clusters, ACBC clusters were differentiated with greater complexity (Fig. 5). ACBC cluster 1 was defined by a desire for high protein per serving, stevia as the primary sweetener, a desire for specifically whey protein products, and openness to ready-to-mix powder and peanut butter-flavored products. These results strongly corroborate findings reported by Oltman *et al.* (2015), which found that consumers driven by high protein amount also reported desires for low sugar content and openness to the use of natural non-nutritive sweeteners. Demographically, cluster 1 had the highest proportion of male respondents, respondents who exercised 5+ times per week, and respondents who reported consumption of protein products for muscle building, compared to the other clusters. These results generally match the trend of young male athletes seeking enhanced athletic performance or muscle health that were identified by McDowall (2007) and Childs *et al.* (2008). ACBC cluster 2 was defined by acceptability for more moderate protein amounts, all-natural products, milk protein, ready-to-drink beverages, and relative preference for protein products that contained carbohydrates and that were sweetened primarily with sucrose. Preference for milk protein was unique to cluster 2, and can likely be attributed to the desire for protein products that are all-natural. These findings are consistent with those reported by Childs *et al.* (2008), which showed that some consumers associate natural protein sources, such as milk, with increased health benefit. Furthermore, consumers with these sentiments were found to have a limited understanding about alternative protein sources such as whey protein, which likely explains their preference for more familiar

sources such as “milk.” The demographics of ACBC cluster 2 were defined by greater racial diversity, more moderate exercise habits, and were the least likely group to report frequent protein product consumption. When viewed conjointly, the ACBC results and demographic make-up of ACBC cluster 2 indicate that they are a consumer group who values health, convenience, and every-day utility from their protein products. Furthermore, the high utility of ready-to-drink milk protein options suggests that cluster 2 may value ready-to-drink protein products for, among other reasons, their versatility and transportability (Rittmanic 2006). Finally, ACBC cluster 3 was defined by a comparatively greater desire for chocolate-flavored products, the bar platform, and low carbohydrate content. ACBC cluster 3 demographically consisted of the highest proportion of female respondents, and was the most likely group to report that they had minimal exercise habits.

Assessment of the consumer clusters derived from each survey type suggests that there are differences in how underlying consumer groups are defined when preferences are viewed explicitly and implicitly. It must be noted that survey methods such as constant sum/chip allocation may suffer from scale use biases, which result in exaggerated consumer differentiation. In this study, ACBC results circumvented this concern through utilization of “borrowed” information from the population during HB utility estimation to derive reasonable estimates on an individual level (Johnson 2000). In this way, ACBC results were less susceptible to outliers and scale misuse within the experiment and give rise to greater explained variation among consumer clusters and generally smaller standard deviations. For this reason, consumer clusters in subsequent analyses were evaluated based upon ACBC results only.

## **Kano Model**

Results of Kano model analysis were analyzed in the overall respondent group and within the consumer clusters derived from the conjoint analysis exercise. Traditional Kano model classification revealed that protein products in bar form were identified as attractive in the overall population and within each cluster. Additionally, cluster 1 categorized all protein content greater than 20g/serving as attractive and cluster 2 identified the ready-to-drink beverage platform as attractive, which was consistent with their ideal build results from the ACBC survey. All other attributes were classified as “indifferent” using traditional Kano classification. While the traditional Kano model is a well-reviewed system for understanding customer satisfaction in product development applications, it has possible shortcomings related to rigid classification methodologies (Matzler and Hinterhuber 1998; Mikulić and Prebežac 2011). To circumvent these concerns, counts from Kano classification were subjected to CA as recommended by Lillestøl (1991), and conclusions were determined heuristically.

Using CA, respondents showed clear differentiation in their classification of the attributes using the Kano model (Fig. 6a). Most of the variability was explained by the dichotomous relationship between rejecter classification and one-dimensional/attractive classification, although many variables failed to project strongly or projected on indifferent classification. The overall population generally characterized artificial sweeteners such as ace-K and sugar alcohols as rejecter attributes, and attributes such as moderate protein load and bar platform as attractive attributes. Although artificial non-nutritive sweeteners were generally rejected, there was a consistent desire for all-natural sweeteners expressed within the overall population. Cluster 1 (Fig. 6b) echoed the overall population negative sentiments for artificial non-nutritive sweeteners, but showed greater classification of high-protein loads and whey protein as

attractive, and showed one-dimensional characterization for attributes such as all-natural, low-carb, and reduced sugar. Cluster 1 was singularly defined by a desire for high protein per serving, a finding that was consistent in both explicit and implicit measurements of preference. Consumer subgroups with a similar focus on high protein load were identified by Oltman *et al.* (2015), and have typically consisted of bodybuilders or athletes. Predictably, cluster 1 reported a higher likelihood that muscle building/muscle health/recovery than the other clusters defined in this study (Table 3).

Cluster 2 (Fig. 6c) showed similar classification to the overall population, but a clear distinction between classification of one-dimensional/must have and indifferent attributes was also observed. This suggests that cluster 2 places greater weight on beliefs about naturalness and nutrition compared to the general population, which is reflected in classification of naturally sweetened, all-natural, and organic as a must have/one-dimensional/attractive attributes. Interestingly, cluster 2 consumers generally classified stevia and monk fruit as rejecter attributes although they classified natural sweetened as attractive/one-dimensional. While the relative dislike for natural non-nutritive sweeteners may simply signal that respondents were unfamiliar with alternative sweeteners, it is possible that the negative results indicate a negative association with non-nutritive sweetener characteristics such as bitter taste (Cardello *et al.* 1999). Parker *et al.* (2018) demonstrated that stevia had intense and lingering bitter and metallic tastes in vanilla-flavored protein beverages, but suggested that these off flavors may be mitigated through the use of sweetener blends. Evaluation of consumer interest in protein products that incorporate sweetener blends instead of relying on a single primary sweetener is an area that requires further exploration.

Cluster 3 (Fig. 6d) exhibited a strong association between attributes that conveyed health or naturalness implications and classification as one-dimensional/must have; conversely, artificial non-nutritive sweeteners were overwhelmingly classified as rejecter attributes. Although cluster 3 showed a clear interest in health-forward attributes, vegan protein products, soy protein, non-soy plant proteins, and natural non-nutritive sweeteners were generally categorized as indifferent. Russel *et al.* (2006) found that the majority of protein product consumers believed soy products are healthy, although only 21% of consumers believed that soy products tasted good. Consumer subgroups that express health-forward sentiments, such as cluster 3, present an opportunity for growth in the plant protein product category, however flavor concerns must be addressed. In an evaluation of fluid milk users and nondairy milk alternative users, McCarthy *et al.* (2017) showed that nondairy milk alternatives attract users effectively for several reasons, but consumers still consider acceptable taste a prerequisite to purchase. Amelioration of flavor concerns in plant proteins or more strategic positioning and education within the dairy sector is integral to tapping the growing consumer desire for healthy, environmentally friendly, or ethically produced products.

### **Maximum Difference Scaling**

All respondents in the study were asked to participate in a MaxDiff exercise for scaling components of protein products (Table 4). Overall, the MaxDiff results closely matched the scaling of share of preference and importance scores from the ACBC and CS surveys. Protein content of 20-29g per serving was the most attractive attribute, followed by all-natural designation, 30-30g protein per serving, and naturally sweetened claim. One notable difference from the ACBC and CS surveys was the high MaxDiff score for all-natural designation. Within the ACBC and CS surveys, label claim received the 6<sup>th</sup> and 7<sup>th</sup> highest importance score,

respectively. The high valuation of all-natural designation was noted by Oltman *et al.* (2015) to be an attractive attribute for protein beverage consumers.

When analyzed within clusters from the ACBC results, differences and similarities in attribute hierarchies were noted. Cluster 1 was differentiated from the other clusters in the MaxDiff exercise by the high value placed on protein servings over 20g per serving, with each attribute receiving a higher ( $p < 0.05$ ) score than was observed in the other clusters. In addition to protein load, whey protein and ready-to-mix powder platform received a higher ( $p < 0.05$ ) score in cluster 1 than in any other cluster. For cluster 2, attributes such as naturally sweetened, all-natural, and 20-29g protein per serving were scored the highest. Furthermore, cluster 2 allotted the highest value of any cluster to attributes such as ready-to-drink beverage platform and sucrose, echoing the differentiating sentiments of the Kano model, ACBC, and CS survey results. Although preference for sucrose -a caloric sweetener- was unique to cluster 2 in this study, it should be noted that findings by Parker *et al.* (2018) suggested that many consumers are open to caloric sweeteners. Furthermore, use of natural caloric sweeteners such as fructose or sucrose, whether used as the sole sweetener, or as a component of a sweetener blend, was shown to ameliorate some of the negative flavor concerns associated with non-nutritive sweeteners. Cluster 3 exhibited a high affinity for naturally sweetened and all-natural attributes, like cluster 2. However, cluster 3 was defined by scores for attributes such as bar platform, reduced sugar, sugar-free, organic, and low carb designation that were significantly higher than any other cluster. Overall, conclusions drawn from the MaxDiff exercise agreed with the within-attribute level ratings from the ACBC and CS surveys. However, the MaxDiff exercises were successful in clarifying the relative importance of these levels in the overall scope instead of being inhibited by the attribute constraints of the ACBC and CS surveys.

## **CONCLUSIONS**

Constant sum and ACBC survey methodologies were both useful and corroborated each other in terms of level share of preference. However, the two methods differed significantly in their calculation of attribute importance, suggesting that a difference exists in explicit and implicit valuation by protein product consumers. ACBC was a superior method for differentiation of underlying consumer clusters compared to the CS survey, although the CS survey was an effective method for evaluating relative preferences between level choices and closely matched utility results for the ACBC survey. Consumers were generally less able to provide reliable measurements of attribute importance using explicit ratings in the CS survey method and tended to over-weight product-defining attributes such as flavor or platform. Stability of ACBC results can be attributed to utility estimation from HB regression, which was the basis for calculated shares of preference. The consumer clusters identified by the ACBC survey identified were clear in their differences as they related to protein product features, and were associated with clear demographic groups. Identification of these consumer groups, coupled with supporting analyses, may provide actionable data for future marketing endeavors and product development within the sports nutrition/protein product category.

## **ACKNOWLEDGEMENTS**

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## REFERENCES

- Albaum, G. 1997. The Likert scale revisited: an alternate version. *J. Market Res. Soc.* 39(2), 331-332.
- Berger, C., Blauth, R., Boger, D., Bolster, C., Dumouchel, W., Pouliot, F., Richter, R., Rubinoff, A., Shen, D., and Timko, M. 1993. Kano's methods for understanding customer-defined quality. *Qual. Manag. J.* 2(4), 3-36.
- Böckenholt, U. and Dillon, W.R. 1997. Some new methods for an old problem: Modeling preference changes and competitive market structures in pretest market data. *J. Mark. Res.* 34, 130-142.
- Cardello, H.M.A.B., Da Silva, M.A.P.A., and Damasio, M.H. 1999. Measurement of the relative sweetness of stevia extract, aspartame and cyclamate/saccharin blend as compared to sucrose at different concentrations. *Plant Foods Hum. Nutr.* 54(2), 119-129.
- Caruso, E.M., Rahnev, D.A. and Banaji, M.R. 2009. Using conjoint analysis to detect discrimination: revealing covert preferences from overt choices. *Soc. Cogn.* 27(1), 128-137.
- Cervellon, M.C., Dube, L. and Knauper, B. 2007. Implicit and explicit influences on spontaneous and deliberate food choices. *Adv. Consumer Res.* 34, 104-109.
- Chen, C., Lee, S.Y. and Stevenson, H.W. 1995. Response style and cross-cultural comparisons of rating scales among East Asian and North American students. *Psychol. Sci.* 6(3), 170-175.
- Childs, J.L., Thompson, J.L., Lillard, J.S., Berry, T.K. and Drake, M.A. 2008. Consumer perception of whey and soy protein in meal replacement products. *J. Sens. Stud.* 23(3), 320-339.
- Chrysochou, P. 2014. Drink to get drunk or stay healthy? Exploring consumers' perceptions, motives and preferences for light beer. *Food Qual. Pref.* 31, 156-163.
- Cohen, S. 2003. Maximum difference scaling: improved measures of importance and preference for segmentation. In *Sawtooth Software Conference Proceedings*, pp. 61-74, Sawtooth Software, Inc., San Diego, CA.
- Cunningham, C. E., Deal, K., and Chen, Y. 2010. Adaptive choice-based conjoint analysis: A new patient-centered approach to the assessment of health service preferences. *Patient.* 3(4), 257-273.
- De Houwer, J. 2006. What are implicit measures and why are we using them? In *The handbook of implicit cognition and addition*, pp. 11-28, Sage Publication, Inc, Thousand Oaks, CA.
- Dekhili, S., Sirieix, L. and Cohen, E. 2011. How consumers choose olive oil: The importance of origin cues. *Food Qual. Pref.* 22(8), 757-762.

- De Pelsmaeker, S., Schouteten, J. and Gellynck, X. 2013. The consumption of flavored milk among a children population. The influence of beliefs and the association of brands with emotions. *Appetite*. 71, 279-286.
- Finlayson, G., King, N. and Blundell, J. 2008. The role of implicit wanting in relation to explicit liking and wanting for food: implications for appetite control. *Appetite*. 50(1), 120-127.
- Friese, M., Wänke, M. and Plessner, H. 2006. Implicit consumer preferences and their influence on product choice. *Psychol. Market*. 23(9), 727-740.
- Govindasamy, R. and Italia, J., 1999. Predicting willingness-to-pay a premium for organically grown fresh produce. *J. Food Dist. Res*. 30(2), 44-53.
- Hughes, G.D. 1971. *Attitude measurement for marketing strategies*. Scott, Foresman and Company.
- Jervis, S.M., Ennis, J.M. and Drake, M.A. 2012. A comparison of adaptive choice-based conjoint and choice-based conjoint to determine key choice attributes of sour cream with limited sample size. *J. Sens. Stud*. 27(6), 451-462.
- Jervis, S.M., Jervis, M.G., Guthrie, B. and Drake, M.A. 2014. The efficacy of using photographs to represent attributes of sliced sandwich bread in an adaptive choice-based conjoint. *J. Sens. Stud*. 29(1), 64-73.
- Johnson, R.M., 2000. *Understanding HB: an intuitive approach*. Sawtooth Software Inc., Sequim, WA.
- Kano, N., N. Seraku, F. Takahashi, and Tsuji, S. 1984. Attractive quality and must be quality. *J. Jpn. Soc. Qual. Control*. 14, 147-156.
- Kahneman, D. and Snell, J. 1990. Predicting utility. In *Insights in decision making: A tribute to Hillel J. Einhorn*, pp. 295-310, University of Chicago Press, Chicago, IL.
- Kahneman, D. and Snell, J. 1992. Predicting a changing taste: Do people know what they will like? *J. Behav. Decis. Mak*. 5(3), 187-200.
- Kulas, J.T., Stachowski, A.A. and Haynes, B.A. 2008. Middle response functioning in Likert-responses to personality items. *J. Bus. Psychol*. 22(3), 251-259.
- Lillestøl, J. 1991. Multivariate statistical methods for quality creation: a review. *Tot. Qual. Manag*. 2(3), 291-304.
- Louviere, J.J. and Islam, T., 2008. A comparison of importance weights and willingness-to-pay measures derived from choice-based conjoint, constant sum scales and best-worst scaling. *J. Bus. Res*. 61(9), 903-911.
- Louviere, J. J. and Woodworth, G. G. 1990. *Best-worst scaling: A model for largest difference judgments*. Working Paper, Department of Marketing and Economic Analysis. Univ. of Alberta, Canada.

- Mai, R. and Hoffmann, S. 2012. Taste lovers versus nutrition fact seekers: how health consciousness and self-efficacy determine the way consumers choose food products. *J. Consum. Behav.* *11*(4), 316-328.
- Matzler, K. and Hinterhuber, H.H. 1998. How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. *Technovation.* *18*(1), 25-38.
- McCarthy, K.S., Parker, M.N., Ameerally, A., DRAKE, S.L. and DRAKE, M.A. 2017. Drivers of choice for fluid milk versus plant-based alternatives: What are consumer perceptions of fluid milk? *J. Dairy Sci.* *100*(8), 6125-6138.
- Mcdowall, J.A., 2007. Supplement use by young athletes. *J. Sports. Sci. Med.* *6*(3), 337.
- Mikulić, J. and Prebežac, D. 2011. A critical review of techniques for classifying quality attributes in the Kano model. *Manag. Serv. Qual.* *21*(1), 46-66.
- Nielsen. 2015. We are what we eat: Healthy eating trends around the world. In *Global Health and Wellness Report- January 2015*, pp. 1-27. The Nielsen Company, New York, NY.
- Oltman, A.E., Jervis, S.M. and Drake, M.A. 2014. Consumer attitudes and preferences for fresh market tomatoes. *J. Food Sci.* *79*(10), S2091-S2097.
- Oltman, A.E., Lopetcharat, K., Bastian, E. and Drake, M.A. 2015. Identifying key attributes for protein beverages. *J. Food Sci.* *80*(6), S1383-S1390.
- Orme, B.K. 2005. MaxDiff system technical paper. Sawtooth Software Research Paper Series. Sawtooth Software, Sequim, WA.
- Orme, B.K. 2009. Maxdiff analysis: Simple counting, individual-level logit, and hb. Sawtooth Software Research Paper Series. Sawtooth Software, Sequim, WA.
- Orme, B.K. 2010. Pages 19-50 in *Getting started with conjoint analysis: strategies for product design and pricing research*. Research Publishers, LLC. Madison, WI.
- Parker, M.N., Lopetcharat, K. and Drake, M.A. 2018. Comparison of natural sweeteners in protein beverages using time-intensity, temporal dominance of sensations, and temporal check-all-that-apply. *J. Dairy Sci.* In Press.
- Rittmanic, S. 2006. US whey proteins in ready-to-drink beverages. US Dairy Export Council, Arlington, VA.
- Russell, T.A., Drake, M.A. and Gerard, P.D. 2006. Sensory properties of whey and soy proteins. *J. Food Sci.* *71*(6), S447-S455.
- Smith, T.A., Lin, B.H. and Huang, C.L. 2009. Growth and development in the US retail organic food sector. *Sustainability.* *1*(3), 573-591.
- Woodside, A.G. and Wilson, E.J. 1985. Effects of consumer awareness of brand advertising on preference. *J. Advertising Res.* *25*(4), 41-48.

Table 1. Attributes and levels used in protein product conjoint and constant sum surveys

Attributes	Platform	Flavor	Protein Type	Amount of Protein	Label Claim	Carbohydrate Claim	Sweetener Claim	Primary Sweetener Type*
Levels	Ready-to-mix Powder	Vanilla	Whey Protein	< 10g/ serving	GMO-free	Low Carb	Naturally sweetened	Fructose
	Ready-to-drink Beverage	Chocolate	Milk Protein	10-19g/ serving	All natural	Carb-free	Reduced Sugar	Stevia
	Bar	Strawberry	Soy Protein	20-29g/ serving	Gluten-free	Contains carbs	Sugar-free/ non-caloric	Monk Fruit
		Peanut Butter	Casein	30-39g/ serving	Lactose-free		Naturally sweetened/ non-caloric	Sucralose
		Cookies and Cream	Other	40-49g/ serving	Organic			Sucrose
				>50g/ serving	No claim			Ace-K
								Sugar alcohols

\*Classification of each sweetener type as natural, artificial, nutritive, and non-nutritive was briefly explained in an infographic prior to the conjoint and constant sum surveys.

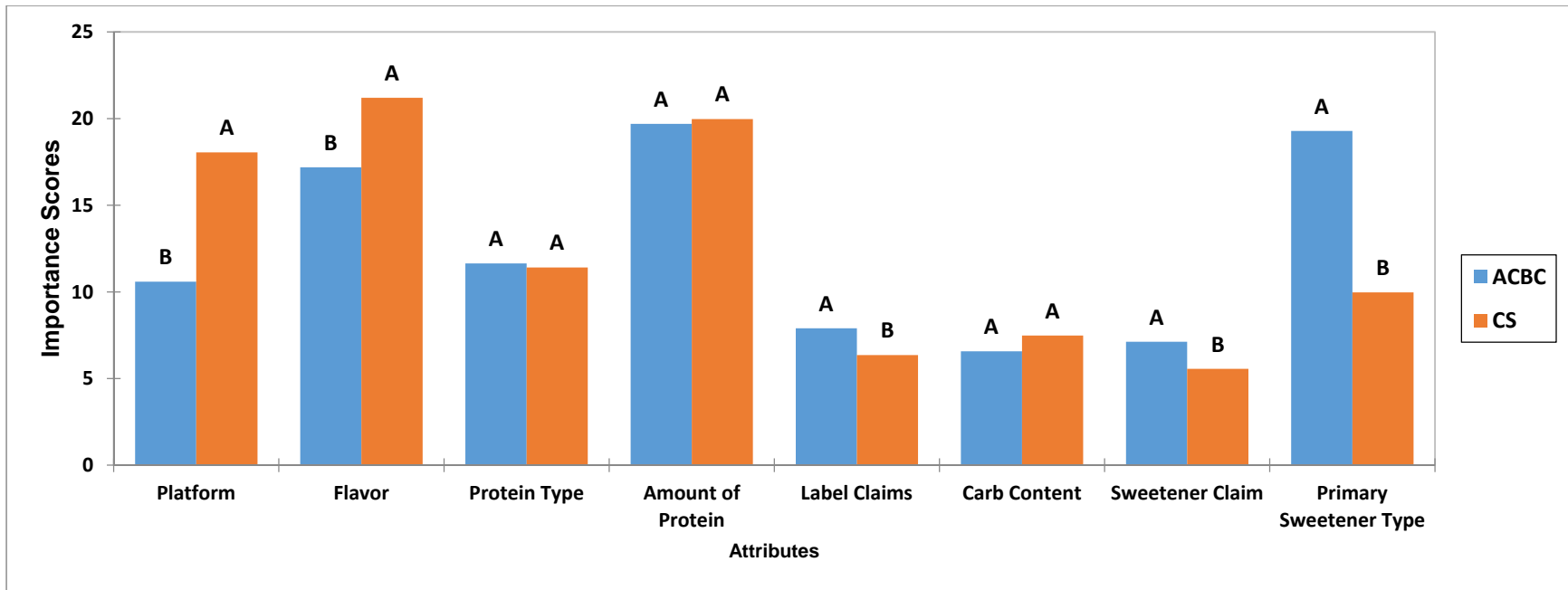


Figure 1. Comparison of protein product attribute importance between ACBC and Constant Sum surveys (n=457). Different letters (a-b) indicate significant differences ( $p < 0.05$ ) between testing methods.

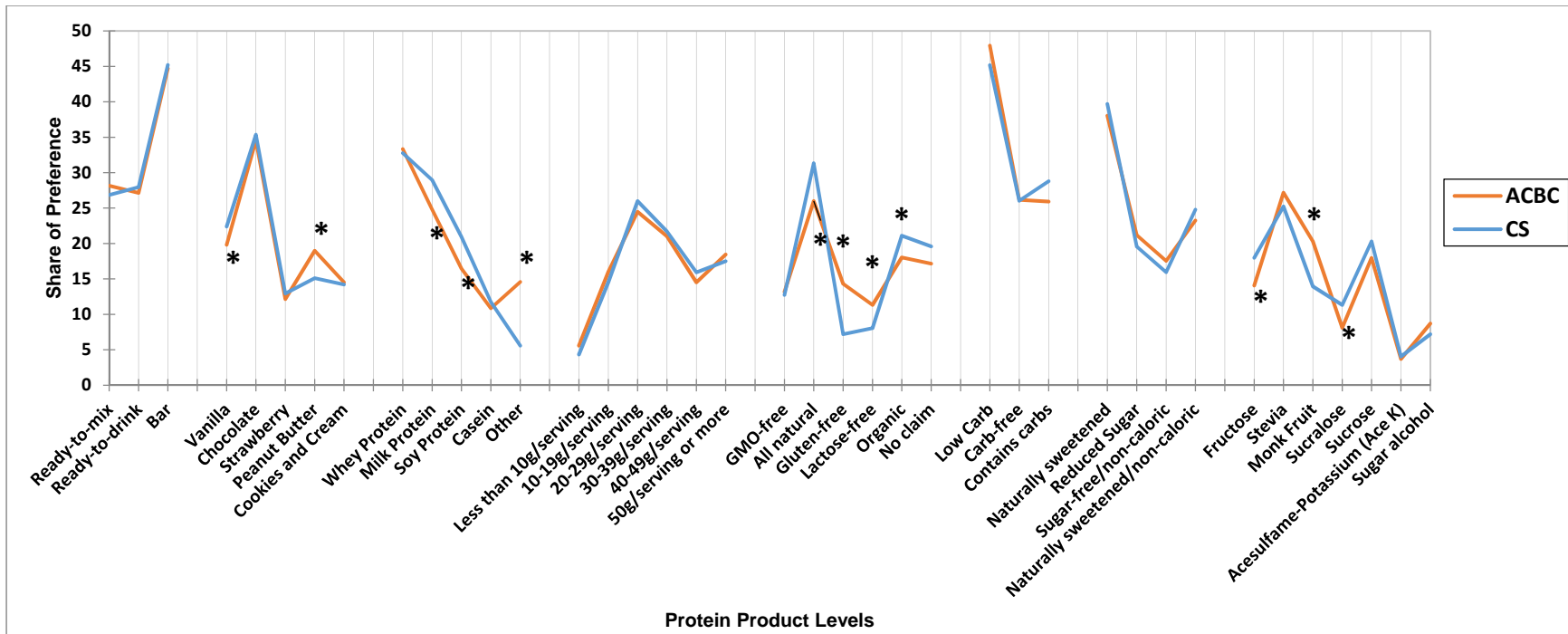


Figure 2. Comparison of level share of preference between ACBC and Constant Sum surveys (n=457)

\*Indicates a significant difference (p<0.05) in share of preference ratings between survey methods

Table 2. Ideal protein product builds for total population and for segmented consumer clusters based on share of preference scores.

<b>Attribute</b>	<b>Platform</b>	<b>Flavor</b>	<b>Protein Type</b>	<b>Protein Amount</b>	<b>Label Claim</b>	<b>Carb Content</b>	<b>Sweetener Claim</b>	<b>Primary Sweetener Type</b>
<b>ACBC Overall (n=457)</b>	Bar	Chocolate	Whey Protein	20-29g/ serving	All-Natural	Low Carb	Naturally Sweetened	Stevia
<b>ACBC Cluster 1 (n=161)</b>	Bar	Chocolate	Whey Protein	30-39g/ serving	All-Natural	Low Carb	Naturally Sweetened	Stevia
<b>ACBC Cluster 2 (n=132)</b>	RTD Beverage	Chocolate	Milk Protein	20-29g/ serving	All-Natural	Low Carb	Naturally Sweetened	Sucrose
<b>ACBC Cluster 3 (n=164)</b>	Bar	Chocolate	Milk Protein	20-29g/ serving	All-Natural	Low Carb	Naturally Sweetened	Stevia
<b>CS Overall (n=457)</b>	Bar	Chocolate	Whey Protein	20-29g/ serving	All-Natural	Low Carb	Naturally Sweetened	Stevia
<b>CS Cluster 1 (n=270)</b>	Bar	Chocolate	Whey Protein	20-29g/ serving	All-Natural	Low Carb	Naturally Sweetened/ Non- Caloric	Stevia
<b>CS Cluster 2 (n=116)</b>	Bar	Chocolate	Milk Protein	20-29g/ serving	All-Natural	Contains Carbs	Naturally Sweetened	Sucrose
<b>CS Cluster 3 (n=71)</b>	Bar	Chocolate	Whey Protein	20-29g/ serving	No Claim	Low Carb	Reduced Sugar	Sucrose

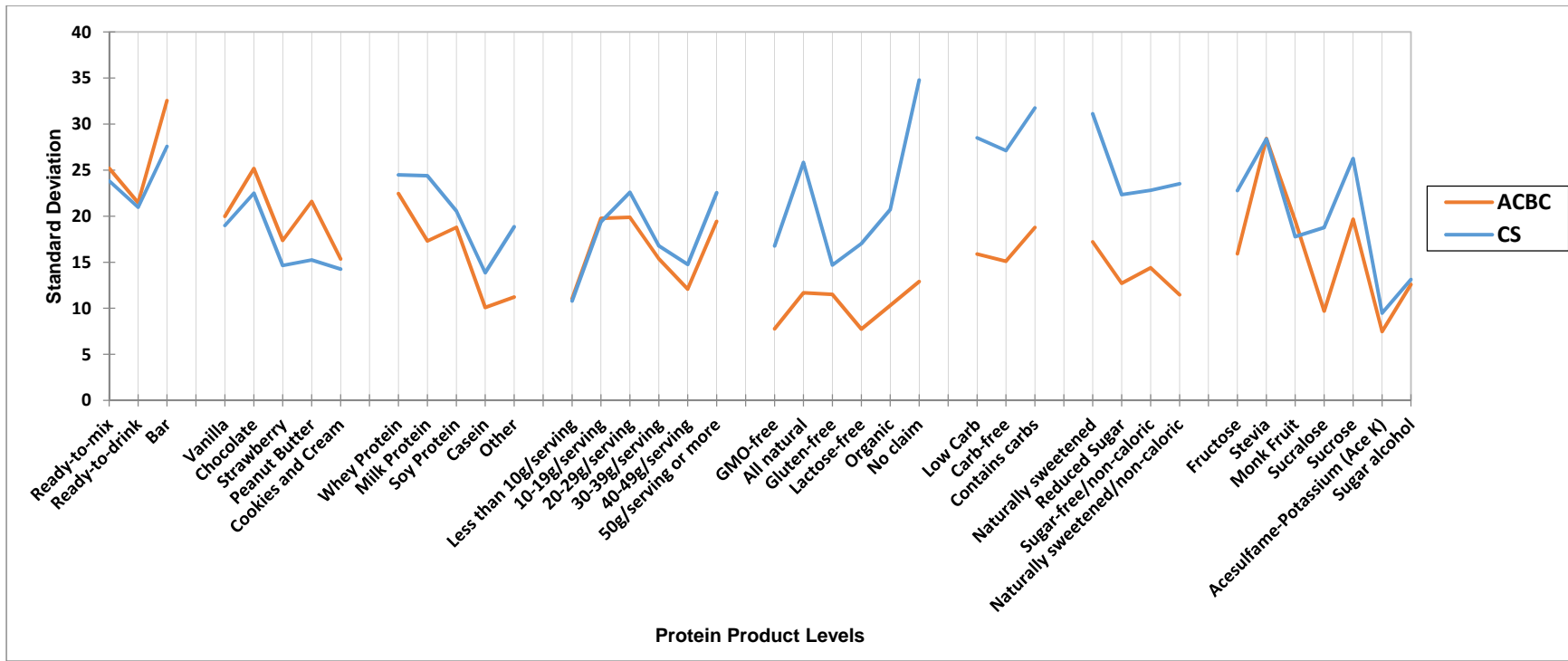


Figure 3. Average standard deviation of share of preference values for ACBC and Constant Sum surveys (n=457)

Table 3. Demographic information for ACBC and CS consumer clusters

		Overall (n=457)	ACBC Cluster 1 (n=161)	ACBC Cluster 2 (n=132)	ACBC Cluster 3 (n=164)	CS Cluster 1 (n=270)	CS Cluster 2 (n=116)	CS Cluster 3 (n=71)
Gender	Female	72.6%	66.5%b	72.0%ab	79.3%a	74.4%a	69.0%a	71.8%a
	Male	27.4%	33.5%a	28.0%ab	20.7%b	25.6%a	31.0%a	28.2%a
Age	18-30 years	33.5%	35.4%a	30.3%a	34.1%a	31.1%a	35.3%a	39.4%a
	31-45 years	30.0%	30.4%a	32.6%a	27.4%a	31.9%a	28.4%a	25.4%a
	>45 years	36.5%	34.2%a	37.1%a	38.4%a	37.0%a	36.2%a	35.2%a
Ethnicity	Caucasian	71.6%	73.9%ab	62.1%b	76.8%a	65.6%b	80.2%a	80.3%a
	Non-Caucasian	28.4%	26.1%ab	37.9%a	23.2%b	34.4%a	19.8%b	19.7%b
Annual Household Income	\$0-\$39,999/year	28.2%	24.2%a	30.3%a	30.5%a	25.2%a	29.3%a	38.0%a
	\$40,000-\$69,999/year	30.0%	34.2%a	28.0%a	27.4%a	32.6%a	24.1%a	29.6%a
	\$70,000-\$99,999/year	23.0%	20.5%a	26.5%a	22.6%a	23.7%a	29.3%a	9.9%b
	\$100,000/year or greater	18.8%	21.1%a	15.2%a	19.5%a	18.5%a	17.2%a	22.5%a
Exercise Frequency	Exercise 2-4 times/week	58.2%	57.8%a	64.4%a	53.7%a	58.5%a	55.2%a	62.0%a
	Exercise 5+ times/week	28.7%	34.8%a	21.2%b	28.7%ab	27.8%a	29.3%a	31.0%a
	Little/No exercise	13.1%	7.5%b	14.4%ab	17.7%a	13.7%a	15.5%a	7.0%a
Protein Product Consumption Frequency*	Frequent Consumption	26.5%	38.5%a	15.2%b	23.8%b	27.8%a	21.6%a	29.6%a
	Infrequent Consumption	19.5%	8.1%b	28.8%a	23.2%a	15.6%b	28.4%a	19.7%ab
	Semi-frequent Consumption	54.00%	53.4%a	56.1%a	53.0%a	56.7%a	50.0%a	50.7%a
Reasons for Protein Product Consumption	Muscle Building/Muscle Health	21.4%	29.8%a	15.9%b	17.7%b	22.2%a	18.1%a	23.9%a
	Nutritional Balance	30.4%	26.1%a	34.1%a	31.7%a	30.7%a	31.9%a	26.8%a
	Meal Replacement	25.6%	26.1%a	27.3%a	23.8%a	25.9%a	25.0%a	25.4%a
	Satiety (Keeps Me Full)	19.7%	14.9%a	18.9%a	25.0%a	18.9%a	21.6%a	19.7%a
	Other	2.8%	3.1%a	3.8%a	1.8%a	2.2%a	3.4%a	4.2%a

\*Consumption frequency of protein products was self-reported by respondents. Infrequent consumption was equal to or less often than once every 3 months, Semi-frequent consumption was defined as about once a month or a few times per month, and frequent consumption was defined as once a week or more often.

\*\*Letters in rows indicate a significant difference ( $p < 0.05$ ) between clusters within the same survey method.



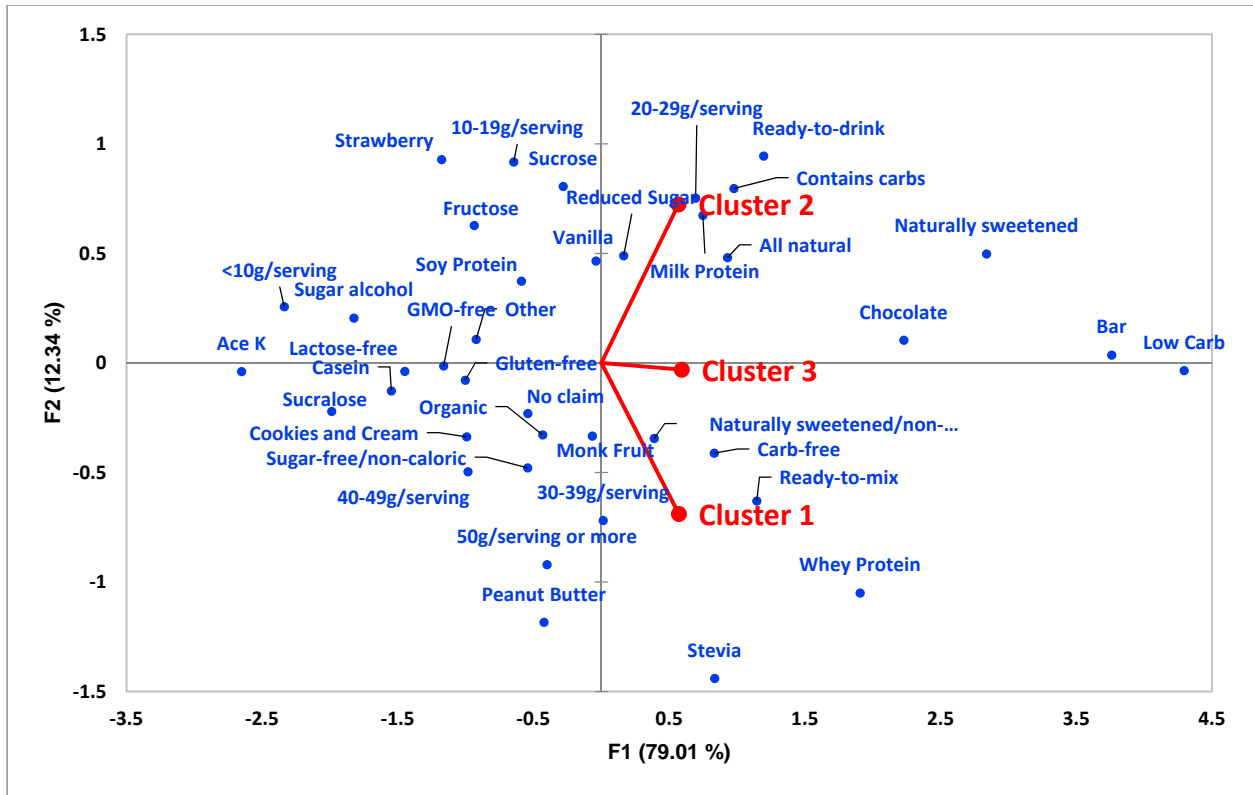


Figure 5. Principal component biplot of respondent clusters from ACBC survey (n=457)

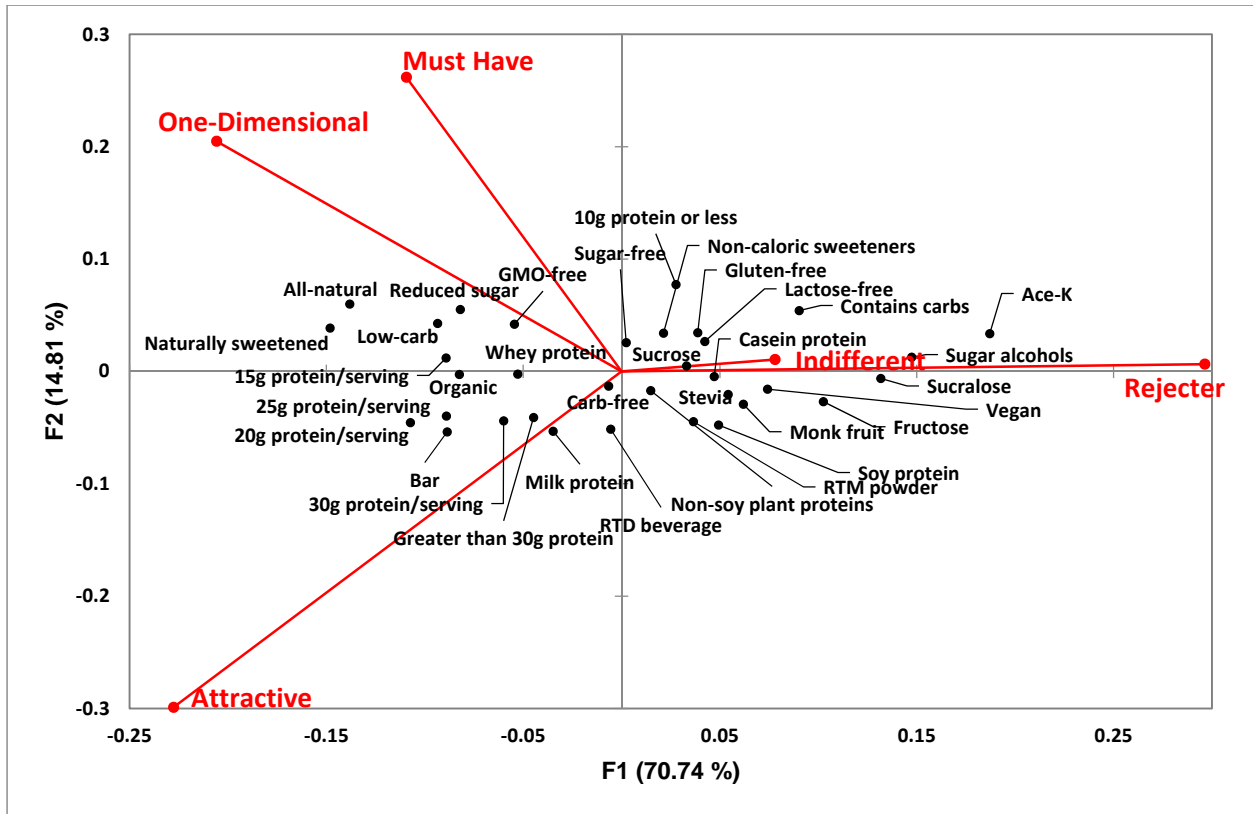


Figure 6a. Correspondence analysis biplot of Kano analysis counts for overall population (n=457) of protein product consumers.

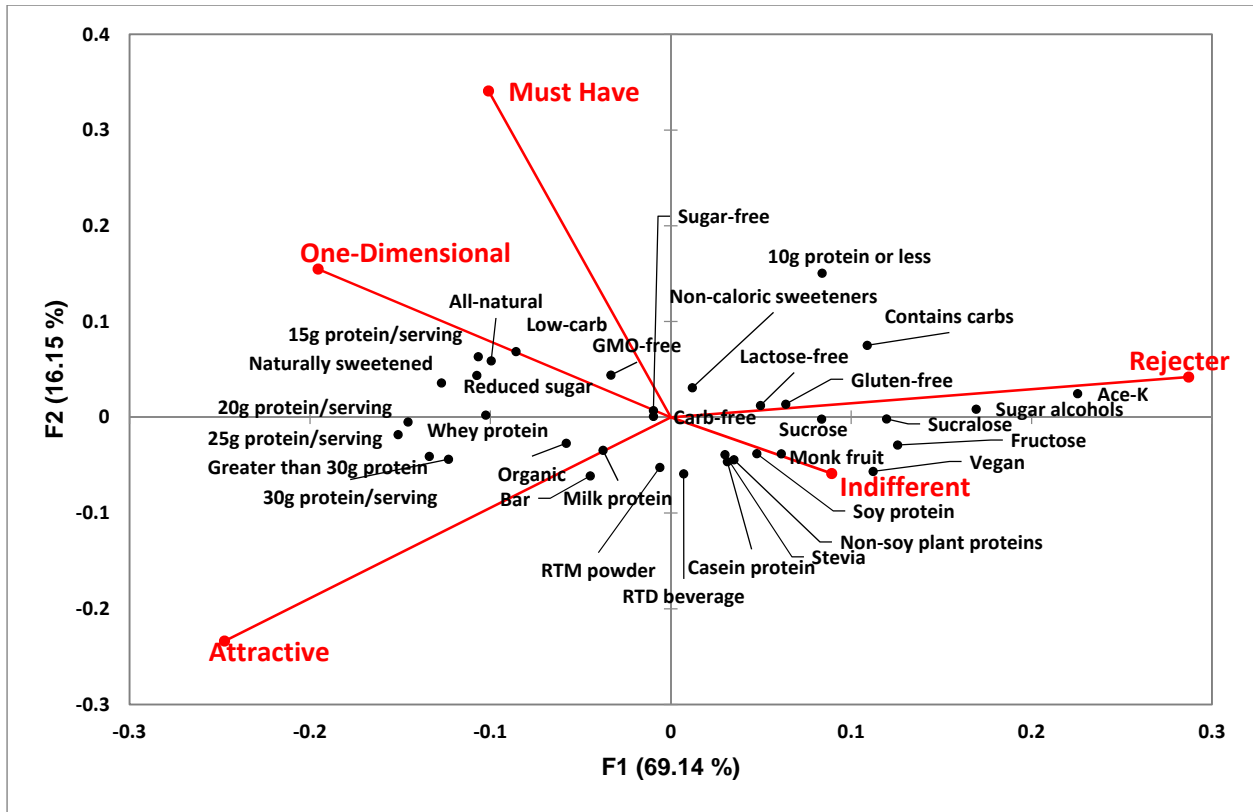


Figure 6b. Correspondence analysis biplot of Kano analysis counts for Cluster 1 (n=161) protein product consumers

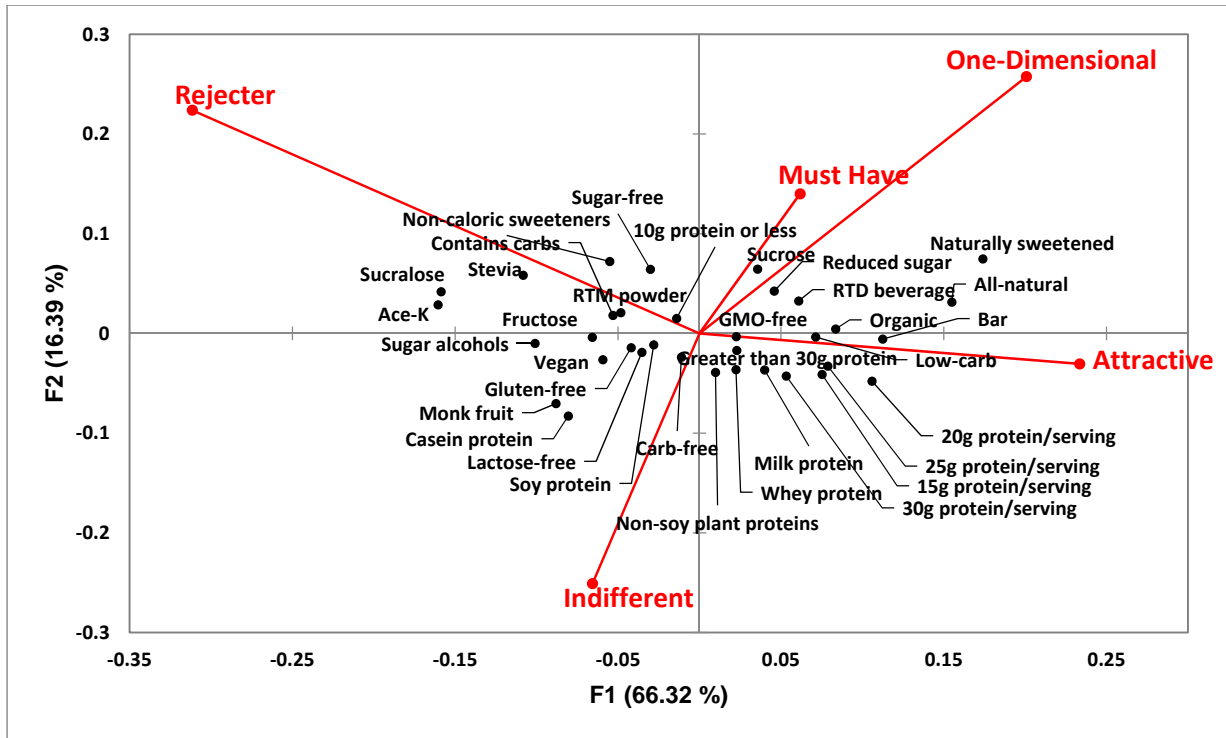


Figure 6c. Correspondence analysis biplot of Kano analysis counts for Cluster 2 (n=132) protein product consumers

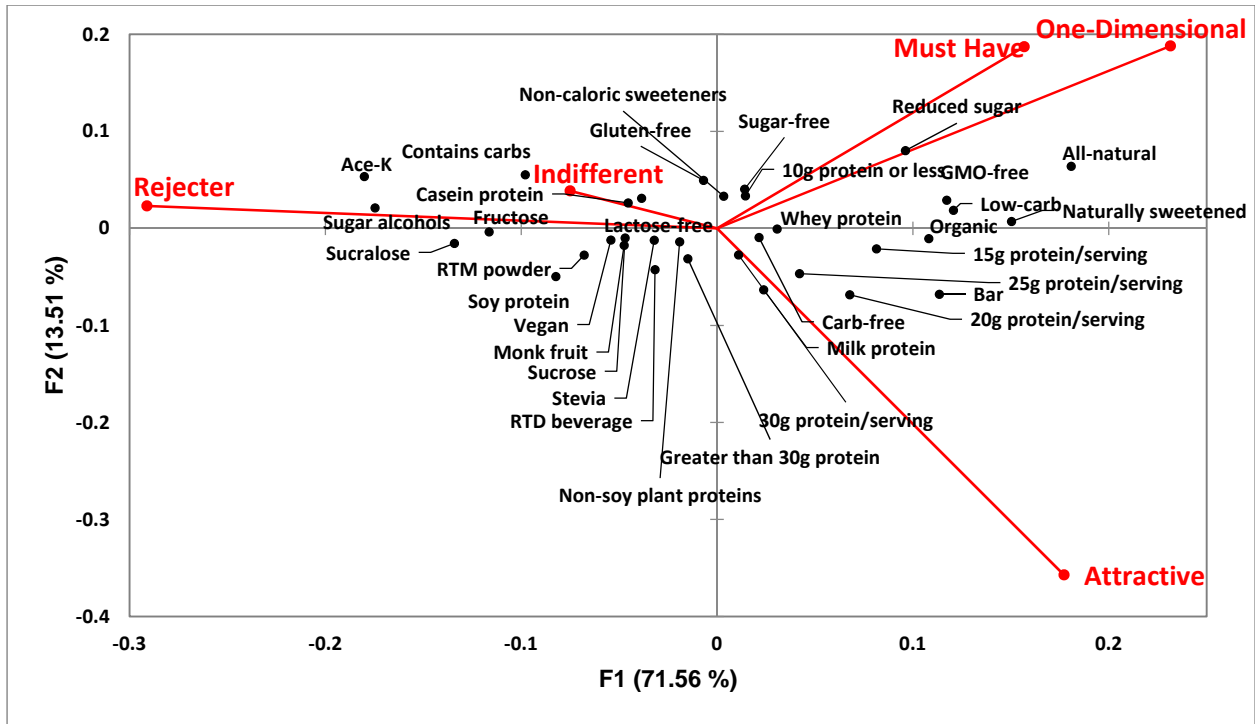


Figure 6d. Correspondence analysis biplot of Kano analysis counts for Cluster 3 (n=164) protein product consumers

Table 4. Maximum Difference (MaxDiff) scaling of protein product attributes by cluster

Attribute	Overall (n=457)	Cluster 1 (n=161)	Cluster 2 (n=132)	Cluster 3 (n=164)
A protein product that is a bar	5.2	4.3b	5.1b	6.2a
A protein product that is a ready-to-mix powder	3.3	3.9a	2.8b	3.1b
A protein product that is a ready-to-drink beverage	4.1	3.5b	5.2a	3.7b
A protein product that has whey protein	3.6	4.9a	3.1b	2.8b
A protein product that has milk protein	2.4	2.1b	2.8a	2.5ab
A protein product that has soy protein	1.4	1.3b	1.6a	1.4ab
A protein product that has non-soy plant protein	1.6	1.1b	1.8a	1.8a
A protein product that has less than 10g of protein/serving	1.5	1.1b	1.7a	1.6a
A protein product that has 10-19g of protein/serving	4.9	4.7a	5.1a	4.9a
A protein product that has 20-29g of protein/serving	6.9	8.0a	6.9b	5.8c
A protein product that has 30-39g of protein/serving	6.4	8.6a	6.1b	4.6c
A protein product that has 40-49g of protein/serving	5.2	7.4a	4.9b	3.1c
A protein product that has 50g or more protein/serving	4.5	6.6a	4.1b	2.6c
A protein product that is naturally sweetened	6.3	5.2b	6.9a	6.8a
A protein product that has reduced sugar	4.8	4.2b	4.2b	5.8a
A protein product that is sugar-free	2.8	2.6b	2.3b	3.3a
A protein product that is sweetened with fructose	1.7	1.4b	1.9a	1.7a
A protein product that is sweetened with stevia	1.9	2.0a	1.4b	2.3a
A protein product that is sweetened with monk fruit	0.7	0.6b	0.8a	0.7ab
A protein product that is sweetened with sucralose	1.2	1.2a	1.2a	1.3a
A protein product that is sweetened with sucrose	2.2	1.8b	2.9a	2b
A protein product that is sweetened with Ace K	0.7	0.7a	0.7a	0.8a
A protein product that is sweetened with sugar alcohols	0.7	0.7a	0.7a	0.8a
A protein product that is GMO-free	2.9	2.5b	2.8ab	3.3a
A protein product that is all natural	6.6	5.6b	6.9a	7.3a
A protein product that is gluten-free	1.2	0.7c	1.2b	1.7a
A protein product that is lactose-free	1.3	1.0b	1.3ab	1.6a
A protein product that is vegan	0.9	0.7a	1.0a	1.0a
A protein product that is organic	3.8	3.0b	4.0a	4.5a
A protein product that is low carb	4.4	3.9b	3.8b	5.3a
A protein product that is carb-free	3.2	3.1ab	2.5b	3.7a
A protein product that contains carbs	1.9	1.8b	2.2a	1.7b

\*Sum of values in each column is 100 total points and results are interpreted as ratio-scaled values

\*\*Means in a row followed by a significant letter are different ( $p < 0.05$ )

**CHAPTER 4:**  
**INFLUENCE OF ETHANOL CONCENTRATION ON SENSORY  
PERCEPTION OF RUMS USING TEMPORAL CHECK-ALL-THAT-  
APPLY (TCATA)**

**INFLUENCE OF ETHANOL CONCENTRATION ON SENSORY PERCEPTION OF RUMS USING TEMPORAL CHECK-ALL-THAT-APPLY (TCATA)**

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## ABSTRACT

Aged liquors are appreciated worldwide for their complexity, which is largely influenced by a given product's temporal profile. The objective of this study was to evaluate the influence of ethanol concentration on temporal sensory perception of dark rums using Temporal Check-All-That-Apply (TCATA). Trained panelists (n=8) profiled seven commercial aged rums, each at four ethanol concentrations (10, 20, 30, and 40% alcohol by volume, ABV) in quadruplicate. Fourteen attributes were profiled. During TCATA evaluation, panelists first profiled aroma attributes, then in-mouth flavor attributes, and finished with aftertaste attributes for the rums. Results were compared as differences in detection frequency over the course of sample assessment. Higher ethanol concentration increased reported frequency and duration of basic taste detection in rums ( $p < 0.05$ ). Flavor attributes including caramel, banana, cherry/almond, cooked apple, and vanilla exhibited peak detection frequencies at 30% ABV that were not significantly different from 40% ABV. These results suggest that ethanol plays a significant role in the temporal sensory perception of aged rums and that sensory differentiation in complex aged rums may peak at 30% ABV.

## **PRACTICAL IMPLICATIONS**

Temporality is an important part of the consumption experience for high-ABV products such as aged rums. Knowing how temporal sensory profiles may change when the product is presented at different alcohol levels will provide valuable insight into how rums may be applied in mixed-drink or culinary applications. In addition, trained panel profiling of high-ABV beverages is typically performed at diluted levels. An outline of the differences in dynamic product profiles at different dilutions may serve as a guidance for evaluations where diluted product outcomes are extrapolated to the undiluted commercial product.

Key Words: Temporal Check-All-That-Apply, TCATA, Rum, Ethanol

## **INTRODUCTION**

Sensory perception of food and beverage products is often a complex association between aromatic profiles, textural attributes, and chemesthesis (Verhagen and Engelen 2006). Furthermore, the perception of these products exists in a dynamic space, with sensory profiles changing and eventually diminishing over the course of consumption (Lawless and Heymann 2010). Time-dependent measurements of sensory perception have been around since the 1930s. However, the ubiquity of modern technology has allowed for temporal measurement methods to become refined and easy to apply in everyday sensory testing. Among the more common methods for evaluating temporal sensory profiles of food, beverage, and cosmetic products are time-intensity (TI), temporal dominance of sensations (TDS), and the newest temporal method, temporal check-all-that-apply (TCATA).

For products that are notably complex or exhibit numerous changes over the course of consumption, TCATA has been shown to be an effective means for mapping temporal profiles. In practice, TCATA is simply an extension of static check-all-that-apply (CATA) exercises

where participants are asked to select all attributes they feel apply to their evaluation experience. Unlike CATA exercises, TCATA profiling is performed on a continual basis, with data typically recorded at each second of evaluation. Panelists are generally instructed to select or deselect options from a set list of attributes to reflect the perceived changes in their product experience. Any number of attributes may be selected at any point in the evaluation process, with selection of no attributes indicating cessation of sensory perception for the given product. Typically, TCATA exercises are performed with up to 10 available attributes, although experiments by Jaeger *et al.* (2018) reported that the use of up to 15 attributes produced sound results. Results from completed TCATA analyses are recorded for each panelist as binary responses for each available attribute at each second of evaluation and may be reported on an aggregate basis to visually depict the dynamic experience of product consumption or use. McMahan *et al.* (2017) showed that TCATA exercises were successful in the simultaneous profiling of basic tastes and mouthfeel factors of sparkling wine samples. In addition, TCATA has been effectively used in the dynamic profiling of several other products such as Syrah wines (Baker *et al.* 2016), fermented dairy beverages (Esmerino *et al.* 2017), and protein beverages (Parker *et al.* 2018).

From a data analysis standpoint, evaluation of pairwise differences in products analyzed using TCATA is a challenge. The two primary approaches to analysis of differences in TCATA profiles are to establish arbitrary significance thresholds based on prior information, or to apply pairwise comparisons based on hypergeometric or binomial distributions at each individual time point (Meyners and Castura 2018). Applications of these statistical tests, while useful for descriptive guidance, are inherently flawed when applied to TCATA data because the binomial proportions evaluated are not independent (Castura *et al.* 2016). Additionally, consideration and correction for factors such as false discovery rate should be addressed. While the aforementioned

data analysis concerns exist with current methods, it should be noted that successful conclusions have been drawn from such applications in a number of recent studies and their use is warranted until improved options are developed (Ares *et al.* 2015; Boinbaser *et al.* 2015, Jaeger *et al.* 2017).

Though temporality is an integral part of the consumption of any food or beverage product, alcoholic beverages such as aged rums are perhaps the most widely appreciated on a temporal basis. Consumers often pay attention to aroma and aftertaste in addition to typical in-mouth attributes related to consumption when consuming rums or other high-ABV liquors. Ethanol concentration has a significant impact on flavor perception in alcoholic beverages (Ickes and Cadwallader 2017a). However, most studies that have explored ethanol effect on sensory perception have been limited to relatively low-ABV beverages such as beer or wine (Goldner *et al.* 2009; King and Heymann 2014; Ramsey *et al.* 2018). Ickes and Cadwallader (2018) recently reported the sensory effects of ethanol concentration that were unique to rum. Specifically, they reported that in static descriptive analyses of rums, similar sensory profiles were exhibited between samples diluted to 20% ABV and commercial 40% samples, with most differences existing in terms of attribute intensity. The study by Ickes and Cadwallader (2018) serves as a valuable resource in terms of distilled spirit sensory evaluation, but the temporal effects related to ethanol concentration in rum remain unknown. This study seeks to answer those questions through the novel application of TCATA so that guidance for consumers, rum producers, and sensory panelists may be improved.

## MATERIALS AND METHODS

### *Sample Selection and Preparation*

Seven commercial aged rums were chosen for TCATA analysis. Rums were selected from a set of 14 commercial aged rums that were evaluated at 20% ABV using traditional descriptive analysis methods (Figures 1a and 1b). All rums were purchased at a local liquor store in Raleigh, NC. Representative samples for TCATA analysis were selected heuristically based on careful examination of sensory profile means and principal component analysis (PCA) biplots to select the greatest differentiation and to ensure proper capture of the category range (Figure 1). To measure the effect of ethanol concentration during evaluation, each sample was prepared at commercial alcohol by volume (ABV) (40%), as well as 30%, 20%, and 10% ABV dilutions. Dilutions were prepared using deionized water to achieve the target ethanol concentrations (v/v). Prepared samples were dispensed in 12 ml aliquots into tulip-shaped glasses (235 ml) and were subsequently covered with watch glasses. Prepared samples were held at 21°C for at least one hour prior to evaluation to ensure headspace equilibration. Sensory profiling of rums was approved by the NCSU Institutional Review Board for Human Subjects (IRB 7743).

### *Temporal Check-All-That-Apply (TCATA)*

TCATA profiling of rums was conducted by 8 trained descriptive analysis (DA) panelists (3 males, 5 females; ages 21-54 y), each with at least 40 h DA experience with aged rum or other aged liquors and 25 h total TCATA training experience. Jaeger *et al.* (2017) reported that panelists familiar with the TCATA task and available attributes tend to exhibit greater sample discrimination. Samples were evaluated by trained panelists in triplicate over the course of twenty-one 30 min sessions. In each session, each panelist evaluated a random presentation of 4 samples of the 28 possible aged rum/dilution combinations. TCATA evaluations of each sample

were performed over a 150 s time domain, which consisted of 4 parts: profiling of orthonasal aroma attributes (0-15 s), deselection phase (15-25 s), in-mouth profiling of flavor attributes, basic tastes, and alcohol burn (25-40 s), and aftertaste evaluation of flavor attributes, basic tastes, and alcohol burn (40-150 s). Following each sample, each panelist was given a five-minute enforced wait time and was instructed to rinse their mouth with water before continuing to the next sample. Evaluations were recorded on iPad interfaces using Compusense Cloud software (Guelph, Ontario). In all, 14 attributes were selected for profiling. Attributes included the following: banana, caramel, cherry/almond, cooked apple, mushroom, smoke, soap, vanilla, woody/twig, ethanol, fusel, alcohol burn, bitter taste, and sweet taste (Table 1). Panelists were allowed unlimited selection and deselection of all attributes over the course of evaluation, with no attribute fading included (Vidal *et al.* 2017). If all perception of attributes ceased during evaluation, participants were instructed to deselect all attributes and allow for the evaluation time to elapse. Attributes in the TCATA evaluation were analyzed for presence only and were not scaled for intensity.

### **Statistical Analysis**

Temporal profiles of the seven commercial aged rums were analyzed in these time domains on an aggregate basis. Smoothed TCATA curves and difference curves comparing ethanol concentrations were constructed using the “TempR” package as proposed by Castura *et al.* (2016). Significant differences in citation proportions for each attribute were determined for each pairwise group of ethanol concentration treatments at each second using the 2-sided Fisher’s Exact Test ( $\alpha=0.05$ ). Citation proportions and differences were graphed using XLSTAT version 19.5.2018 (Addinsoft, Paris, France).

## RESULTS AND DISCUSSION

Analysis of TCATA profiles allowed for elucidation of the differences in aged rum samples due to ethanol concentration ( $p < 0.05$ ). Differences were analyzed in 3 primary domains: orthonasal evaluation (0-15 s), in-mouth evaluation (25-40 s), and aftertaste evaluation (40-150 s).

### *Orthonasal Evaluation*

Results from pairwise difference curves in the orthonasal evaluation timeframe showed that there were small differences in temporal sensory evaluation when aged rums were nosed at different ethanol concentrations. In general, only minor differences were observed between treatments of neighboring ethanol concentration. Compared to the 10% ABV treatment (Figure 2), 20% ABV (Figure 3) had higher citation proportions ( $p < 0.05$ ) for fusel and woody/twig attributes toward the end of the nosing interval (Figure 4). Similarly, a higher citation proportion for fusel aroma was noted in the 30% ABV treatments (Figure 5) compared to the 20% ABV treatments (Figure 6). These results suggest that fusel and woody notes may be harder to detect orthonasally at dilutions below 30% ABV, or may be associated with slightly delayed elicitation of perception. At 40% ABV (Figure 7), there was a higher citation proportion ( $p < 0.05$ ) observed for ethanol aroma, and no significant increase in fusel aroma perception was noted compared to 30% ABV (Figure 8). These results show that overall, there are minimal differences in perception of orthonasal aroma attributes in aged rums due to ethanol concentration, outside of alcohol-related attributes (fusel and ethanol). Experiments by Ickes and Cadwallader (2017a) reported that increased ethanol concentration generally resulted in decreased instrumental perception of volatiles in static headspace systems. In general, orthonasal evaluations by human participants showed marked agreement with these instrumental findings.

### ***In-mouth and Aftertaste Evaluation***

Compared to 10% ABV (Figure 2), evaluations at 20% ABV (Figure 3) were characterized by higher peak citation proportions for all attributes except bitter taste and soapy flavor. Furthermore, the average time to peak citation rate for evaluated attributes (except mouthfeel burn) following in-mouth evaluation of the rums was about 1.8s longer for rums prepared at 20% ABV, compared to rums prepared at 10% ABV. These results suggest that there is a substantial increase in the magnitude of sensory perception when aged rums are evaluated at 20% ABV versus 10% ABV and a subsequent delay in peak citation proportion. Discrepancies due to utilization of a longer list of attributes were reported by Jaeger *et al.* (2018) to be a concern in TCATA tasks. In this study, it is hypothesized that the increased flavor impact associated with the increase from 10% to 20% ABV introduced greater flavor complexity and forced panelists to discriminate competing attributes, resulting in slight delays in peak citation proportion.

In terms of differences, 20% ABV evaluations were differentiated from 10% ABV evaluations primarily by differences in basic taste perception, and burn, although many aromatic perceptions also differed (Figure 4). Significant differences in citation proportions for both burn and sweet taste were noted shortly after initial product consumption during in-mouth evaluation ( $p < 0.05$ ). Differentiation of aromatic components of the rums did not increase in the same fashion as burn and sweet taste during the in-mouth portion of evaluation, which was likely due to disturbed perception associated with the trigeminal burn response. Dominance from basic taste and burn attributes in distilled spirits was reported by Fiches *et al.* (2016) using temporal dominance of sensations analyses and suggests that the true sensory profile of high-ABV products is experienced post-swallowing/expectoration. Compared to 10% ABV, 20% ABV

resulted in a significantly higher citation proportion for burn was noted throughout the entire product evaluation period, and higher sweet taste perception was noted until it subsided around 60 seconds after initial consumption during aftertaste evaluation. Aside from burn and sweet taste perception, aftertaste evaluation at 20% ABV was generally characterized by higher citation proportions than evaluations at 10% ABV and showed extended perception duration for caramel, vanilla, woody/twig, smoky, cherry/almond, and banana attributes. These results indicate that overall, 10% ABV evaluations of aged rum samples may be a poor representation of product temporal profile and, presumably, attribute intensities, especially if product evaluations are intended to provide extrapolated information about an undiluted commercial product.

Furthermore, these results have implication for commercial brands regarding brand identity. In a study of standard alcoholic beverage preparation among Northern California restaurants, it was found that mixed drinks were prepared at about 14% ABV and rum staples such as rum and coke were only prepared at about 12% ABV on average (Kerr *et al.* 2008). Under these conditions, it is unclear if the full complexity of commercial rums can be appropriately evaluated, and there is reason to believe that efforts should be made to posture aged rum products for consumption at 20% ABV or above.

Evaluation of high-ABV alcoholic beverages for descriptive sensory applications has traditionally been carried out at 20% ABV to circumvent fatigue concerns. While the aforementioned findings suggest that 20% ABV evaluations are more representative of the complexity characteristic of the aged rum category, investigation into how 20% ABV evaluations compare to 30% ABV and undiluted 40% ABV evaluations is also warranted. When temporal profiles were compared, 20% (Figure 3) and 30% ABV (Figure 5) exhibited comparable average time to peak citation rate for the evaluated attributes, suggesting that

temporal profiles were similar. Although the evolution of temporal profiles was similar, some marked differences were still observed. Towards the end of in-mouth evaluation, significantly higher citation proportions were observed for both burn and ethanol at 30% ABV (Figure 6). Aside from extended burn perception, there were no significant differences in flavor perceptions noted until about 45s after initial consumption (~70s time point). Increased ethanol content has been shown to increase aftertaste duration and intensity of attributes such as sweet taste, bitter taste, astringency, dark fruit, burn, and spice (Baker *et al.* 2016; Ramsey *et al.* 2018). At 30% ABV, the extended aftertaste portion of evaluation showed increased perception of attributes such as caramel, smoky, cherry/almond, vanilla, and woody/twig compared to 20% ABV evaluation. Aftertaste following swallowing or expectoration, commonly referred to as “finish,” of alcoholic beverages such as wine is commonly associated with quality (Jackson 2002). With the substantial growth in the premium spirit market over the last few decades, quality measurements and understanding of product features such as finish complexity is important (Cole 2017).

Distilled spirits are consumed in a variety of ways, including neat (undiluted), with ice (on the rocks), and in mixed drink applications. Another popular method of consumption that has been purported to increase the sensory experience is to prepare distilled spirits with “a splash” of water. To investigate claims that mild dilution increases sensory perception of distilled alcoholic beverages from a temporal perspective, comparisons of 30% and 40% ABV sample evaluations were made. Overall, temporal profiles and average time for peak citations were similar between 30% (Figure 5) and 40% ABV (Figure 7) evaluations. Additionally, only minor differences were noted between the two ethanol concentrations regarding citation rates over the course of

evaluation. Observed differences (Figure 8) were primarily due to extended duration of post-peak burn perception and higher citation proportion for sweet taste over the course of evaluation.

Evaluation of flavor attribute differences showed that some attributes favored 30% ABV, while others showed greater expression at 40% ABV. Specifically, fusel and vanilla exhibited higher citation proportions in portions of in-mouth evaluation and cherry/almond flavor was higher from about the 90-110s timepoints at 30% ABV. These results are consistent with findings by Goldner *et al.* (2009) which showed that perception of some fruity flavors in wine favored lower ethanol concentrations. On the other hand, the attributes caramel, mushroom, and cooked apple showed times of higher citation proportions in the aftertaste for samples prepared at 40% ABV. Overall, these results suggest that there is evidence that certain attributes and aspects of distilled spirit consumption may be enhanced at 30% versus 40% (neat) consumption. Furthermore, the decreased duration of burn exhibited at 30% ABV compared to undiluted product may be motivation enough to consider slight dilution for sensory profiling purposes.

The relatively similar temporal profiles found in the 30% vs 20% and 40% vs 30% ABV comparisons poses the need to explore how well 20% ABV evaluations can approximate the temporal sensory experience at 40% ABV. Overall, evaluations at 20% ABV (Figure 3) showed a similar temporality to 40% ABV (Figure 7) evaluations, but some marked differences were noted (Figure 9). Smoky flavor and burn mouthfeel showed differences in time to peak citation rate, with peak citation rates 4 and 6 seconds later, respectively, at 40% ABV compared to 20% ABV. Additionally, difference curves of the two treatments showed that there were significant differences in the duration of elevated citation rate for caramel, woody/twig, and vanilla. These findings suggest that 20% ABV evaluations of age rum samples effectively mirror the sensory and temporal profiles of 40% ABV commercial beverages, however, evaluations at 20% ABV

may fail to capture some of the information related to aged rum complexity and attribute duration. For sensory professionals, samples diluted to ~20% ABV have traditionally been used to avoid fatigue concerns (Ickes and Cadwallader 2018; Donnell *et al.* 2001). Findings from this study confirm that overall, 20% ABV dilutions are a strong approximation of the temporal profile exhibited by commercial 40% ABV products. However, 30% ABV aged rum treatments did exhibit clear advantages to 20% ABV samples and were near-perfect approximations of temporal and sensory perceptions found in 40% ABV samples. For this reason, careful consideration should be made to account for the balance between results that reflect the commercial product and assuaging sensory fatigue.

## **CONCLUSIONS**

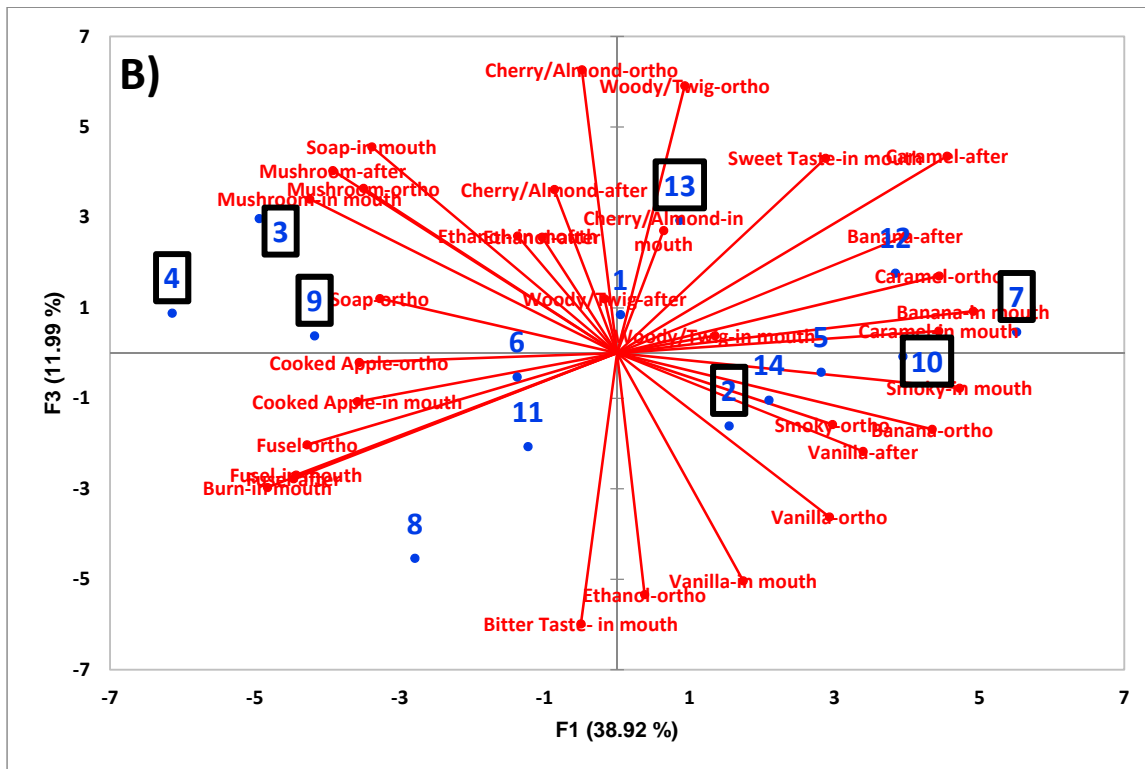
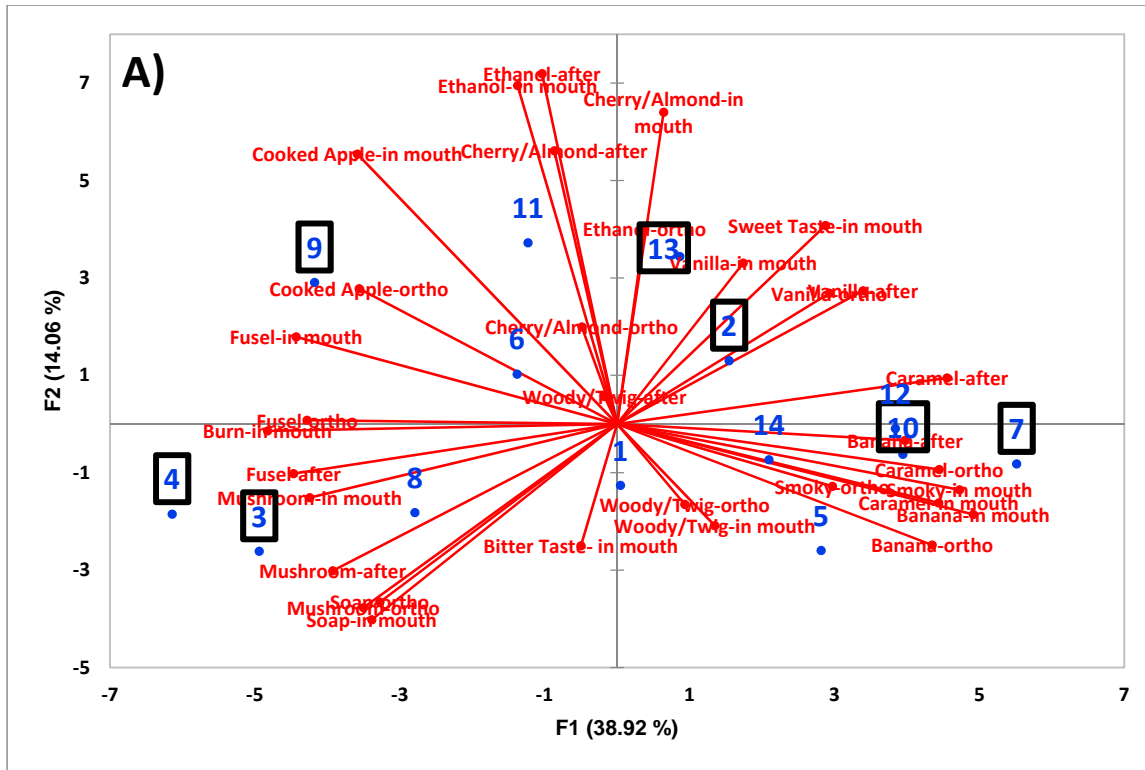
Overall, the results of this study suggest that there are clear differences in the temporal profiles of aged rums at different ethanol concentrations in terms of attribute perception and duration. Implications of these differences may be viewed from a practical use (such as mixed drink applications), as well as a trained sensory profiling perspective, where diluted sample evaluations are extrapolated to undiluted commercial product conclusions. TCATA analysis revealed that significant information may be lost from evaluations under 20% ABV when comparing aged rums and extrapolating to undiluted product, especially in regard to aftertaste evaluation. Furthermore, analysis of difference curves between ethanol concentrations suggest that 30% ABV may be the ideal concentration for evaluating diluted products without alteration or loss of attribute perception. Dilutions down to 20% ABV may be adequate for expression of key aged flavor attributes, although losses in attribute duration and peak perception of attributes such as burn and basic tastes are expected. These results may act as guidance for aged rum producers looking to posture their products as mixed drink components because 20% ABV

preparations maintain undiluted sample qualities for the most part. Furthermore, understanding the differences in perception of aged liquors due to ethanol concentration from a temporal standpoint is necessary for product development and trained sensory analysis endeavors.

## REFERENCES

- Ares, G., Jaeger, S.R., Antúnez, L., Vidal, L., Giménez, A., Coste, B., Picallo, A. and Castura, J.C. 2015. Comparison of TCATA and TDS for dynamic sensory characterization of food products. *Food Res. Int.* 78, 148-158.
- Baker, A.K., Castura, J.C. and Ross, C.F. 2016. Temporal check-all-that-apply characterization of Syrah wine. *J. Food Sci.* 81(6), S1521-S1529.
- Boinbaser, L., Parente, M.E., Castura, J.C. and Ares, G. 2015. Dynamic sensory characterization of cosmetic creams during application using Temporal Check-All-That-Apply (TCATA) questions. *Food Qual. Pref.* 45, 33-40.
- Castura, J.C., Antúnez, L., Giménez, A. and Ares, G. 2016. Temporal Check-All-That-Apply (TCATA): A novel dynamic method for characterizing products. *Food Qual. Pref.* 47, 79-90.
- Cole, Z.D., 2017. Growth and Development of Craft Spirit Tourism: The Fermenting Giant? In *Craft Beverages and Tourism*, pp. 25-40. Palgrave Macmillan, London, UK.
- Donnell, E.M., Hulin-Bertaud, S., Sheehan, E.M. and Delahunty, C.M., 2001. Development and learning process of a sensory vocabulary for the odor evaluation of selected distilled beverages using descriptive analysis. *J. Sens. Stud.* 16(4), 425-445.
- Esmerino, E.A., Castura, J.C., Ferraz, J.P., Tavares Filho, E.R., Silva, R., Cruz, A.G., Freitas, M.Q. and Bolini, H.M. 2017. Dynamic profiling of different ready-to-drink fermented dairy products: A comparative study using Temporal Check-All-That-Apply (TCATA), Temporal Dominance of Sensations (TDS) and Progressive Profile (PP). *Food Res. Int.* 101, 249-258.
- Fiches, G., Saint Eve, A., Jourdren, S., Déléris, I., Brunerie, P. and Souchon, I. 2016. Temporality of perception during the consumption of French grape brandies with different aging times in relation with aroma compound release. *Flavour Fragr. J.* 31(1), 31-40.
- Goldner, M.C., Zamora, M.C., Di Leo Lira, P.A.O.L.A., Gianninoto, H. and Bandoni, A. 2009. Effect of ethanol level in the perception of aroma attributes and the detection of volatile compounds in red wine. *J. Sens. Stud.* 24(2), 243-257.
- Ickes, C.M. and Cadwallader, K.R. 2017a. Effects of ethanol on flavor perception in alcoholic beverages. *Chemosens. Percept.* 10, 119-134.
- Ickes, C.M. and Cadwallader, K.R., 2017b. Characterization of sensory differences in mixing and premium rums through the use of descriptive sensory analysis. *J. Food Sci.* 82(11), 2679-2689.
- Ickes, C.M. and Cadwallader, K.R. 2018. Effect of ethanol on flavor perception of Rum. *Food Sci. Nutr.* In Press.

- Jack, F. 2003. Development of guidelines for the preparation and handling of sensory samples in the Scotch whisky industry. *J. Inst. Brew.* 109(2), 114-119.
- Jackson, R.S. 2002. *Wine Tasting: A Professional Handbook*, p. 14, Elsevier, San Francisco, CA.
- Jaeger, S.R., Beresford, M.K., Hunter, D.C., Alcaire, F., Castura, J.C. and Ares, G. 2017. Does a familiarization step influence results from a TCATA task? *Food Qual. Pref.* 55, 91-97.
- Jaeger, S.R., Alcaire, F., Hunter, D.C., Jin, D., Castura, J.C. and Ares, G. 2018. Number of terms to use in temporal check-all-that-apply studies (TCATA and TCATA Fading) for sensory product characterization by consumers. *Food Qual. Pref.* 64, 154-159.
- Kerr, W.C., Patterson, D., Koenen, M.A. and Greenfield, T.K. 2008. Alcohol content variation of bar and restaurant drinks in Northern California. *Alcohol. Clin. Exp. Res.* 32(9), 1623-1629.
- King, E.S. and Heymann, H., 2014. The effect of reduced alcohol on the sensory profiles and consumer preferences of white wine. *J. Sens. Stud.* 29(1), 33-42.
- Lawless, H.T. and Heymann, H. 2010. Time-intensity methods. In *Sensory evaluation of foods*, pp. 179-201. Springer, New York, NY.
- Leksrisompong, P.P., Lopetcharat, K., Guthrie, B. and Drake, M.A. 2012. Descriptive analysis of carbonated regular and diet lemon-lime beverages. *J. Sens. Stud.* 27(4), 247-263.
- McMahon, K.M., Culver, C., Castura, J.C. and Ross, C.F. 2017. Perception of carbonation in sparkling wines using descriptive analysis (DA) and temporal check-all-that-apply (TCATA). *Food Qual. Pref.* 59, 14-26.
- Meyners, M. and Castura, J.C. 2018. The analysis of temporal check-all-that-apply (TCATA) data. *Food Qual. Pref.* 67, 67-76.
- Parker, M.N., Lopetcharat, K. and Drake, M.A. 2018. Consumer acceptance of natural sweeteners in protein beverages. *J. Dairy Sci.* In Press.
- Ramsey, I., Ross, C., Ford, R., Fisk, I., Yang, Q., Gomez-Lopez, J. and Hort, J. 2018. Using a combined temporal approach to evaluate the influence of ethanol concentration on liking and sensory attributes of lager beer. *Food Qual. Pref.* 68, 292-303.
- Verhagen, J.V. and Engelen, L. 2006. The neurocognitive bases of human multimodal food perception: sensory integration. *Neurosci. Biobehav. Rev.* 30(5), 613-650.
- Vidal, L., Castura, J.C., Coste, B., Picallo, A., Jaeger, S.R. and Ares, G. 2017. Analysis of TCATA Fading data: Imputation of gaps in temporal profiles. *Food Qual. Pref.* 59, 114-122.



Figures 1a-b. Principal component biplots of descriptive sensory analysis of commercial rums by trained panelists

\*“Ortho”=orthonasal evaluation, “In mouth”=in mouth evaluation, “After”=aftertaste evaluation

Table 1. Sensory attributes for aged rums

<b>Modality</b>	<b>Attribute</b>	<b>Description</b>	<b>Training Reference</b>
<b>Aromatics</b>	Banana	Aromatic characteristic of ripened bananas	Mashed ripened bananas
	Caramel	Aromatic characteristic of caramelized sugar	Caramel syrup (The J.M Smucker Company; Orrvile, OH)
	Cherry/Almond	Aromatic characteristic of cooked cherries or almond extract	Almond extract (McCormick & Co. Inc.; Hunt Valley, MD)
	Cooked Apple	Aromatic characteristic of cooked or stewed apple varieties	Applesauce (Mott's; Plano, TX)
	Ethanol	Aromatic associated with ethanol	Ethanol (40% in water)
	Fusel	Aromatic associated with isoamyl or other fusel alcohols	0.4 mg/mL isoamyl and 1 mg/mL isobutyl alcohol
	Mushroom	Aromatic associated with fresh cut mushrooms	Chopped white mushrooms soaked in water
	Smoky	Aromatic associated with hardwood smoked products	Smoked oak wood chips
	Soap	Aromatic associated with soap or detergent	Ivory soap chips (Procter & Gamble; Cincinnati, OH); decanoic acid (500 ppm)
	Vanilla	Aromatic characteristic of vanilla extract or marshmallows	Ethyl vanillin (100 ppm); marshmallows
	Woody/Twig	Aromatic characteristic of fresh-cut wood	Oak wood chips
<b>Basic Tastes</b>	Bitter	Basic taste stimulated by caffeine, and other bitter substances	Caffeine (0.08% in water)
	Sweet	Basic taste stimulated by sucrose or other sugars	Sucrose (5% in water)
<b>Mouthfeel</b>	Burn	Perception of trigeminal pain/irritation from exposure to ethanol while sample is in the mouth	Cinnamon oil (500 ppm)

Adapted from Ickes and Cadwallader (2017b), Ickes and Cadwallader (2018), and Leksrisompong *et al.* (2012)

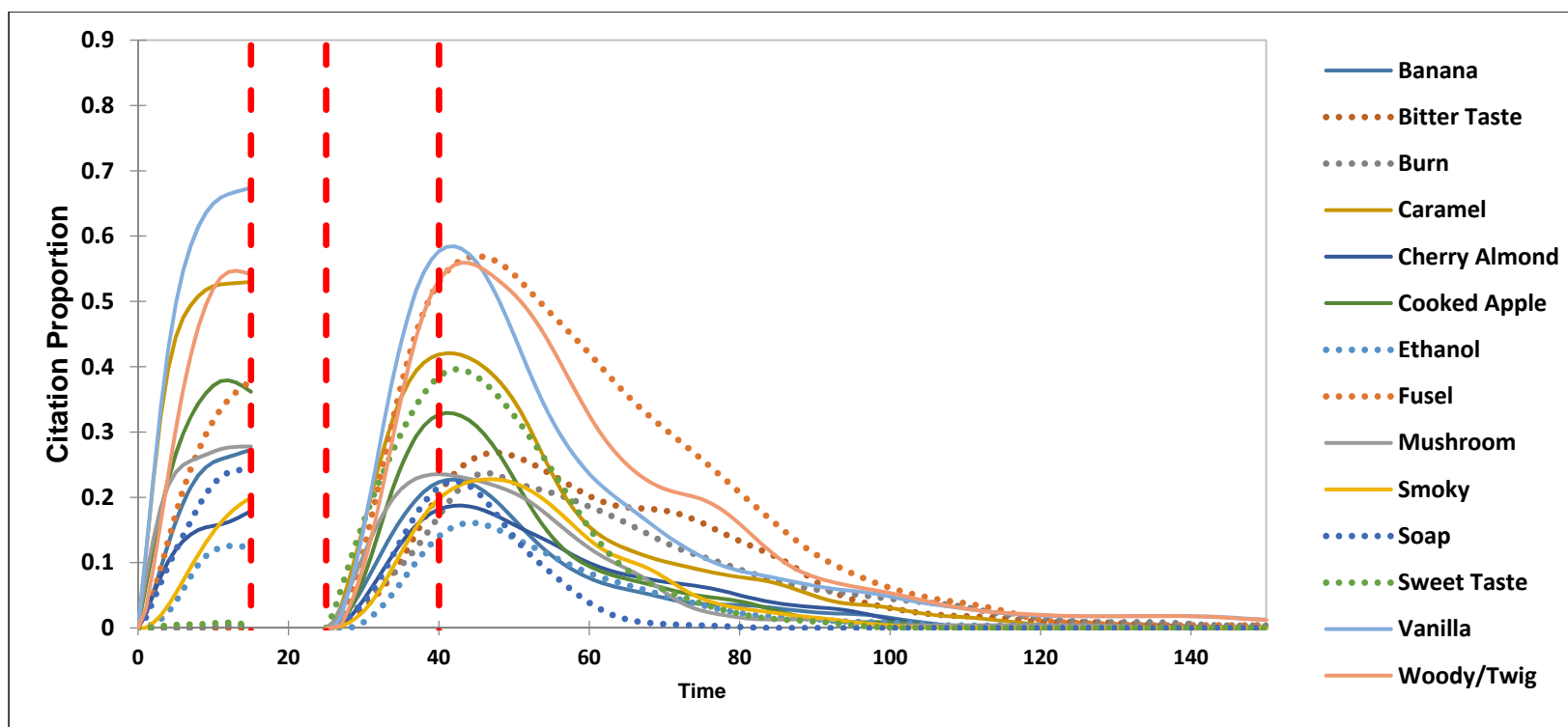


Figure 2. TCATA curves for 10% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)

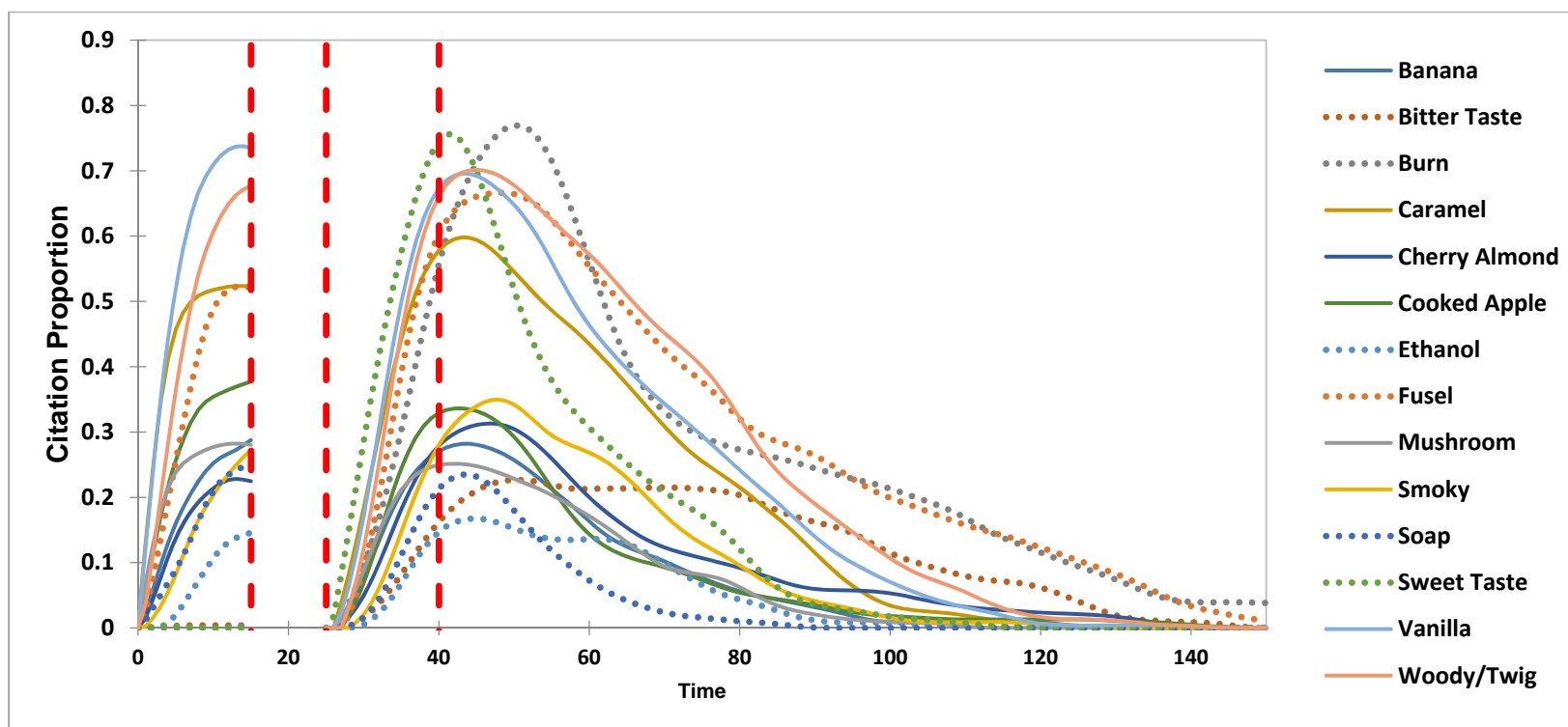


Figure 3. TCATA curves for 20% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)

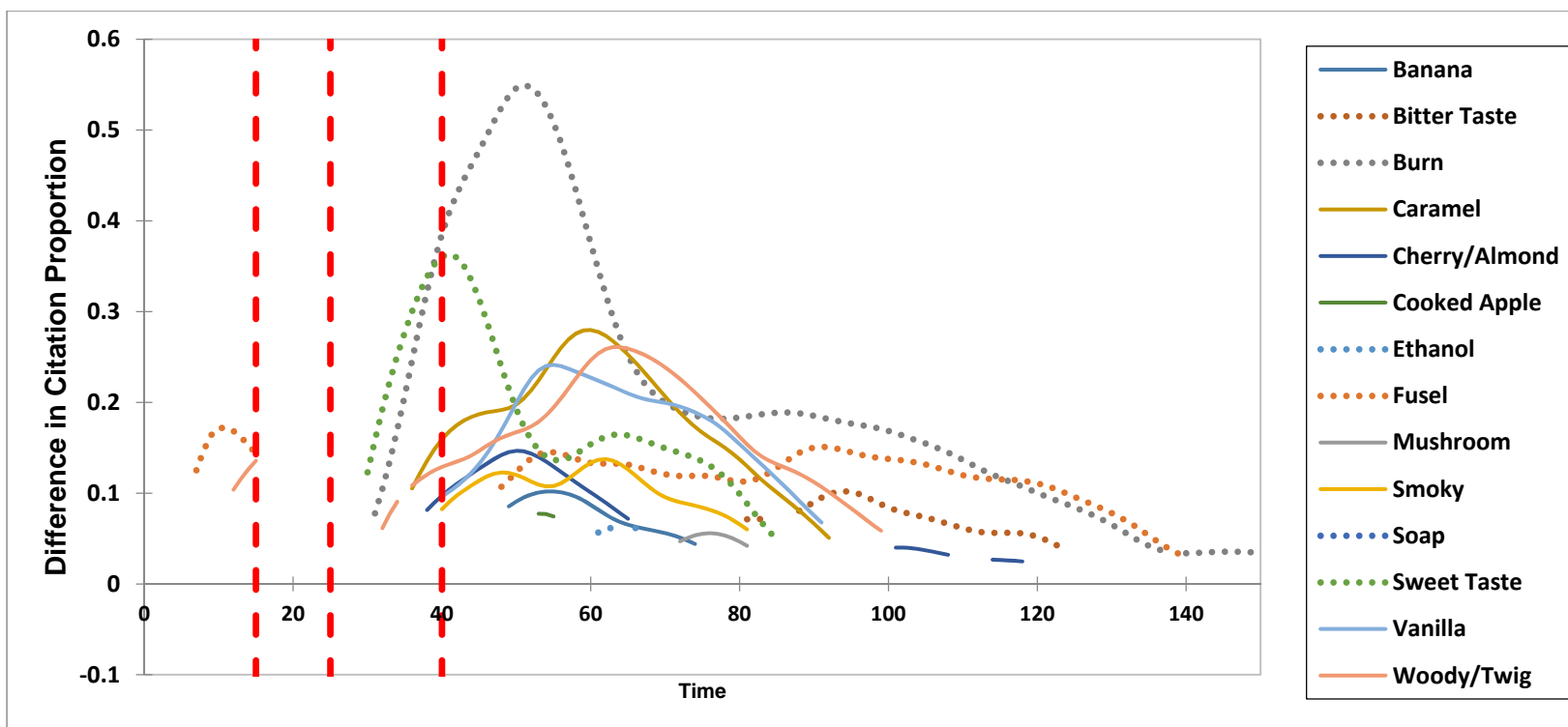


Figure 4. TCATA difference curves for 20% ABV vs. 10% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)

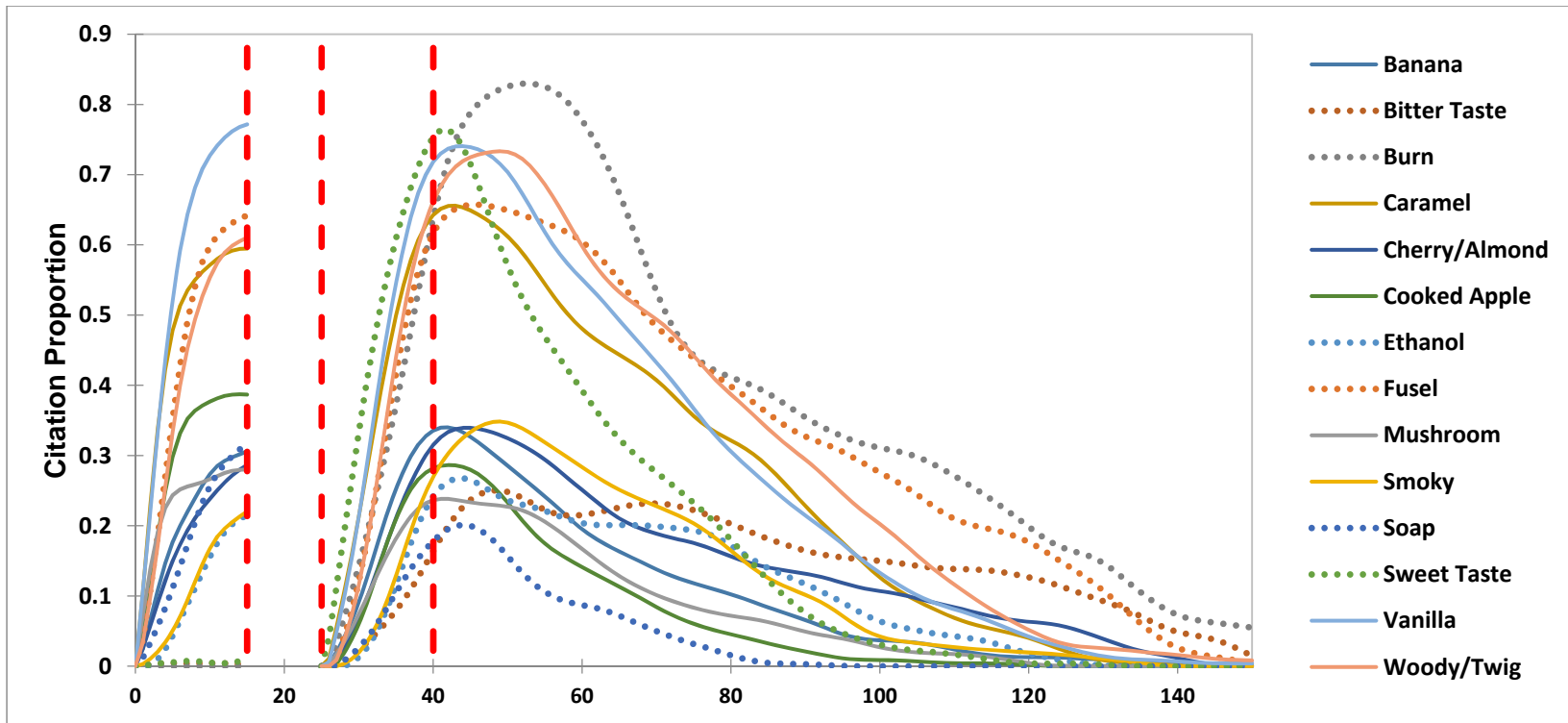


Figure 5. TCATA curves for 30% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)

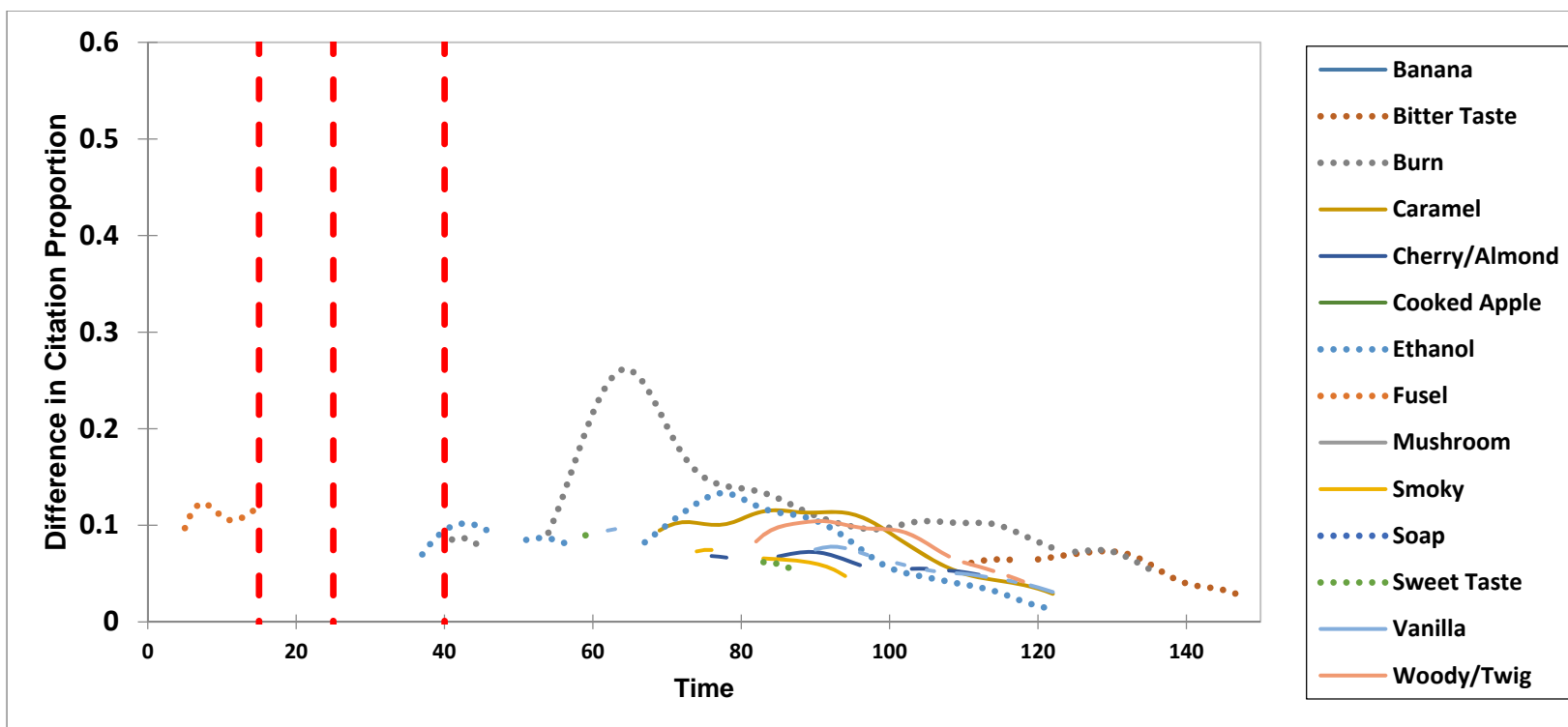


Figure 6. TCATA difference curves for 30% ABV vs. 20% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)

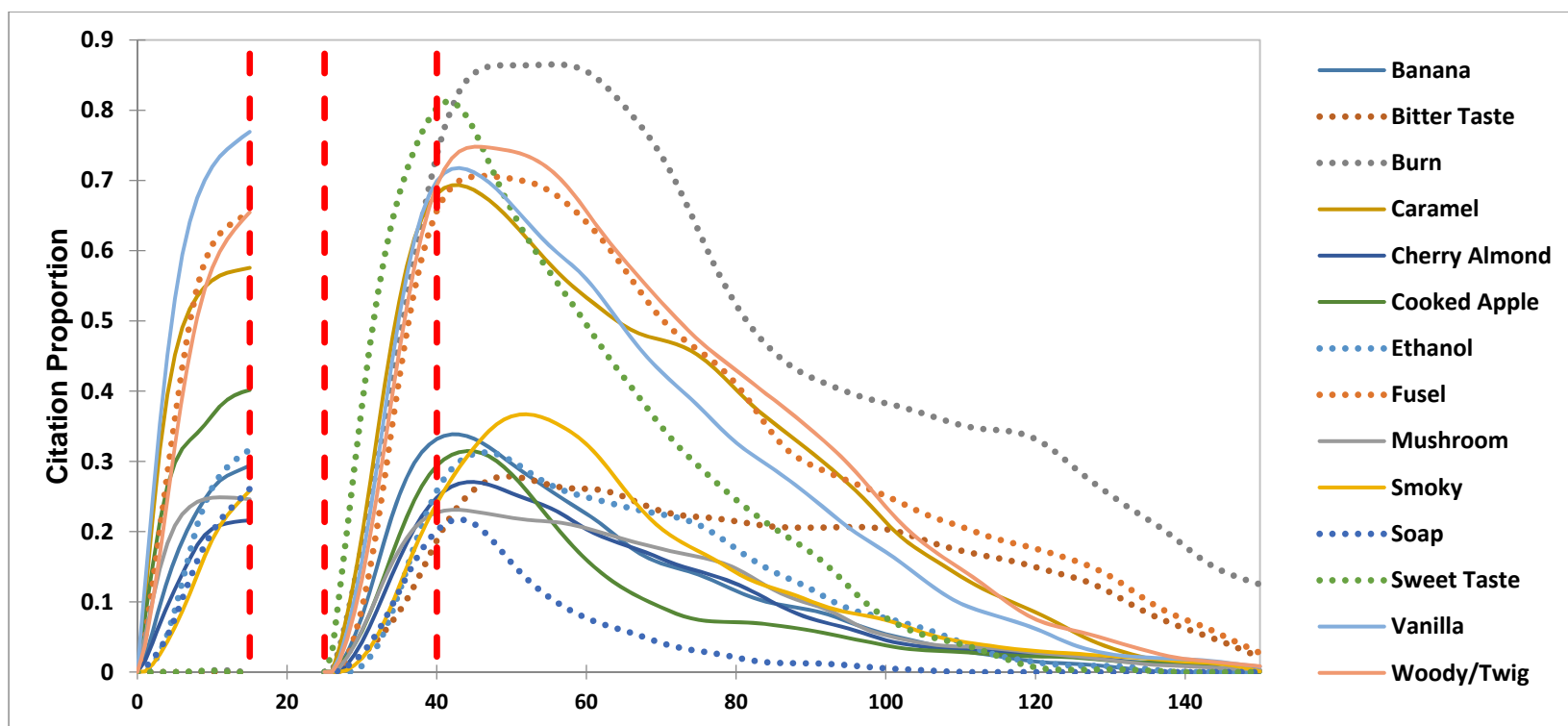


Figure 7. TCATA curve for 40% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)

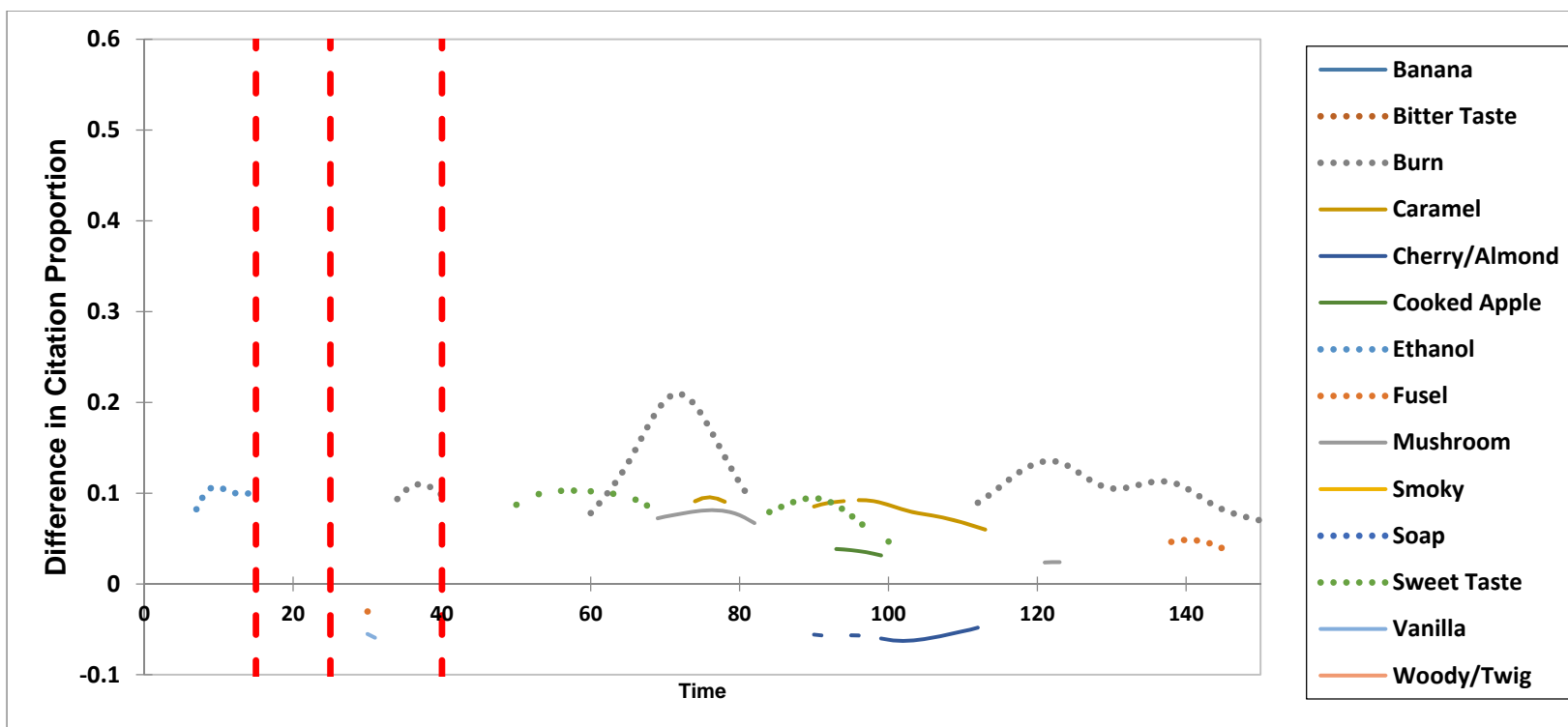


Figure 8. TCATA difference curves for 40% ABV vs. 30% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)

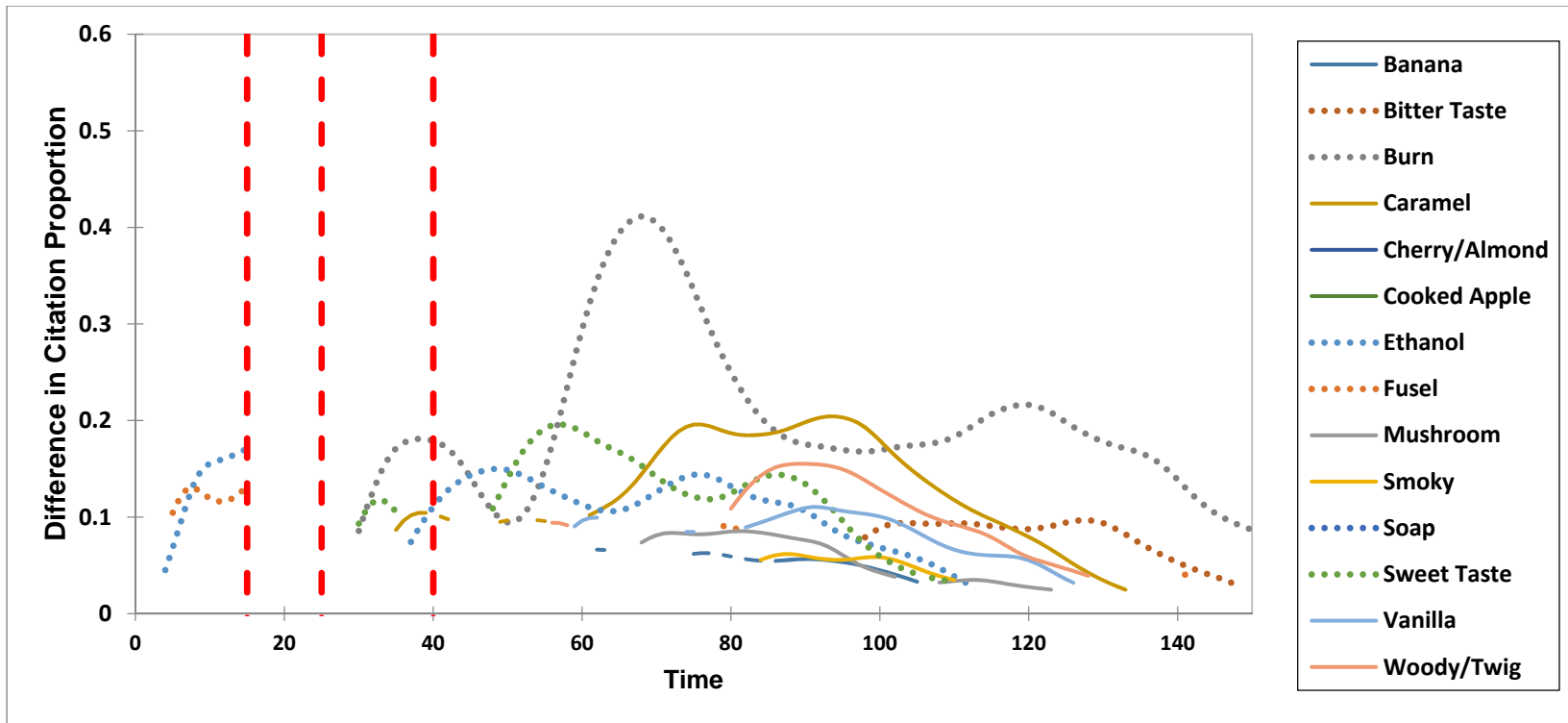


Figure 9. TCATA difference curves for 40% ABV vs. 20% ABV aged rums

\*Vertical lines denote important timepoints over the course of evaluation (Nosing: 0-15s, In-mouth: 25-40s, Aftertaste: 40-150s)