ABSTRACT

RACETTE, CLARA MARIE. Using Online Survey Methodologies and Acceptance Testing to Assess Consumer Perception of Dairy Products (Under the direction of Dr. MaryAnne Drake).

Dairy products, including fluid milk and cheese, are considered a staple food in many American households and schools. However, consumer perception of these products, including expectations and wants/needs for different dairy product categories, is not homogenous among consumers. Investigation into the segmentation of category users is important for guiding strategic product development and meeting consumer needs. Three studies were conducted to investigate consumer segmentation for product optimization. In the first study, an online survey (n=510) was conducted to understand consumer perception of hot pepper cheese. Hot pepper cheese consumers answered Maximum Difference (**MXD**) exercises and an Adaptive Choice Based Conjoint (**ACBC**) activity surrounding hot pepper cheese attributes. Subsequently, natural hot pepper cheeses (**HPC**s) were manufactured in duplicate with 5 different hot pepper blends with a range of heat intensities and distinct color differences. Trained panel profiling and consumer acceptance testing (n=194 consumers) were conducted on the cheeses. Conceptually, the overall ideal HPC was a Monterey Jack with medium-sized, multicolored pieces of jalapeno peppers and a medium heat/spiciness. HPC consumers confirmed a preference for multicolored pepper pieces and a moderate burn intensity when tasting HPCs.

The second study evaluated consumer perception of Cheddar cheese color to better understand how changes to federal legislation surrounding colorants in natural Cheddar cheese may affect consumption. We were also interested in determining if a perceptual relationship exists between color and other characteristics of Cheddar cheese. Two online surveys on Cheddar cheese color and flavor attributes (n=1226 and n=1183, respectively) were conducted, followed by a consumer acceptance test on six commercially available Cheddar cheeses (n=196).

Overall, consumers preferred light orange color in Cheddar cheese over dark orange or white Cheddar cheese, but distinct segmentation was observed for Cheddar color preference among Cheddar consumers. White and light orange Cheddars were perceived as more natural than dark orange Cheddars conceptually and in consumer acceptance testing.

In the third and final study, parental understanding and perception of school lunch milk was evaluated in order to better understand how changes to school lunch milk and school lunch milk regulations are perceived by parents. Four focus groups (n=34) were conducted with parents of school-aged children (5-13 y) who purchased milk as part of a lunch at school. Two subsequent online surveys were conducted with parents of school-aged children (Survey 1 n=216, Survey 2 n=133). Both surveys included questions to evaluate knowledge of milk nutrition and attitudes regarding milk and flavored milk. Parents perceived milk to be healthy and a good source of vitamin D and calcium. The ideal school lunch milk for parents was unflavored (white milk) or chocolate, 2% fat, ultrapasteurized, with all-natural and hormone-free label claims, packaged in a cardboard gabletop carton. For school lunch chocolate milk (Survey 2), 3 distinct clusters of parents with differing opinions for children’s chocolate milk were identified. Segmentation analysis revealed that parents were divided on the use of sugar alternatives in chocolate milk served in schools, with some parents highly in favor of these ingredients and others less so. Current school lunch milk options, which are limited to skim and 1% plain and flavored milk, may not meet parental expectations for their children. In order to further bolster parent positive attitudes towards milk and flavored milk, manufacturers of school lunch milk should consider the use of natural sugar alternatives in chocolate milk as a means of reducing the sugar content while highlighting milk calcium, vitamin D, and protein.

Using Online Survey Methodologies and Acceptance Testing to Assess Consumer Perception of Dairy Products

by
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BIOGRAPHY

Clara Racette was born on May 28th, 1997 to Joseph and Dorothee Racette in Plattsburgh, New York. She grew up running around outside and generally making messes with her two older brothers, James and Louis. Clara graduated from Bethlehem Central High School in Delmar, New York in 2015 and moved to Corvallis, Oregon to pursue a B.S. degree in Food Science at Oregon State University. While studying at OSU, Clara worked as a lab assistant at the Center for Sensory & Consumer Behavior Research which sparked her interest in sensory science. She also worked in the Arbuthnot Dairy Center pilot plant making Beaver Classic™ Cheddar cheeses which only furthered her love of all things cheese. After graduating with her B.S. in 2018, Clara moved back to the east coast to pursue a Master's degree in Food Science under the advisement of Dr. MaryAnne Drake. Clara worked in the lab for 9 months before beginning her degree program in August 2019. Outside of the lab, Clara loves cultivating her houseplant jungle, traveling, and trying new foods. She also enjoys new sewing projects, from making face masks to reupholstering wingback chairs.

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Many of us are familiar with the proverb “It takes a village to raise a child.” To me, this phrase succinctly describes the countless number of people involved in order for our stories to happen. As it turns out, it also takes a village to write a thesis. It’s difficult to summarize in just a few short paragraphs how immensely grateful I am for all of the people who have supported me in the pursuit of my goals, but here goes nothing.

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CHAPTER 1:

LITERATURE REVIEW: EVALUATION METHODS FOR SPICY FOODS AND SENSORY METHODOLOGY USED TO EVALUATE CONSUMER PERCEPTIONS OF HOT PEPPER CHEESE

Literature Review

Clara Racette

Introduction

Consumption of cheese has been on the rise in the United States since 2000. In 2019, the United States Department of Agriculture (**USDA**) reported American cheese consumption as 15.5 lbs per capita, compared to 12.7 lbs in 2000 (Shahbandeh, 2020). Mintel reports that consumer desire for cheese products is driven by health, protein and flavor, while motivation to try new cheese products is driven by unique flavors and all-natural ingredients (Kamp, 2020). With increasing consumer interest in innovative and diverse cheese products, there has been a subsequent increase in the flavored cheese category, including cheese products that contain hot peppers. 41% of consumers in a Mintel study from November 2019- June 2020 (n=9009) indicated that they purchase and consume Pepper Jack cheese, compared to 39% from August 2019 Mintel data (n=1401). Traditionally, hot pepper cheese has been constrained to pepper jack, which refers to Monterey Jack cheese with sweet peppers, habaneros, and/or jalapenos. However, in recent years, the category has grown to include different cheese types, such as Cheddar, Gouda, and Colby Jack, as well as new pepper types. Hot pepper cheese products are made by adding pepper pieces and other flavorants to the cheese curds prior to pressing, resulting in a cheese that has pepper pieces dispersed throughout the loaf. With increasing variety in the category, it is important for cheese manufacturers to understand the specific sensory properties of hot pepper cheese in order to create products that better meet consumers' needs and desires. There has been little research conducted specifically on hot pepper cheese, but numerous studies have addressed hot peppers and cheese products individually. This literature review will examine previous research on these products as well as any existing research on hot pepper cheese to explore how analytical and sensory methodologies can be used to characterize the aromatic chemesthetic properties of hot pepper cheeses as well as consumer acceptance of these products.

Overview of the *Capsicum* Species

The term pepper refers to the fruit of the *Capsicum* genus of pepper plants, which originated in the neotropics of South America and have since spread around the world (Perry, 2012). There are many varieties of *Capsicum* species, however only 5 species are recognized as domesticated: *C. annuum, C. chinense, C. frutescens, C. baccatum, and C. pubescens. C. annuum* is the most widely cultivated of the five domesticated species and contains a wide range of pepper types, including sweet peppers, mild peppers, and hot peppers. Some of the most common peppers in North American markets, such as jalapenos, poblanos, serranos, bell peppers, and cayenne peppers, belong to the *C. annuum* species. *C. annuum* species are the most common peppers seen in European and American cuisine as a result of their introduction to Europe by Christopher Columbus and other Mesoamerican explorers (Eshbaugh, 2012). *C. chinense* contains spicier pepper varietals, including habaneros and "habanero-type peppers" such as Scotch Bonnet peppers, which are commonly seen in South American and Caribbean foods, but have been increasingly present in American dishes as consumers develop an interest in ethnic ingredients, which is discussed further later in this review. *C. frutescens, C. baccatum,* and *C. pubescens* are less common in American markets, with the exception of the *C. frutescens* species known as the Tabasco pepper, which is used to make the popular American Tabasco sauce (Eshbaugh, 2012).

Most peppers in the *Capsicum* species contain a family of substances known as capsaicinoids, a group of alkaloids which are characterized by their chemical and sensory properties. There are more than twenty known capsaicinoids, however capsaicin, dihydrocapsaicin, nordihydrocapsaicin, homocapsaicin and homodihydrocapsaicin are the most common in chili peppers (Reyes-Escogido et al., 2011). Capsaicin and dihydrocapsaicin are thought to account for upwards of 90% of the capsaicinoids present in chili pepper, and are subsequently responsible for most of the sensory characteristics of hot peppers (Peña-Alvarez et al., 2009). Due to their rising popularity in food and pharmacological applications, many research projects have been conducted on capsaicinoids, particularly capsaicin.

Properties of Capsaicin

Capsaicin and its analogues are synthesized in the placenta, or pith, of chili peppers. The placenta is the central core of the pepper fruit that contains the seeds (Pierre-Louis, 2016). Capsaicin is formed from condensation of the compound vanillylamine and different fatty acids through the action of the enzyme capsaicin synthase. The resulting compound is a branched-chain vanillylamide of a monocarboxylic acid, shown in Figure 1 (Damodaran et al., 2007). Capsaicinoids are differentiated by a number of characteristics, including the length of their lateral chain, the presence or absence of double bonds, and the location where branching begins within the molecule. The lateral or aliphatic side chain of capsaicinoids ranges from 9 to 11 carbons in length and contains a varying number of double bonds in different positions within the chain (Figure 1). The fatty acid residue used during the condensation reaction affects the length of the lateral side chain, which subsequently plays a role in determining the identity of the capsaicinoid. These structural differences result in distinctive sensorial characteristics among the group of compounds, which is further elucidated later in this review.

Capsaicin (*trans*-8-methyl-N-vanillyl-6-nonenamide) is the result of vanillylamine reacting with the fatty acid 8-methyl-6-nonenoic acid through the action of capsaicin synthase.

The biosynthetic pathway of capsaicin is commonly broken down into two sub-pathways that produce the necessary constituents for the reaction: the phenyl propanoid pathway that produces vanillylamine and the branch chain fatty acid pathway that creates the fatty acid residues for the condensation reaction. The phenyl propanoid pathway begins with the essential amino acid phenylalanine and progresses through a series of five enzymatic steps to produce vanillin. Vanillin is then converted to vanillylamine through the action of amino transferase (Kehie et al., 2014). The branched chain fatty acids pathway begins with the essential amino acid valine and produces branched fatty acid residues through a series of enzymatic steps (Figure 2). Research is ongoing to fully understand all of the components involved in the biosynthesis of capsaicin. There is also significant industrial interest in manipulating the capsaicin synthesis pathway in order to increase production of the compound due to its rising use in food and pharmacological products. Studies have been conducted on this subject within a wide range of fields, including agriculture, biochemistry, and genetics.

Factors that Affect Capsaicin Content of Capsicum Species

The capsaicinoid profile of a *Capsicum* sample is subject to a number of factors, including, but not limited to: pepper genotype, availability of biosynthetic precursors and environmental factors. Genotype is the most influential parameter that affects capsaicinoid content of peppers (Meckelmann et al., 2015). Presence of capsaicinoids is inherited via the dominant gene *Pun1* in *Capsicum* species (Stewart et al., 2007). The presence or absence of *Pun1* determines whether a pepper will be pungent (spicy) or non-pungent (mild). In addition, it has been hypothesized that the genes *Catf-1* and *Csy1* along with *Pun1* are responsible for the creation of capsaicin synthase, an enzyme crucial for the production of capsaicin (Albrecht et al., 2012). The total capsaicin content of pepper species is primarily influenced by the availability of its synthetic precursors, phenylalanine and 8-methyl-6-nonenoic acid. Increasing the concentration and bioavailability of these compounds results in a subsequent increase in the accumulation of capsaicin (Lindsey and Yeoman, 1984; Prasad et al., 2006). The regulation of capsaicin content is also affected by the stage of development. In habanero peppers, it has been found that capsaicin content increases as the fruit ripens, reaching its peak at 45-50 days from the time that the flowers form into fruit. After this point, capsaicin degrades into secondary products, which affects the sensory profile of the peppers (Contreras-Padilla and Yahia, 1998). Environmental factors have been shown to influence the capsaicin content of pepper species. Researchers studied a variety of quality and sensory characteristics, including capsaicinoid content and color, in 23 chili pepper samples grown in three different locations. Most pepper species showed an increased in capsaicinoid content when grown in an environment with low precipitation and moderate light exposure (Meckelmann et al., 2015). It has also been hypothesized that stress plays a role in the capsaicin content of pepper species. One study illustrated the concentrations of capsaicin and dihydrocapsaicin were higher in water-stressed Padron pepper plants than in control plants with sufficient access to water. Test plants were given either a low, medium, or high concentration of water relative to the control group of plants, and it was seen that plants with the lowest availability of water produced the most capsaicinoids (Estrada et al., 1999). These results support the conclusions published by Meckelmann et al. in 2015. A similar phenomenon was observed when evaluating the effect of nitrogen and potassium availability on capsaicin content. Habanero pepper plants under fertilization stress produced a higher capsaicin content than plants that were treated with potassium or nitrogen solutions (Medina-Lara et al., 2008).

Physiological Response to Capsaicin

Capsaicinoids are distinguished by their ability to impart a thermal (hot) and nociceptive (burning or stinging) sensation (Smutzer and Devassy, 2016). The biological response to capsaicinoids is classified as a chemesthetic process, which refers to chemically induced sensations that occur in the mouth, nose, and skin (Lawless and Heymann, 2013). It has been postulated that pain responses to chemical irritants, including capsaicin, are a protective mechanism that allow for the detection of potentially harmful agents in the environment such as toxins (Green, 2012). This is supported by capsaicinoid stimulation in the oral cavity resulting in defensive reflexes in other parts of the body. This includes responses such as sweating and increased salivary flow. Research has shown that increased salivary flow as a result of oral stimulation with capsaicin is accompanied by increased production of salivary secretory immunoglobulin A (SIgA). SIgA is an important factor in the immunological function of saliva as an antibacterial agent that protects the body (Kono et al., 2018).

Capsaicinoids interact with Transient Receptor Potential Vanilloid type 1 (TRPV1) receptor proteins, which are cation channels located in sensory neurons in the oral cavity (Lawless and Heymann, 2013). Each TRPV1 receptor contains six transmembrane domains. Capsaicin interacts with the region spanning domains 3 and 4 of TRPV1. The activation of TRPV1 results in Ca^{2+} ions flowing into the cell, subsequently depolarizing the neuron and initiating action potential firing. This cascade reaction results in neuropeptides such as substance P being released in the spinal cord and brain (Smutzer and Devassy, 2016). Substance P is an important component of the central nervous system, as it modulates the response for both heat and pain. This helps to explain why capsaicin has both a heating and stinging effect on the palate.

The structure-activity relationship of capsaicin has been heavily studied due to its application in pharmacological pain relief. In order to evaluate the host-ligand relationship of capsaicin and the TRPV1, the chemical structure of capsaicin is often broken into three distinct molecular regions: the head (aromatic ring), neck (amide bond), and tail (fatty acid carbon chain) (Yang and Zheng, 2017). Capsaicin binds to TRPV1 in a "tails-up, heads-down" configuration which allows the fatty acid chain to bind to the walls of the channel through van der Waals forces. The amide bond and aromatic ring, in particular the phenolic 4-OH group within the ring, participate in hydrogen bonding with glutamic acid residues within the channel. This particular configuration dictates the specificity of capsaicin to TRPV1, as larger molecules have a different electron cloud configuration that prevents the ligand bonding exhibited by capsaicin (Fattori et al., 2016).

Evaluating Pungency

The chemesthetic effect of capsaicinoids is also referred to as "pungency." Pungency is defined as the ability to impart burning, sharp, or stinging sensations (Damodaran et al., 2007). It is important to note that chemesthetic effects are not constrained to pungency, as other compounds induce chemesthetic sensations such as cooling from menthol or tingling from carbon dioxide in carbonated beverages (Green, 2012). This review will exclusively focus on evaluation of pungency instead of other chemesthetic sensations as pungency pertains directly to sensory analysis of hot pepper cheese. The intensity and character of pungency sensation in peppers and in other pungent foods such as black pepper and ginger can be measured both using both sensory-based methods and instrumental techniques.

Qualitative Sensory Analysis of Peppers and Capsaicinoids

A common method for reporting quantitative sensory pungency of peppers is the Scoville Heat Unit (SHU). SHU values refer to the Scoville heat scaling method, in which heat level is determined organoleptically using a trained panel, usually comprised of five individuals. For this method, an exact weight of dried pepper is first dissolved in alcohol to extract the capsaicinoid components, then filtered and diluted with sugar water. Trained panelists are given a series of sugar solution samples containing decreasing concentrations of pepper until no heat sensation is detected (Scoville, 1912). Peppers are assigned a value in SHU based on the level of dilution required to eliminate any sensation of heat. SHU values can then be converted to parts per million of heat (ppmH) based on sample dry weight (Collins et al., 1995). There are five levels of sensory pungency based on the Scoville scale: non-pungent (0–700 SHU), mildly pungent (700–3,000 SHU), moderately pungent (3,000–25,000 SHU), highly pungent (25,000–70,000 SHU), and very highly pungent (>80,000 SHU). Due to variability in the capsaicinoid concentration of peppers, a range of SHU values is assigned for each pepper species.

The Scoville method is limited in that it produces quantitative data on the detection of heat but does not address any descriptive attributes of chili pepper burn such as duration of heat or location of sensation. In addition, this method is highly subjective, as it relies on the chemesthetic perception of heat by human subjects. Human panels can be highly variable both person-to-person and panel-to-panel. Frequent consumers of spicy foods are less sensitive to capsaicin, and even non-frequent consumers can become quickly desensitized to the effects of capsaicin within a single evaluation session (Lawless and Heymann, 2013). Several methods have been published that address the limitations of simple Scoville scaling and attempt to correct for them. For example, the American Spice Trade Association (**ASTA**) utilizes a modified version of Scoville heat scaling in which five pre-screened panelists are given ascending concentrations of pepper solutions in 5% sucrose and a negligible amount of alcohol. The concentrations utilized in the exercise are based on a predetermined threshold. Threshold of sensation is defined as the concentration at which three out of the five panelists detect warmth or a burning sensation (Lawless and Heymann, 2013).

In addition to the limitations discussed above, Scoville heat scaling does not distinguish between individual capsaicinoids or their relative abundance in the sample. Todd et al. 1977 studied sensory perception of nordihydrocapsaicin, capsaicin, dihydrocapsaicin, homocapsaicin and homodihydrocapsaicin with a trained panel using modified Scoville scaling to test whether pungency effects of capsaicinoids could be distinguished from one another. The study found estimated SHU vales for each of the studied capsaicinoids and calculated total pungency using these values. Calculated pungency was then compared to the concentration of each capsaicinoid determined by gas chromatography. Finally, total pungency and capsaicinoid concentration were plotted against organoleptic determination of heat. Researchers found that the calculated values of pungency were highly correlated with sensorial perception of spiciness (R=0.95). In addition, results showed that panelists grouped nordihydrocapsaicin, capsaicin, and dihydrocapsaicin together in terms of sensation, characterizing them by a rapid bite felt in the back of the palate and throat. In contrast, homocapsaicin and homodihydrocapsaicin produced a longer bite sensation that was of lower intensity. However, the panel was unable to distinguish individual capsaicinoids within groups from one another (Todd et al., 1977).

In order to address the descriptive characteristics of chili pepper burn and individual capsaicinoids, qualitative sensory methods must be used. In order to fully describe heat sensation, a heat profile or sensory lexicon must be used. The combination and quantity of capsaicinoids in a chile pepper determine its overall heat profile. In order to accurately describe differences in chile pepper heat profiles, a sensory lexicon for this specific purpose was developed at New Mexico State University's Chile Pepper Institute. Researchers selected 41 varietals of chile pepper that included representative samples from all domesticated forms of the *Capsicum* plant, including *C. annum, C. baccatum, C. chinense, C. frutescens,* and *C. pubescens*. Mature fruit samples were diced and served at room temperature to a panel of trained panelists. Samples were evaluated one session at a time to reduce carryover effects. Preliminary characteristics identified by the panel were developed into a list of key attributes to describe heat sensation. The final lexicon includes five attributes: Development, Duration, Location, Feeling, and Intensity. These descriptors help to categorize chili pepper heat in terms of temporal sensation, where the sensation is experienced, and what the sensation feels like in the mouth. For the purposes of this research, intensity refers to analytical measurements of capsaicinoids that were converted into SHU and then translated into consumer language (mild, medium, hot, very hot, or extremely hot). Using this lexicon, jalapeno peppers are categorized by rapid heat development, gradual loss of heat, sensation felt in the tip of the tongue and front of the mouth, flat heat, and an intensity categorization of hot (Guzmán and Bosland, 2017). While this lexicon specifically addresses the sensory properties of red peppers, other projects have evaluated the descriptive characteristics for other pungent foods (discussed in next section).

Further studies examined the relationship between specific capsaicinoids and sensory perception. Krajewska and Powers (1977) used a trained panel to examine the sensory properties of individual naturally-occurring capsaicinoids, including nordihydrocapsaicin, capsaicin, dihydrocapsaicin, and homodihydrocapsaicin, as well as vanillylamide of n-nonanoic acid which is also referred to as synthetic capsaicin. The panel first studied the relationship between pungency intensity and capsaicinoid concentration using magnitude estimation scaling using a 0.156 ppm capsaicin solution as reference. Results of magnitude estimation showed that capsaicin and dihydrocapsaicin were the most pungent and had the highest rate of change in pungency with increasing concentration. In contrast, nordihydrocapsaicin was the least pungent and exhibited the lowest rate of pungency change with concentration. Homodihydrocapsaicin was found to be an intermediate between dihydrocapsaicin and nordihydrocapsaicin. Panel results also indicated that at concentrations below 0.156 ppm, individual capsaicinoids were not significantly differentiated, while at concentrations above 0.156 ppm, capsaicin and dihydrocapsaicin were significantly more pungent than the other capsaicinoids studied. Panelists also described the type of sensation and location where each sensation was felt and the duration of sensation, similar to the methods employed at New Mexico State University described above. Nordihydrocapsaicin was described as having a "pleasant" and "warming" character that was felt in the front of the mouth and dissipated quickly. Capsaicin and dihydrocapsaicin were found to be more irritating, with a "sharp and stinging bite" that was experienced in the mid-palate and throat. Homodihydrocapsaicin was described as "very irritating, harsh, and very sharp." The effects of homodihydrocapsaicin were felt in the throat and back of the tongue. In addition, homodihydrocapsaicin was characterized by a "peppery smell" and "sour taste" that distinguished it from other capsaicinoids (Krajewska and Powers, 1988).

Pungency in Other Foods

Pungent effects are known to occur outside of the capsaicinoid family. Pungency has been observed in a variety of spices, including black pepper (piperine), cinnamon (cinnamaldehyde), clove (eugenol), and cumin (cuminaldehyde), along with other common flavorants such as ginger (gingerols, shogaols, or zingerone), mustard, wasabi, and horseradish (allyl isothiocyanate). While studies have sought to characterize the pungency of these chemesthetic agents, they have been less thoroughly studied than capsaicin (Cliff and Heymann, 1992). Researchers have studied the descriptive characteristics of selected pungent compounds, including capsaicin, piperine, cinnamaldehyde, cuminaldehyde, eugenol, ginger oleoresin, and ethanol. These compounds were compared on pungent qualities (burning, tingling, numbing, and overall pungency), temporal qualities (lag time and overall duration), and oral spatial characteristics (longitudinal location, lateral location, and localization/diffusivity) to develop oral characteristic profiles for each compound. A principal component analysis (**PCA**) biplot was generated to illustrate differences between the compounds evaluated (Figure 2). Cinnamaldehyde, ethanol and eugenol were characterized by numbing and tingling properties, while capsaicin, piperine, and ginger oleoresin produced a distinct burning sensation (Cliff and Heymann, 1992).

Another commonly utilized pungent food is the Sichuan (Szechuan) pepper or Chinese prickly ash (*Zanthoxylum bungeanum*) which is not closely related to the black pepper or red pepper species. Sichuan pepper is known for its ability to impart a tingling, numbing sensation which is known as *má* in Chinese cuisine (Haley and McDonald, 2016). This tingling effect is caused by α-hydroxysanshool, an alkylamide. Similar to capsaicinoids, sanshools activate the TRPV1 receptor in the oral cavity, but also activate the transient receptor potential cation channel, subfamily A, member 1, (**TRPA1**) which is thought to be responsible for the unique tingling or vibrating sensation caused by Sichuan pepper (Koo et al., 2007). While Sichuan peppers have been less extensively studied than red peppers, a number of recent projects have examined their sensory properties. Yang et al. 2020 generated a descriptive lexicon for Sichuan peppers with 32 flavor and aroma attributes, with “pungent,” “numbing,” and “tingle,” describing the chemesthetic sensations imparted by samples. Other sensory attributes included peppery, green, citrus, minty, and floral (Yang et al., 2021). Zhang et al. 2018 evaluated the pungent properties and temporal profile of Sichuan peppers using quantitative descriptive analysis, temporal dominance of sensation (**TDS**), and temporal intensity (**TI**) studies. They found that Sichuan peppers with higher SHU values also demonstrated higher intensities of tingling, burning, astringency, numbing, and bitterness. Spicier samples also displayed a longer duration of burning and numbing attributes than sample with lower SHU values in the study (Zhang et al., 2018).

Sensory Analysis of Pungent Foods

Characterizing and quantifying the intensity of pungent compounds can be difficult due to a number of factors, including significant variation between panelists, panelist fatigue, sensitization, and de-sensitization (Ward, 2016). Sensitization refers to the process in which intensity of a sensation increases as the concentration of a compound increases. Sensitization occurs in two forms: self-sensitization, in which the intensity of sensation for a single compound increases as the taster is exposed to that compound several times within a short period of time, and cross-sensitization, where stimulation from one compound increases the intensity of sensation for a different compound. Desensitization is the process by which repeated exposure to a compound results in decreased intensity of sensation. Desensitization can also occur in self- and cross- forms similar to those seen with sensitization (Ward, 2016). Several studies have been conducted to evaluate the cross-sensitization and cross-desensitization effects of various compounds on capsaicin, which is discussed in further detail later in this review.

The effects of sensitization, desensitization, and fatigue should be mitigated to ensure the reliability and accuracy of sensory data on pungent foods. This is commonly done with an enforced rest period between samples, as well as a limit on the number of pungent samples and references evaluated in one session. In descriptive analysis of spicy foods, it is recommended that panelists be trained to memorize the sensation induced by pungent references, as consuming references during evaluation can be fatiguing and sensitizing in and of itself (Ward, 2016). Panelists should taste no more than seven pungent products per day with a rest period of 8 minutes with a water rinse or 16 minutes without a water rinse, as this procedure decreases the likelihood of sensitization and desensitization between spicy samples. This assertion is based upon the works of Green 1989 and Allison et al. 1999. Green et al. 1989 studied the length of time between stimuli and reported that rapid and repeated exposure (1 evaluation/min for 25 min) to capsaicin at a concentration of 3 ppm resulted in increased intensity of heat sensation. In contrast, requiring panelists to wait for 15 minutes between evaluations resulted in a desensitization effect (Green, 1989). Researchers at the Sensory Analysis Center at Kansas State University tested salsas of varying heat intensities with a range of rest times from 5 – 25 minutes depending on the SHU value of the salsa being tested. Mild and medium samples (rest time 5 and 8 minutes respectively) showed a slight sensitization effect, while hot samples (rest time 15 minutes) demonstrated a slight desensitization effect, which supports Green’s findings (Dowell et al., 2005). Sensitization and desensitization have also been studied in other pungent compounds. Previous studies have evaluated the irritation produced by menthol, ethanol, and zingerone (Cliff and Green, 1994; Dessirier et al., 1999; Green and Schullery, 2003) and observed that each compound produces a distinct sensitization/desensitization response pattern. For example, zingerone has been shown to primarily cause desensitization rather than sensitization. Differences in response pattern to pungent compounds have been attributed to the activation of different excitatory mechanisms within the oral cavity by each compound. These differences in sensory attributes mean that not all compounds require the same rest period between evaluations. Eib et al. 2020 used a 90-second rest period between samples in their study of the relationship between mustard pungency and allyl-isothiocyanate content (Eib et al., 2020).

Rest periods are commonly combined with palate cleansers to ensure that evaluation of one sample has a minimal effect on other samples. Studies have also evaluated the use of interstimulus palate cleansers with descriptive analysis of spicy or pungent foods. Palate cleansers are used to prevent adaption and sensitization that may occur between product evaluations, as well as remove residual product from the oral cavity (Lucak and Delwiche, 2009). Due to the lipophilic nature of pungent compounds, some researchers have used dairy foods with high fat contents as palate cleansers. For example, researchers evaluating the pungency of mustard used distilled water and toast coated with mascarpone cheese as a cleanser between evaluations (Eib et al., 2020). Other work has focused on investigating the ideal palate cleanser to use during sensory analysis of pungent foods. In a 2008 study, researchers evaluated various palate cleansers with a range of representative foods with distinctive sensory characteristics, including hot/spicy foods as represented by spicy tortilla chips. Researchers conducted a literature review to determine the most commonly documented palate cleansers used in food science research and generated the following list: table water crackers, spring water, pectin solution, whole milk, chocolate, and warm water). Selected foods were evaluated with all palate cleansers. All of the palate cleansers were determined to be effective for hot/spicy foods, with 100% of attributes failing to show a significant difference between replicates on a 9-point categorical intensity scale (Lucak and Delwiche, 2009). This research supports the conclusion that distilled water and unsalted crackers are an effective palate cleanser between spicy samples.

While Lucak and Delwich 2008 used a 9-point categorical scale, intensity of heat sensation can be measured using a number of scaling techniques. The most common techniques include categorical scales, line scales, and magnitude scales (Ward, 2016). Allison et al. 1999 used 15-cm line scales in the evaluation of oral heat when assessing spicy tomato salsas. This is in line with the ASTM International standard for sensory evaluation of red pepper heat (ASTM International E1083 2011). Other researchers evaluating desensitization and stimulus-induced recovery have used a labeled magnitude scale (**LMS**) with the descriptors “barely detectable,” “weak,” “moderate,” “strong,” and “very strong” (Rentmeister-Bryant and Green, 1997). Green also uses a similar LMS with the addition of the descriptor “strongest imaginable” at the top of the scale to account for very spicy samples, seen in Figure 3(Green et al., 1987).

Instrumental Methods of Measuring Pungent Compounds

In order to accurately and efficiently quantify and identify specific capsaicinoids, instrumental methods must be used. Several different methods, including spectrophotometry (Awasthi and Singh, 1973), high-performance liquid chromatography (Al Othman et al., 2011; González-Zamora et al., 2013) and gas chromatography (Thomas et al., 1998; Peña-Alvarez et al., 2012) have been used for quantitation of capsaicinoids from peppers. Ultraviolet (**UV**), mass spectrometry, fluorescent, spectrophotometric, colorimetric, and electrochemical detectors can be used for detection of capsaicinoids, however reverse-phase HPLC using a UV detector is most common for analysis of capsaicin. UV detection using a 280 nm wavelength is generally recommended for capsaicin detection in chili pepper samples. Other excitation/emission wavelengths can also be used for detection of capsaicinoids in more complex food matrices such as sauces (Bolliet, 2016). González-Zamora, et al., 2013 utilized HPLC with Diode-Array Detection (**HPLC-DAD**) for analysis of a selection of *Capsicum* pepper species. However, the standard method for industry purposes is Association of Official Agricultural Chemists (**AOAC**) International Official Method 995.03, which utilizes HPLC in combination with UV detection (Association of Official Agricultural Chemists International, 1996). Method 995.03 was developed through a collaborative effort by the American Spice Trade Association (**ASTA**) to create a more efficient liquid chromatographic procedure for evaluating capsaicinoids (Parrish, 1996). For this method, peppers are first dried, and then crushed or ground into a powder before extracting into ethanol. The sample is then injected into a liquid chromatograph and analyzed using a UV or fluorescence detector (AOAC, 1996). This method is limited to determination of capsaicinoids between 750-650,000 Scoville units. Al Othman et al. 2011 analyzed samples of Capsicum peppers imported from India and purchased in Saudi Arabia using this method in order to evaluate the average daily intake of capsaicin for citizens of Riyadh (Al Othman et al., 2011). While industry has accepted the parameters of HPLC analysis of capsaicin using the AOAC recommended method, research continues on the optimum analytical method for HPLC analysis of capsaicin to maximize accuracy and efficiency of the analysis. In particular, the best media with which to extract capsaicin out of dried chili peppers remains a topic of interest. Researchers at New Mexico State University proposed an improved HPLC method in 1995 that utilizes acetonitrile as an extraction media (Collins et al., 1995). In 1996, researchers at the University of Santiago de Compostela proposed the use of refluxing acetone in order to extract capsaicinoids from dried chili pepper fruits (López Hernández et al., 1996). While HPLC is the most common methodology for quantitatively analyzing capsaicinoids, GC analytical methods for capsaicinoids have also been shown to be effective. Pena-Alvarez et al. 2012 utilized ultrasound-assisted extraction (**USAE**) with gas chromatography mass spectrometry (**GC-MS**) and compared the results to Soxhlet and solid-phase microextraction (**SPME**) to create an optimized analytical procedure that minimizes extraction time and maximizes extraction efficiency. The three methods produced different results for different peppers analyzed, but USAE obtained approximately 70% capsaicinoid concentration and was therefore determined by the authors to be acceptable. Researchers found a wide range of capsaicin concentration in the 11 pepper samples evaluated (101-6800 µg/g).

While HPLC is the standard method for analyzing capsaicinoid concentration, other pungent compounds require different analytical methods depending on their volatile behavior. For example, allyl isothiocyanate, cinnamaldehyde and eugenol are commonly analyzed using gas chromatographic (**GC**) methods. Other compounds, such as gingerol, are thermally unstable and therefore cannot be analyzed using GC. Instead, these compounds must be analyzed using liquid chromatographic methods such as HPLC (Bolliet, 2016). While analytical methods are critical for the quantification of specific capsaicinoid species, these techniques typically do not provide an accurate prediction of how a human would perceive the spiciness of a sample. This highlights the importance of combining sensory and analytical data to create comprehensive flavor profiles for hot peppers and pepper products.

Relating Sensory and Analytical Data of Pungency

Human perception of capsaicin may be affected by other factors that cannot be controlled for in an analytical experiment. For example, HPLC analysis of peppers used for a hot pepper cheese may not accurately reflect how spicy the consumer perceives the final product to be, as ingredients in the cheese such as milk fat and other basic taste compounds may interfere with the perception of capsaicinoids. In order to accurately evaluate the relationship between capsaicinoid concentration and consumer perception, it is best to use both instrumental and sensorial methods.

A wide variety of studies have been conducted in order to more closely evaluate the relationship between sensorial, analytical and organoleptic measurements of chili pepper heat. Researchers at Washington State University utilized an electronic tongue in combination with consumer evaluation to determine the relationship between analytical data and consumer perception of spicy paneer cheese. Capsaicin solutions of 1.875, 3.75, 7.5, 15, and 30 ppm were generated, spiked into paneer cheese samples, and evaluated by both consumers and the electronic tongue. Consumers evaluated capsaicin solutions using difference from control tests in a controlled environment. Consumers were able to discriminate between spiked samples at 3.75, 7.5, and 15 ppm of capsaicin. Participants were not able to discriminate between samples with low concentrations (0 and 1.875 ppm) and samples with high concentrations (15 and 30 ppm). This finding is in accordance with Beidler's description of the relationship between concentration of a substance and its sensory response, which is described in further detail later in this review. The electronic tongue exhibited a 93% discrimination rate, which led researchers to conclude that it may be useful for analyzing samples outside the range of human discrimination (Schlossareck and Ross, 2019). Studies have also attempted to correlate pungency values for individual capsaicinoids with overall pungency. Krajewska and Powers 1977 demonstrated that the overall pungency of an unknown sample can be obtained by adding the pungency effects of each capsaicinoid in the sample. Pungency effects are calculated by multiplying threshold values determined by trained panel magnitude estimation scaling by the concentration of the capsaicinoid in the sample. For this study, a trained panel evaluated mixtures of capsaicinoids at known concentrations using magnitude estimation scaling. Researchers then compared the results of the panel to predicted pungency values generated using a regression equation.

Capsaicinoids in Food Products

As capsaicinoids have a wide range of applications, a corresponding diversity of research has been done on these compounds. Within the field of food and ingredient applications alone, there has been a range of research studies conducted on chili peppers and capsaicin, including food safety applications, sensory perception of capsaicinoids, and the function of capsaicin in food products. Previous research concerning capsaicinoids has been constrained to naturally occurring compounds, i.e. derived from *Capsicum* species, particularly in food and consumer goods applications. However, synthetic derivations of capsaicinoids are beginning to make their way into the food industry. In 2019, the European Food and Safety Authority (EFSA) approved the novel ingredient phenylcapsaicin, a chemically derived analog of capsaicin, to be used in food supplements and specialized foods for medical purposes (EFSA Journal, 2019). Currently, medicinal use of capsaicin and its derivatives is largely constrained to topical applications for pain relief (Anand and Bley, 2011). However, research into other possible uses for capsaicin is ongoing, including projects evaluating the use of capsaicin in anti-inflammatory, gastro-protective, and anti-obesity applications (Basith et al. 2016; Spencer and Dalton, 2020).

Extrinsic Properties of Capsaicinoids

Capsaicin was first identified by Thresh in 1876, and its chemical composition and structure was described by Nelson in 1919 (Nelson, 1919). In its pure form, capsaicin typically presents as an odorless white crystalline solid. Capsaicin is lipophilic and is soluble in fat, oil, and ethanol while exhibiting moderate hydrophobicity (Reyes-Escogido et al., 2011). The compound has a relatively low melting point, which is important for its function as a topical pain reliever as it easily penetrates the skin (Katritzky et al, 2003). Capsaicin also contains a double bond in its carbon side chain, which results in *cis/trans* isomerism in the molecule. However, the *cis* form is less stable than the *trans* form due to steric hindrance between the $-CH(CH_3)_2$ group and the rest of the side chain, which results in only the *trans* form occurring naturally (Reyes-Escogido et al., 2011).

Capsaicin and the Basic Tastes

A variety of methods have been employed in order to investigate the effect of capsaicin stimulation on perception of basic tastes. Simons et al. (2002) used a novel technique involving bilateral application of capsaicin and basic taste solutions to the dorsal anterior tongue in order to evaluate taste suppression following capsaicin treatment. Subjects were asked to evaluate five tastant solutions (sucrose, monosodium glutamate, sodium chloride, citric acid, and quinine) and familiarize themselves with the basic tastes. Researchers then applied a capsaicin solution to the anterior half of the dorsal surface of the tongue and potassium chloride as a blind control to the opposite half of the tongue. Subjects rinsed their mouths with warm water to remove excess capsaicin and potassium chloride solution, and then evaluated the intensity of the burning sensation using a 0-10 intensity scale. Finally, subjects were provided with a sample of each of the tastant solutions described above and asked to choose which side of the tongue was experiencing a stronger taste sensation in a two-alternative forced choice manner. Subjects also scaled the intensity of the taste using a 0-10 intensity scale for each side of the tongue. Researchers found that capsaicin had a suppressive effect on perception of sweet and bitter taste, along with umami taste (Simons et al., 2002).

The presence of capsaicin in a food product can drastically alter perception of the product sensory characteristics. Capsaicin has a significant effect on the perception of basic tastes, although there is disagreement regarding the magnitude and direction of the effect for certain tastes (Green and Hayes, 2003; Lawless, 1986). It is generally agreed that capsaicin has a suppressive effect on the perception of bitter taste and sweet taste, likely due to the fact that these tastants are modulated through similar pathways. Both are processed via G-coupled receptor proteins (T1R and T2R, respectively) in taste buds, and are often found side-by-side, although they are expressed in different cells (Lawless and Heymann, 2013). Previous studies have reported that more than 96% of taste receptor cells that exhibited the bitter receptor T2R6 also exhibited the TRPV1 receptor for capsaicin (Moon et al., 2010). In addition to capsaicin suppressing sweet taste perception, it has been shown that sweet taste compounds have an inhibitory effect on the perception of capsaicin burn. Green and Schullery 2003 tested the effect of sucrose on capsaicin bitterness and burn by having subjects evaluate capsaicin solutions (100 or 320 μM in deionized water and ethanol) and capsaicin-sucrose mixtures (0.5 M sucrose) and compare the intensity of both bitterness and burn in different areas of the tongue. Subjects described a “moderate” intensity of bitterness in the circumvallate region of the tongue for the capsaicin solution, and a burning sensation was detected in the fungiform region. The addition of sucrose resulted in average bitterness ratings in the circumvallate region being lowered by 87% (Green and Schullery, 2003). It has been postulated that the relationship between capsaicin and sweet taste are significantly influenced by mixture suppression, which is consistent with findings regarding the relationship between bitter and sweet taste. Suppression effects between sweet and bitter compounds were independent of concentration, which indicates that mixture suppression is a result of neural interactions rather than chemical ones (Lawless, 1979).

Similar to sweet taste and bitter taste, the sensation of umami is processed through a T1R receptor, although umami and sweet receptors are expressed in different cells (Lawless and Heymann, 2013). Interestingly, different studies have drawn conflicting conclusions in regard to the relationship between umami perception and stimulation with capsaicin. Simons et al. (2002) reported that subjects experienced a lower intensity of umami when evaluating monosodium glutamate solution following stimulation with capsaicin. This led researchers to speculate that capsaicin has a suppression effect on umami perception similar to that which was observed in sweet taste and bitter taste, likely due to interaction with G-coupled protein receptors that process these tastants (Simons et al., 2002). In contrast, Kapaun and Dando 2017 found that all basic tastes with the exception of umami were suppressed by application of a solution containing 4.9 μM capsaicin along with basic taste compounds (citric acid, monosodium glutamate, sodium chloride, quinine, and sucrose).

Human Factors in Consumption of Spicy Foods

In their 2019 report on flavor innovation in the food industry, Mintel identified chili pepper sauce and habanero pepper sauce as fast-growing menu items, with these sauces experiencing a 71% and 52% increase in incidence on menus from 2018-2019 respectively. In the same report, 48% of consumers self-reported that they like spicy foods and 27% reported that they love them (n=1,876) (Roberts, 2019). In their 2019 and 2020 reports on U.S. cheese consumption, Mintel also demonstrates that the number of Pepper Jack consumers has risen from 39% (n=1,401) to 41% (n=9,009) from 2019 to 2020. These statistics provide insight into current consumer attitudes toward spicy foods and hot pepper cheese. It has been observed that consumer interest in international flavors, including spicy/pungent flavors, has been on the rise and is predicted to continue increasing in 2021 (Roberts, 2019).

With increasing consumer interest in spicy foods, a number of researchers have sought to better understand the psychological factors that drive liking for spiciness and heat. Consumer liking for capsaicin is not homogenous, as some consumers dislike any level of capsaicin irritation, while others actively seek higher levels of pungency (Dalton and Byrnes, 2016). Researchers have studied this variety in hedonic response to spicy foods and posited a number of theories about why preference is so variable ranging from psychological and social to physiological and biological factors (Duffy, 2007; Byrnes and Hayes, 2013).

Physiological Factors

Conflicting results have been documented regarding the relationship between age and sensitivity to capsaicin (Fukunaga et al., 2005; Just et al., 2007) Fukunaga et al. 2005 found that the mean threshold concentrations of capsaicin in the young and the elderly participants were 2.3 lmol/L and 2.1 lmol/L, respectively which was not considered a significant difference (Fukunaga et al., 2005). However, Just et al. 2007 reported that sensitivity to capsaicin decreases with age, as younger subjects (<40 years) in their study were observed to have significantly lower threshold scores for capsaicin than older subjects (Just et al., 2007). Hummel et al. 2003 did not study capsaicin sensitivity, but reported that older healthy subjects in their study displayed decreased intranasal trigeminal sensitivity to eucalyptol and benzaldehyde (Hummel et al., 2003) Older adults (79. 0+/-5.7 years) were also observed to have a slower response to topically-applied capsaicin compared to younger adults (26.9+/-4.6 years) (Zheng et al., 2000). Further research is required to conclusively establish any relationship between age and sensitivity to orally-induced capsaicin.

Several studies have observed that frequent/regular users of spicy products consistently indicated the intensity of oral-induced capsaicin burn lower than non-users and have a higher detection threshold for capsaicin than non-users (Lawless et al., 1985; Stevenson and Yeomans, 1993; Kalantzis et al., 2007; Nolden and Hayes, 2017). Two theories have been proposed to explain this phenomenon. The predominant theory is that spicy product user have undergone capsaicin desensitization induced by repeated exposure through the diet. It has been suggested that prolonged exposure to capsaicin induces rapid receptor endocytosis and lysosomal degradation in sensory neurons, thereby decreasing sensitivity to agonists (Sanz-Salvador et al., 2012). However, Prescott and Stevenson 1994 proposed that differences between users and non-users of spicy products are based in differences in judgement and not in sensitivity. Prior experience with chiles and spicy foods may influence how individuals use scaling methods for capsaicin burn in a laboratory setting (Stevenson and Prescott, 1994). Nolden and Hayes (2017) asked study participants to recall the most intensely spicy meal they had ever consumed and concluded that prior experience does not appear to explain differences in burn ratings of sampled capsaicin, refuting Prescott and Stevenson's theory. Previous research has also suggested that "supertasters" or individuals with more fungiform papillae on their tongues, perceive a great amount of chemesthetic sensation from chili peppers, black pepper, and other chemesthetic agents (Prescott and Swain-Campbell, 2000; Duffy, 2007).

Psychological Factors

No differences have been observed in sensitivity to capsaicin between genders. However, the relationship between gender and spicy food liking and intake of spicy foods has been studied. Byrnes and Hayes (2015) used a general labeled magnitude scale (gLMS) and 10 mL aliquots of 25 uM capsaicin to assess perceived burn intensity of capsaicin and asked participants to rate their liking of spicy meals. A negative correlation was observed between perceived and liking of a spicy meal. It was also found that men who consume spicy foods may be more strongly motivated by extrinsic rewards (Sensitivity to Reward), while women displayed stronger motivation by intrinsic rewards (Sensation Seeking) (Byrnes and Hayes, 2015). Food neophobia, or avoidance of unfamiliar or novel foods, has also been observed to play a role in spicy food liking and perception. Törnwall et al 2014 grouped participants into “basic” eaters and “adventurous” eaters and found that adventurous eaters expressed higher liking for sour and spicy foods and were also less food neophobic based on scores generated using The Food Neophobia Scale (FNS) (Törnwall et al., 2014) It has been previously observed that consumers who indicate they prefer intensely spicy foods enjoy the sensation of pungency (Rozin and Schiller, 1980). Byrnes and Hayes 2013 used a personality survey in combination with a generalized Degree of Liking (gDOL) exercise to assess the effect of personality characteristics on spicy food liking and consumption. They found that individuals with a tendency toward Sensation Seeking exhibit a positive correlation with spicy food consumption, while individuals with a Sensitivity to Punishment had a nonsignificant negative relationship with spicy food liking (Byrnes and Hayes, 2013). Risk-seeking behavior has also been correlated with spicy food intake, as individuals who exhibit thrill-seeking behavior are more likely to enjoy and consume spicy foods (Wang et al., 2016).

Assessing Product Differences and Consumer Opinion

Sensorial differences between products can be assessed objectively through descriptive analysis or through consumer acceptance testing. Objective sensory analysis methods are used to generate data that is analagous to instrumental data using a panel that has been trained and calibrated (Lawless and Heymann, 2013). This data can then be used to create standalone comprehensive product profiles or be used in conjunction with consumer acceptance data to understand drivers of liking. Consumers' conceptual opinions of products or beliefs surrounding a product category can also be measured using quantitative consumer research methods, including online surveys with research techqniues such as Maximum Difference scaling and conjoint analysis.

Descriptive Analysis

Descriptive analysis techniques are used to qualitatively assess a product and quantify its attributes using a trained panel to build a comprehensive flavor, aroma, and/or texture profile. There are several distinct methodologies for descriptive analysis, including Quantitative Descriptive Analysis™, Spectrum™ method and Free-Choice Profiling. (Murray et al., 2001). While each methodology has a different approach to data collection, the basic framework begins with selection of panel members and lexicon selection (if already established) or terminology generation (if no established lexicon). A sensory lexicon is a standardized product-specific vocabulary that aids panelists in the detection and identification of flavor, aroma, and texture characteristics. A comprehensive lexicon should include the list of products that were used to develop the lexicon as well as a list of all attributes with written definitions and references (Lawless and Civille, 2013). After a vocabulary has been selected or generated, the panel is trained on products using the lexicon to ensure that they product consistent results. Once the panel is producing data with minimal noise and variation, they are ready to begin evaluating products and generating profiles. Results of descriptive analysis can be correlated to analytical results to better understand the sensory impact of flavor-active compounds in a sample. Descriptive profiles can also be related to consumer testing results using external preference mapping to evaluate the drivers of liking for specific products (Yenket, 2011).

Descriptive analysis is conducted in order to understand if and how samples differ in their sensory attributes and can also be utilized to evaluate panelist performance as a whole and on an individual level. Descriptive data is most often analyzed using analysis of variance (ANOVA) to determine if significant differences exist between samples across attributes. If significant differences between samples are found, further analysis can be conducted. This includes post-hoc testing such as Fisher's exact test with a Bonferroni correction to execute pairwise comparisons on samples and further illustrate differences, or principal component analysis (**PCA**). PCA is a data compression technique used in order to graphically represent interrelationships among multidimensional sample spaces such as descriptive data with several attributes (dependent variables) and products (independent variables). Dependent variables are combined into linear combinations to maximize variance, thereby simplifying interpretation and allowing for quick judgements of product differences (Lawless and Heymann, 2013).

Consumer Acceptance Testing

Acceptance testing involves the evaluation of food products by untrained consumers to better understand how products are perceived. Acceptance testing is distinct from objective sensory testing methods such as difference testing or descriptive analysis, as objective tests seek to identify and quantify differences between products, while acceptance testing is used to assess consumer liking and opinion of products (Lawless and Heymann, 2013). Traditionally, hedonic scales and just-about-right (JAR) scales have been used as a diagnostic tool to assess the degree of acceptability of foods. Previous work has shown that a minimum of 50 consumers is required to make any statistically relevant conclusion about product liking, although 100 or more are recommended (Hough et al., 2006; Drake, 2007; Mammasse and Schlich, 2014).

Several methodologies have been proposed for assessing consumer liking of products, including the labeled hedonic scale (Lim et al., 2009), hedonic ranking (Kozak and Cliff, 2013), and the 9-point hedonic scale (Peryam and Pilgrim, 1957). Of these methods, the 9-point hedonic scale is by far the most commonly used for consumer applications. This scale uses 9 categories (1=dislike extremely and 9=like extremely) to assess acceptance of a concept. Values are typically converted to their respective numbers and analyzed using analysis of variance (**ANOVA**) or other statistical techniques (Wichchukit and O'Mahony, 2015). Other methods have been proposed to assess consumer liking of products, such as hedonic ranking (Kozak and Cliff, 2013). Researchers evaluated consumer liking of apple cultivars and yogurts using a traditional 9-point hedonic scale, ranking with ties, and ranking without ties, and found that ranking exercises that did not allow ties introduced "artificial" variability to the data set. Therefore, they concluded that the 9-point hedonic scale was preferable over hedonic ranking methods if ties are not used (Kozak and Cliff, 2013). Liking scales can be applied to products as a whole (overall liking) and to liking of specific product attributes (sweetness, crunchiness, etc.). Liking questions can also be used in conjunction with other questions as a diagnostic tool to understand how products can be improved, a technique referred to as "penalty analysis."

The term "penalty analysis" refers to the technique of assessing the impact of perceived product defects on consumer liking of a product. This can be done in a number of ways. The most common method of penalty analysis is just-about-right (**JAR**) scaling, which is a statistical technique that typically uses consumers' responses to an overall liking question and a 5-point attribute-specific labeled categorical scale (1=not enough, 3 = just about right, and 5 = too much) to assess the effect that perceived "flaws" in products have on consumer liking of products (Rothman and Parker, 2009). A penalty is considered the decrease in mean overall liking scores for consumers who perceived the product as sub-optimal or “non-JAR.” Many studies have utilized this technique to assess consumer acceptability of foods, including reduced-fat Cheddar cheeses, restaurant menu items, and vanilla yogurt (Wadhwani and McMahon, 2012; Narayanan et al., 2014; Lawless et al., 2016). However, JAR scaling has been criticized for scaling bias in that consumers tend to use the middle of the scale, thereby decreasing the sensitivity of the scale (Moskowitz, 2001). Li et al. 2014 also argue that JAR scales are flawed in that they assume consumers’ concepts of “too little” and “too much” are equal in magnitude (Li et al., 2014). In order to address some of these limitations, alternative methods to assessing penalty analysis have been proposed. Moskowitz proposed utilizing directional scales in combination with JAR scaling and liking in order to assess which attributes of pizza drive overall liking in order to aid product developers (Moskowitz, 2001).Other researchers liking in combination with check-all-that-apply (CATA) questions, have been applied as an alternative mechanism to understand how consumer liking is impacted by perceived flavor defects (Tarancón et al., 2020; Harwood and Drake, 2021).

Conjoint Analysis

Conjoint analysis is a technique that measures consumer trade-off decisions through survey responses to complete product profiles (Green and Srinivasan, 1978). Conjoint analysis as a market research technique was first described by Green and Rao (1971) as a mechanism for understanding the joint effect of multiple independent variables on a dependent variable, such as the effect of product attributes on purchase intent (Green and Rao, 1971). Conjoint exercises utilize different attributes of a product with distinct levels in order to assess which characteristics consumers consider “deal-breakers.” For example, Rizzo et al. 2020 used package size as an attribute in an online conjoint exercise on lactose-free milk products with the levels pint, quart, half-gallon, and gallon (Rizzo et al., 2020). Several types of conjoint analysis have been proposed for use in food science and sensory research. The first conjoint technique utilized by researchers was full-profile conjoint analysis, in which participants view a complete set of the product profiles. This technique is limited to six or fewer attributes due to a high chance of participant fatigue (Green et al., 2001). Adaptive conjoint analysis (**ACA**) was developed by Sawtooth Software in 1987 in order to address this problem. ACA uses a self-explication task and a set of partial profile descriptions, which are presented in pairs to simplify participants' tasks and increase data quality. The pairs presented vary depending on earlier responses to profile pairs (Johnson, 2001). Choice-based conjoint (**CBC**) was developed in 1993 to further increase the efficiency of conjoint exercises and effectively quantify interactions between attributes in a conjoint exercise using part-worth utilities at the individual level (Anonymous, 2017). Finally, adaptive choice-based conjoint (**ACBC**) uses respondents' previous responses to online survey questions in order to generate an individually designed exercise for each participant. ACBC exercises begin with a build-your-own (BYO) question set in which consumers choose from a list of provided options to build their ideal product concept, followed by a series of screening tasks. Screening tasks involve consumers selecting which product profiles they would be open to purchasing from a set of options that are based on their BYO concept. After completing all screening tasks, consumers participant in a choice tournament in which their preferred options are shown against each other in order. ACBC also generates part-worth utilities, which are then analyzed using Hierarchical Bayes (HB) analysis in order to determine utility scores for each attribute and level. Jervis et al. (2012) compared ACBC and CBC to determine the effectiveness of each method in assessing key choice attributes of sour cream with a limited sample size. It was found that both methods provided similar outcomes for consumer preferences for sour cream products. Additionally, the researchers reported that estimation of perception of brand was possible with ACBC but not with CBC (Jervis et al., 2012). Many other studies have used conjoint techniques to assess consumer perception of food products, including chocolate milk, bacon, and lactose-free milk (Kim et al., 2013; McLean et al., 2017; Rizzo et al., 2020).

Conjoint analysis is most commonly analyzed using multiple regression and analysis of variance (Green and Srinivasan, 1978). Conjoint exercises yield utility scores, which are scaled to sum to zero within each attribute, meaning that levels within an attribute receive either a positive or a negative utility score. Negative utility scores do not necessarily correlate with lower liking for a product attribute. However, they do indicate which characteristics are relatively less appealing to consumers within the data set (Orme, 2006).

Kano Analysis

Kano analysis is used to evaluate consumer needs and wants for a product, including consumers' basic needs, performance characteristics of a product, and any attributes that consumers consider exciting or attractive (Madzík, 2018). Kano analysis was originally developed by Noriaki Kano in the mid-1980s for use in quality assurance as a tool for assessing consumer satisfaction (Kano et al., 1984; Rotar and Kozar, 2017). Kano's model utilizes a series of questions surrounding the presence or absence of features to assess consumer perception of product attributes. Consumers must select which statement best describes how they feel about the presence or absence of the feature using five answer choices that address each of the following concepts: "I like it," "I expect it," "I don't care," "I can live with it," or "I dislike it " (Xu et al., 2009; Kim et al., 2013). Kano questions are presented in both a positive (present) and negative (absent) scenario to comprehensively assess how attributes are perceived by consumers.

Responses from a Kano exercise are grouped into one of three categories: basic needs, performance needs, and delight needs. These categories are further broken down into Attractive, Indifferent, Must-Be, Performance (One-Dimensional), Questionable, or Reverse characteristics. Attractive characteristics are those which consumers do not expect, but which result in increased satisfaction with a product. Must-Be characteristics are expected by consumers, but satisfaction does not increase if they are present. However, satisfaction with the product will decrease if these qualities are not present. In contrast, performance or one-dimensional characteristics increase consumers' satisfaction if they are present and decrease satisfaction if they are absent. Questionable characteristics are those which receive conflicting or contradicting responses from consumers regarding their presence and absence. For example, if consumers indicate they expect a product feature to be both present and absent, this would be classified as a "Questionable" attribute. Reverse characteristics decrease consumer satisfaction if they are present, indicating that consumers would prefer not to see them in a product (Rotar and Kozar, 2017). Analysis of Kano data is done by generating a frequency table that contains the number of responses that meet the criteria for each of the six categories described above. For example, if consumers indicate that they like when a feature is present, and either expect it to be absent, don't care if it's absent, or can live with it if it's absent, the feature is considered attractive (Xu et al., 2009).

Kano analysis can be applied to a wide range of products, but a smaller number of studies have applied this technique to the food and restaurant industry (Ponnam et al., 2011; Chen, 2012; Kim et al., 2013; Djekic et al., 2020). Kim et al. (2013) utilized Kano analysis to evaluate the effect of chocolate milk attributes on consumer satisfaction/dissatisfaction and found that distinct groups of consumers responded differently to fat content levels (fat free, 1% fat, 2% fat, and whole milk).

Maximum Differential Scaling

Maximum differential scaling (MaxDiff) or 'Best Worst Scaling' is used to evaluate how respondents place importance on attributes of a product. MaxDiff was developed by Jordan Louviere in 1987 as an improvement on the method of paired comparisons (Louviere and Woodworth, 1991; Anonymous, 2020). MaxDiff allows researchers to efficiently evaluate participants' opinions on a long list of items while minimizing fatigue. Participants in a MaxDiff exercise are asked to select the item they think is "best" and which is "worst" from a short list (subset) of options (usually 3-5 items) that is taken from a larger list of attributes. Louviere posited that participants choose the pair of items that reflects the maximum difference in importance, thus the technique is called Maximum Difference scaling. By having participants select the "best" and "worst" choice, researchers are able to conduct simultaneous paired comparisons on a subset of items, which is more efficient than asking participants to complete individual paired comparisons on the entire list. For example, if a participant indicates that Item 1 is the best and Item 4 is the worst on a list of four items (Items 1, 2, 3, and 4), the researcher is informed of five out of six possible paired comparisons: 1>2, 1>3, 1>4, 2>4, 3>4. These comparisons can be completed with a single question instead of five. MaxDiff exercises include multiple sets of items (repeated measures) in order to fully assess all of the options in the study (Orme, 2018). MaxDiff data is commonly analyzed using multinomial logit, latent class multinomial logit, or hierarchical Bayes estimation, which are all methods that utilize choice data to estimate importance scores for items in a MaxDiff experimental design (Anonymous, 2020). A higher importance score for an item in a MaxDiff exercise indicates that consumers place more value on that item, while lower importance scores indicate less value or importance.

MaxDiff scaling has been applied in a number of food product and consumer studies both as a method of understanding consumer perception of foods and as a cross-validation technique for other research methodologies. Jaeger et al. 2008 compared best-worst scaling compared to monadic rating of consumer preferences of pork patties and found that best–worst scaling was a more discriminatory method of evaluating differences without a significant increase in panelist fatigue (Jaeger et al., 2008). McLean et al. 2107 used MaxDiff scaling in conjunction with an adaptive choice-based conjoint exercise to understand consumer perception of commercially available pork bacon products. Other researchers have used MaxDiff or best-worst scaling to evaluate fluid milk attributes (Harwood and Drake, 2018; Bir et al., 2019), and wine (Mueller et al., 2009). Del Toro-Gipson et al. (2021) utilized a MaxDiff exercise as cross-validation for an adaptive choice-based conjoint to comprehensively investigate consumer perception of smoked Cheddar products. It was found that method of smoking, smoke intensity type of food, and type of cheese were more important to consumers (Del Toro-Gipson et al., 2021). These factors were then further tested using consumer acceptance testing to assess if consumers' conceptually preferred product aligned with their preferences for actual food products. MaxDiff has also been used to understand consumer motivations around a product category. Schiano et al. (2020) utilized a series of MaxDiff exercises to understand how consumers define dairy sustainability, and which terms are most important for consumers when it comes to sustainability of dairy and plant-based dairy alternatives (Schiano et al., 2020).

Objectives

With increasing variety in the pepper cheese category, it is important for cheese manufacturers to understand the desirable sensory properties of hot pepper cheese to facilitate product development and strategic positioning. The objective of this study was to evaluate consumer perception of hot pepper cheese products using a combination of quantitative survey methods, descriptive analysis techniques, and consumer evaluation of actual hot pepper cheeses.

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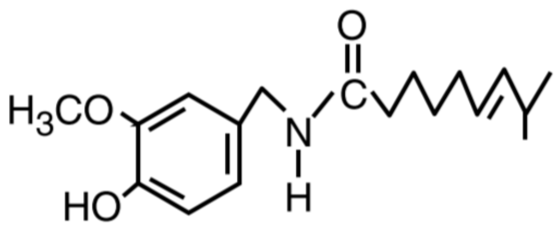
Figures

Figure 1.1: Chemical Structure of Capsaicin (Fennema, 2004)



(XV) Capsaicin

Figure 1.2: PCA Biplot of Pungent Compounds (Cliff and Heymann, 1992)

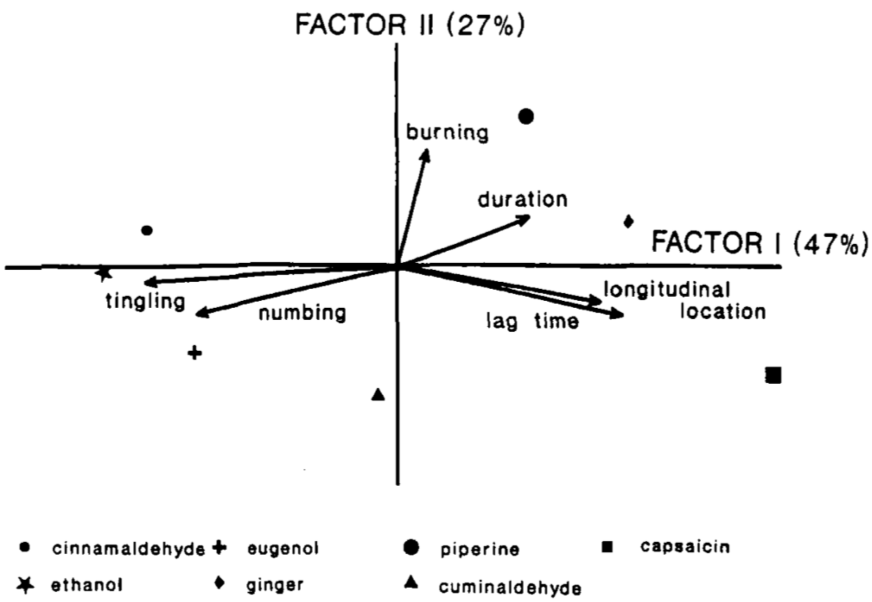
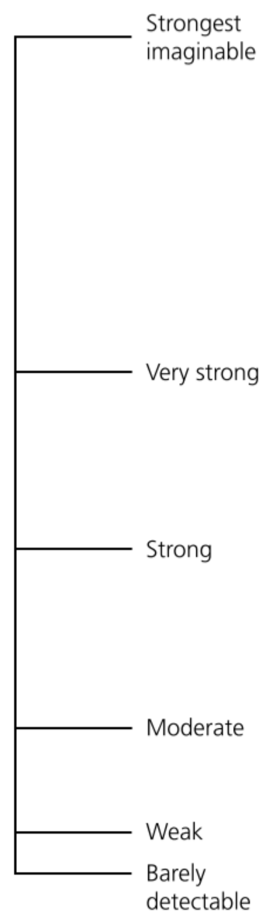


Figure 1.3: Labeled Magnitude Scale (LMS) from Green et al. 1996



CHAPTER 2:

CONSUMER PERCEPTION OF NATURAL HOT PEPPER CHEESES

Consumer Perception of Natural Hot Pepper Cheeses

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INTEPRETIVE SUMMARY

The flavored cheese market, including hot pepper cheeses, has seen consistent growth in the past several years. The ideal hot pepper cheese profile for several consumer groups was identified. Consumers demonstrated preference for multicolored pepper pieces in pepper cheeses both conceptually and by acceptance testing. Consumers who preferred mild/medium spicy foods preferred hot pepper cheeses that were less intense in hot pepper burn than consumers who self-reported preference for hot/spicy foods.

ABSTRACT

Hot pepper cheese (**HPC**) is a growing category of flavored natural cheese. The objective of this study was to evaluate consumer perception of HPC using a combination of quantitative survey methods and consumer evaluation of HPC. An online survey (n=510) was conducted to understand drivers of purchase for the hot pepper cheese category. Hot pepper cheese consumers answered Maximum Difference (**MXD**) exercises and an Adaptive Choice Based Conjoint (**ACBC**) activity focused on hot pepper cheese attributes. Subsequently, natural HPCs were manufactured in duplicate with 5 different hot pepper blends with a range of heat intensities and distinct color differences. Trained panel profiling and consumer acceptance testing (n=194 consumers) were conducted on the cheeses. Three clusters of consumers were identified from the online survey. Cluster 1 (n=175) were traditional HPC consumers, while Cluster 2 (n=152) preferred milder HPCs. Cluster 3 (n=183) showed preference for spicier HPCs as well as novel HPCs, such as those made with habanero peppers or white Cheddar cheese. Conceptually, the overall ideal HPC was a Monterey Jack with medium-sized, multicolored pieces of jalapeno peppers and a medium heat/spiciness. Heat/spiciness intensity and type of cheese were the most

important attributes. The five HPCs used in consumer testing had a distinct range (low to high) of hot pepper burn/heat intensity by trained panel profiling. Consumer overall liking increased as hot pepper burn/heat intensity increased to a certain point, indicating HPC consumers may have an optimal point for heat/spiciness in HPC. Consumers also preferred HPC with multicolored pepper pieces over those with a single pepper color, consistent with survey results. Consumers who self-reported that they prefer mild/medium spicy foods (mild consumers) preferred HPCs that were less intense in hot pepper burn than consumers who self-reported preference for hot/spicy foods (hot consumers). Most HPC consumers prefer HPCs with higher heat intensity and are also motivated by visual characteristics of HPC.

INTRODUCTION

Consumption of cheese has been on the rise in the United States since 2000. In 2019, the United States Department of Agriculture (**USDA**) reported American cheese consumption as 15.5 lbs per capita, compared to 12.7 lbs in 2000 (Shahbandeh, 2020). In August 2020, Mintel surveyed consumers who self-reported eating cheese more often than they did in the last year to provide more context to these trends. Consumers (n=479) indicated that they snacked on cheese more often, used it in more meals, and consumed more types of cheese. Cheese consumers also reported that unique flavors and all-natural ingredients were motivating factors for purchasing and consuming a new cheese (Kamp, 2020). With increasing consumer interest in innovative and diverse cheeses, there has been a subsequent increase in the flavored cheese category, including cheeses that contain hot peppers. Forty-one percent of consumers in a Mintel study from November 2019- June 2020 (n=9009) indicated that they purchased and consumed pepper jack cheese, compared to 39% from August 2019 Mintel data (n=1401) (Kamp, 2020). Traditionally, hot pepper cheese has been constrained to pepper jack, which refers to Monterey Jack cheese with sweet peppers, habaneros, and/or jalapenos. However, in recent years, the category has grown to include different cheese types, such as Cheddar, Gouda, and Colby Jack, as well as new pepper types.

Hot pepper cheeses are made by adding pepper pieces and/or other flavorants to the cheese curds prior to pressing, resulting in a cheese that has pepper pieces dispersed throughout the loaf. To our knowledge, few studies have specifically addressed the sensory perception of hot pepper cheese. Some studies have evaluated the perception of capsaicin burn in cheese matrices. Carden et al. (1999) studied perception of heat in cheese sauces with varying fat and fat mimetic levels using a trained panel and found that reducing fat content increased perceived burn from capsaicin. Other researchers have used paneer cheese as a matrix to study perception of capsaicin burn in order to correlate consumer results with electronic tongue analysis (Schlossareck and Ross, 2019). Other researchers have utilized consumer acceptance testing and survey methods to evaluate consumer perception of different options in the flavored and specialty cheese categories, such as raw milk Gouda and smoked cheeses (Colonna et al., 2011; Del Toro-Gipson et al., 2021).

A number of studies have utilized quantitative consumer research methodologies to assess consumer perception of food products. Kano analysis was originally developed by Noriaki Kano for use in assessing consumer satisfaction in quality assurance (Kano et al., 1984; Rotar and Kozar, 2017). This technique utilizes a series of questions regarding the presence or absence of features to assess consumer basic needs for a product along with the characteristics that excite them. Consumer responses in a Kano exercise are grouped into one of three categories: basic needs, performance needs, and delight needs. These categories are further broken down into Attractive, Indifferent, Must-Be, Performance (One-Dimensional), Questionable, or Reverse characteristics. Performance characteristics follow the “more is better rule” while must-be characteristics are those that consumers consider basic needs. Attractive characteristics are unexpected by the consumer, but result in increased satisfaction with the product, while reverse characteristics are those that the consumer would prefer not to see in a product (Rotar and Kozar, 2017). Kano analysis can be applied to a wide range of products, but only a small number of studies have applied this technique to the food and restaurant industry (Ponnam et al., 2011; Chen, 2012; Kim et al., 2013; Djekic et al., 2020). Kim et al. (2013) utilized Kano analysis to evaluate the effect of chocolate milk attributes on consumer satisfaction/dissatisfaction and found that distinct groups of consumers responded differently to fat content levels (fat free, 1% fat, 2% fat, and whole milk).

Conjoint analysis is an effective tool in guiding product development by quantifying consumer preferences for food product attributes (Moskowitz, 2001). This method uses a series of complete product profiles to assess which attributes and attribute levels that consumers place value on. This approach has been utilized to identify key attributes for many foods including sour cream, chocolate milk, protein beverages, and bacon (Jervis et al., 2012; Kim et al., 2013; Oltman et al., 2015; McLean et al., 2017). Other studies have used Maximum Difference (**MXD**) scaling, also known as Best-Worst scaling, to assess the importance that consumers place on individual product attributes and label claims. This methodology asks consumers to choose the "best" and "worst" items from a list of provided options in order to conduct simultaneous paired comparisons on a long list of items (Orme, 2006). Schiano et al. (2020) used a series of MXD exercises to assess consumer perception of the sustainability of dairy products and plant-based dairy alternatives and rank the importance of dairy attributes in terms of sustainability. Del Toro-Gipson et al. (2021) utilized a combination of methods including focus groups, two online surveys, and a consumer acceptance test to evaluate perception of smoked Cheddar cheeses.

Results of these studies provide actionable insights for food manufacturers and provide further guidance to sensory researchers on the use of quantitative consumer research methods. With increasing variety in the category, it is important for cheese manufacturers to understand the desirable sensory properties of hot pepper cheese to facilitate product development and strategic positioning. The purpose of this study was to gain a better understanding of consumer perception of HPCs.

MATERIALS AND METHODS

Experimental Overview

An online survey using ethnographic questions, Maximum Difference (**MXD**) scaling, a Kano exercise, and an Adaptive Choice-Based Conjoint (**ACBC**) exercise was conducted. This survey was conducted to establish consumer familiarity with and preference for attributes of HPC, including extrinsic and intrinsic characteristics. Following completion of the survey, five natural Monterey Jack cheeses with a range of pepper colors and burn intensities were manufactured in duplicate. Descriptive analysis and a consumer acceptance test were conducted on the cheeses.

Participants

All testing was conducted in compliance with North Carolina State University Institutional Review Board (**NCSU IRB**) regulations. All participants were contacted using an online database of >10,000 consumers from the greater Raleigh/Durham/Chapel Hill, NC area maintained by the Sensory Service Center at North Carolina State University (**SSC**). Consumers who reported that they did not have any food allergies, intolerances, or dietary restrictions, and who purchased and consumed HPC could qualify for this study. Additional qualification criteria for the survey and consumer acceptance test are subsequently specified.

Online Survey

The objective of the online survey was to establish a baseline of consumer familiarity with attributes of HPC, including its visual appearance, spiciness, and other intrinsic characteristics. The online survey was developed using Lighthouse Studio (Sawtooth Software version 9.8.1, Orem, UT). The survey was uploaded to a database maintained by the Sensory Service Center, North Carolina State University, which consists of over 10,000 consumers. Participants who were 18 years of age or older were able to enter the survey (n=1386). Participants who indicated that they purchased HPC (n=510) first completed a series of psychographic questions, including familiarity with HPC characteristics and purchase/consumption frequency of HPC. Familiarity was measured using a 5-point scale where 1= not at all familiar, 2= slightly familiar, 3=somewhat familiar, 4=very familiar, and 5= extremely familiar. Next, they answered questions about their ideal balance of pepper flavor and cheese flavor in HPC using a semantic differential (sliding scale) question where -100 = only cheese flavor, 0 = both cheese and hot pepper flavor, and 100 = only hot pepper flavor. Following the semantic differential question, survey participants completed a MXD exercise on HPC characteristics, followed by a series of questions for Kano analysis. Consumers were then asked to indicate which extrinsic and intrinsic factors of HPC influenced their purchase decisions using a check-all-that-apply (**CATA**) list. Participants finished the survey with an ACBC exercise.

The MXD exercise consisted of 14 different purchase factors for HPCs, including extrinsic qualities such as all-natural and organic labels, and intrinsic factors such as type of pepper used, type of cheese used, and spiciness intensity. Respondents were asked to indicate which item was “Most Important” and which item was “Least Important” from a list of

attributes. Each respondent completed fifteen sets of best-worst questions with four items in each set. These questions were asked to evaluate which attributes consumers placed the most importance on when selecting an HPC to purchase and consume and to gain a better understanding of the role of visual appearance of pepper cheese in purchase decisions.
The Kano exercise consisted of 56 total statements regarding HPC attributes, including 28 “positive” statements such as “is fortified with vitamins” and 28 directly opposite “negative” statements such as “is not fortified with vitamins.” Consumers were asked to rate each statement on a 5-point scale where 1= I enjoy it that way, 2 = I expect it that way, 3= I am neutral, 4= I dislike it, but I can live with it, and 5= I cannot accept it (Anonymous; Rotar and Kozar, 2017).

The ACBC included a build-your-own (**BYO**) exercise followed by 8 screening tasks with four concepts per screening task and concluded with a choice tournament with 3 concepts per choice task. During the BYO portion of the exercise, survey participants used a provided list of attributes and levels to build their ideal HPC. The ACBC design was comprised of 6 attributes: type of cheese, type of pepper, size of pepper pieces, amount of pepper pieces, pepper color, and spiciness intensity with levels within each attribute. Attributes related to visual characteristics (type of cheese, size of pepper pieces, amount of pepper pieces and pepper color) were also displayed in a graphic format in the ACBC. Graphics were generated using Adobe Illustrator® (v23.0.3, Adobe Inc., San Jose, CA) for each unique combination of levels (108 graphics in total) and were displayed during the BYO exercise and with each concept during the screenings tasks and the choice tournament.

Evaluation of natural hot pepper cheese

Following completion of the online survey, five natural HPCs with a range of pepper burn intensities and visual characteristics were manufactured by an industry partner (Twin Falls, ID). Two lots of full fat pasteurized milk Monterey Jack cheese were produced (25 kg cheese per lot). Diced peppers were sourced from commercial sources and included hatch peppers, red and green jalapenos, and orange habaneros to generate a range of pepper color and pepper burn (**Table 1**). Pepper combinations were premixed, added to drained cheese curds (3.5% w/w), and mixed thoroughly. Cheese curds with the pepper inclusions were transferred into stainless steel hoops lined in cheese cloth and pressed at 60 psi for 30 min. Cheese blocks (5 kg) were cooled using forced air coolers at 5˚C. The duplicate cheese lots were manufactured within 1 week of other. Cheeses were shipped by overnight carrier to Raleigh, NC at 30 days. Trained panel and consumer testing occurred within a 2 week period when the cheeses were 50 days old.

Descriptive Analysis

Seven trained panelists (5 females, 2 males, ages 22-54 y) each with at least 60 h of previous experience with the descriptive analysis of cheese evaluated HPC cheeses from each lot in duplicate. A 0 to 15 point universal intensity scale consistent with the Spectrum™ descriptive analysis method (Meilgaard et al., 2007) was used for analysis. An established cheese lexicon was applied with two additional attributes, pepper aromatic and hot pepper burn (Drake et al., 2001). Hot pepper burn is also referred to as pungency or burn intensity (Cliff and Heymann, 1992; Allison et al., 1999; Guzmán and Bosland, 2017) and is separate from the aromatics imparted by hot peppers. Pepper aromatic was defined for this study as aromatics associated with freshly chopped peppers (chopped green and red bell peppers were used as an example), while hot pepper burn was defined as the specific chemesthetic sensation of burning associated with hot peppers (cinnamon oil and capsaicin were used as examples). Each cheese was cut into a 3 cm cube and placed into a lidded 60 mL soufflé cup with a randomly generated 3-digit code and tempered to 15°C. Samples were prepared with overhead lights off to prevent light oxidation.

Paper ballots were used for data collection. A 10 min rest was enforced between samples. Panelists were instructed to expectorate samples, rinse their mouths with deionized water and take a bite of unsalted saltine cracker. Each panelist evaluated each lot in duplicate in separate sessions.

Consumer Testing

A consumer acceptance test modified for COVID-19 safety was conducted in October 2020 using consumers recruited from the database maintained by the SSC. Consumers aged 18-64 y that purchased and consumed HPC at least once a month were recruited. Data was collected using an electronic ballot using Compusense Cloud software (Compusense Inc., Guelph, Canada). Cheeses from both lots were pooled for consumer testing as descriptive analysis results showed the two lots were not significantly different in sensory profile ($p>0.05$) (results not shown). Each consumer was provided with four of the five cheeses in a balanced incomplete block (**BIB**) design. A total of 200 consumers were recruited to provide at least 160-180 completed ballots on each of the five cheeses. Each cheese was cut into a 3 cm cube and placed into a lidded 60 mL soufflé cup with a randomly generated 3-digit code. Samples were prepared with overhead lights off to prevent light oxidation. For this test, qualified consumers picked up a thermal bag (ULINE, Pleasant Prairie, WI) with coded samples, a Ziploc® bag of unsalted saltines and a commercial bottle of spring water. Consumers were instructed to take the samples home and then to click on the provided hyperlink to complete the test within 4 h of pickup.

Once consumers clicked on the ballot link and initiated the test, they were asked to rank the cheeses in order of how much they liked their appearance (1=most liked, 4=least liked), by the amount of pepper pieces they could see in the sample (1=most pepper pieces, 4=least pepper pieces), and how spicy they thought the cheeses would be based only on appearance

(1=spiciest/hottest and 4=least spicy/mildest). Following the ranking questions, cheeses were evaluated monadically in a randomized order. For each cheese, consumers were first asked to evaluate appearance liking (no tasting). Liking questions were evaluated using a 9-point hedonic scale where 1= dislike extremely and 9=like extremely. Next, consumers evaluated the amount of pepper pieces using a 5-point just-about-right (**JAR**) scale where 1 and 2 = not enough pepper pieces, 3 = just about right and 4 and 5 = too many pepper pieces. Consumers then evaluated their liking of the color of the pepper pieces. Next, consumers indicated overall liking. Next, they answered spiciness liking and a spiciness JAR question where 1 and 2 = not spicy enough, 3 = just about right, and 4 and 5 = too spicy. Cheese flavor and pepper flavor liking were evaluated next, followed by a flavor balance JAR where 1 and 2 = too much cheese flavor, 3 = just about right, and 4 and 5 = too much pepper flavor. Panelists then evaluated saltiness liking and saltiness JAR using a 5-point scale in which 1 and 2 = not salty enough, 3 = just about right, and 4 and 5 = too salty. Following flavor questions, panelists evaluated the texture of the cheeses, including liking and a texture JAR question in which 1 and 2 = too soft, 3 = just about right, and 4 and 5 = too firm. Finally, panelists indicated their purchase intent using a 5-point scale in which 1 and 2 = will not buy, 3 = might or might not buy, and 4 and 5 = will buy. Participants were required to rest for ten minutes and cleanse their palates with unsalted crackers between cheeses. After tasting all four cheeses, participants were asked to rank the cheeses in order of preference (1=most preferred and 4=least preferred). Participants finished the test by answering demographic questions, including their personal spice level preference, frequency of HPC consumption, pepper type familiarity, and factors of purchase and consumption for HPC. After completing the test, participants were compensated with a $20 gift card to a local store.

Statistical Analysis

MaxDiff and ACBC scores from the online survey were evaluated using hierarchical Bayesian (**HB**) regression using Lighthouse Studio (Sawtooth Software, Version 9.8.0, Orem, UT). All other analyses were performed with XLSTAT (version 2019.3.1, Addinsoft, Boston, USA) at 95% confidence ($p<0.05$). Cluster analysis of individual importance scores was performed using Euclidean distances and Wards linkage to categorize respondents with similar answers into separate groups. Analysis of variance (**ANOVA**) with means separation (Fisher's LSD with a Bonferroni correction) was performed on the trained panel attribute intensities and consumer liking data. Consumer JAR questions were analyzed with penalty analysis and chi squared analysis with the Marasculio procedure for multiple comparisons.

RESULTS AND DISCUSSION

Online Survey Participant Demographics

A total of n=1386 consumers entered the online survey. Of these participants, n=510 met the criteria for participation previously described. Participants were mostly female (69% vs 31% male). Survey participants represented a range of ages, with 20% of participants aged 18-24 y old, 30% 25-34 y old, 20% 35-44 y old, 14% 45-54 y old, and 16% 55 y old or older. Most survey participants (78%) self-identified as white/Caucasian, 10% identified as Asian/Indian, and 9% identified as black/African American. Consumers indicated high frequency of spicy food consumption, with 65% reporting consuming spicy foods at least once per week, 25% reported spicy food consumption once every two weeks, and 10% reporting occasional (around once per month) spicy food consumption. Almost half (47%) of consumers preferred “medium” spicy products, 11% preferred mild, 37% preferred hot, and 6% preferred extremely hot. A similar distribution of preference for spice/burn was documented in a series of online surveys conducted in 12 countries with n=500 participants each, with 40% of consumers self-reporting as “medium” users, 28% self-reporting as “hot” users, and 7% self-reporting as “extremely hot” users (Anonymous, 2019). Participants indicated the highest familiarity with jalapeno peppers, returning a 4.5 overall score on a 5-point familiarity scale where 1=not at all familiar and 5=extremely familiar. Participants were also familiar with habaneros (3.9), chipotles (3.7), and poblanos (3.5). However, consumers indicated limited familiarity with Carolina Reaper peppers (2.6), hatch chiles (2.4), and Scotch Bonnet peppers (2.3). Most survey participants were moderate HPC users, with 26% reporting HPC consumption about once per week, 25% about once every two weeks, and 23% about once per month. Twelve percent of survey participants indicated they consume HPC about 3-5 times per week. Overall, consumers indicated they prefer a balance of hot pepper and cheese flavor in HPC, returning a score of 2.96 on a sliding scale where -100 = only cheese flavor and 100= only hot pepper flavor.

Consumers indicated familiarity with HPC (4.0 on a 5-point familiarity scale), but were less familiar with different cheeses (2.8) and peppers (2.7) used in HPCs. Consumers also indicated limited familiarity with the spiciness intensity of different peppers (3.3). Price and type of cheese were the most-checked CATA attributes when consumers were asked to indicate which factors influenced their decision to purchase HPC (84% and 78% respectively). Consumers also indicated that appearance of cheese (73%), spiciness intensity (67%), and type of pepper (52%) were influential. Extrinsic factors, such as sustainably sourced (18%), ethical treatment of cows (18%), organic (16%), and GMO-free (16%) were less important in purchase decisions.

Maximum Difference (MXD) Exercise

MXD exercises generate importance scores, which indicate the amount of value that consumers place on a product attribute when making purchase decisions. Higher importance scores reflect a greater degree of importance for an attribute (Orme, 2006). MXD results from the HPC online survey show that spiciness intensity and type of cheese, followed by price, are the most important attributes of HPC to consumers (**Figure 1**). Spiciness intensity and type of cheese were not different from each other ($p>0.05$), and were the most important attributes for HPC purchase ($p<0.05$). Consumers indicated that extrinsic characteristics such as organic labels, brand name, GMO-free labels, and packaging, were least important to them, consistent with their CATA responses earlier in the survey. These results aligns with those observed by Del Toro-Gipson et al. (2021) who observed that consumers valued type of cheese and type of smoke over label claims and other extrinsic characteristics when purchasing smoked cheeses.

Kano Analysis

In Kano analysis, consumer responses to both the presence and absence of a product feature are used to categorize features into one of six categories: Attractive, Indifferent, Must-Be, Performance, Questionable, or Reverse (Rotar and Kozar, 2017). A majority of consumers were indifferent about HPC characteristics, with low price being the only characteristic that was perceived as attractive overall (data not shown). Price is generally a universally attractive attribute for food (McLean et al., 2017; Harwood and Drake, 2018; Speight et al., 2019). Kim et al. (2013) also observed that chocolate milk consumers were indifferent to a majority of chocolate milk attributes in a Kano exercise, but found fat content attractive (Kim et al., 2013). "DHA-fortified," "name brand," and "fortified with vitamins" received the highest percentage of neutral or indifferent responses (83.9%, 80.0%, and 78.8% respectively), which might be expected given that these are not attributes/labels commonly associated with natural cheeses of any kind. However, other HPC characteristics received lower frequencies of indifferent responses and higher frequencies in the attractive, performance, and must-be categories, indicating there may be groups of consumers who perceive these characteristics differently. "Contains pepper pieces" was an indifferent characteristic for only 35.1% of respondents, with 21.4% indicating pepper pieces in HPC are attractive, 20.4% indicating pepper pieces are a performance attribute, and 20.4% indicating that pepper pieces are a must-be attribute for HPC. Similarly, "locally produced" and "contains more than one pepper type" were perceived as attractive by a number of consumers (41.2% and 36.9% respectively). "Contains natural preservatives to extend shelf life" and "intense spiciness" were also perceived as attractive by a subset of consumers (29.8% and 25.9% respectively).

Responses to Kano questions were segmented using consumer self-reported preferred spice/heat level in spicy foods to evaluate if spice preferences influenced consumer satisfaction characteristics in HPC. Mild consumers (n=55) found “mild spiciness” and “low price” attractive, but were indifferent toward all other HPC characteristics. Medium consumers (n=238) found “low price” attractive but were indifferent toward other characteristics. Hot consumers (n=188) were indifferent to all characteristics, but the same number of individuals in this group found “intense spiciness” attractive as the number of those who were indifferent to this characteristic. Extra hot consumers (n=29) indicated that “contains more than one pepper type, “intense spiciness,” and “low price” were attractive, and an equal number of consumers in this group also found “melts well” and “locally produced” attractive.

Adaptive Choice-Based Conjoint (ACBC) Exercise

Conjoint exercises produce values known as utility scores, which are derived from hierarchical Bayesian (HB) estimation analysis. These values are zero-centered and rescaled to allow all values to sum to 100. More positive scores are representative of more appealing levels within an attribute, while more negative scores represent less appealing characteristics (Orme, 2006). Overall, the ideal HPC for consumers was a Monterey Jack cheese with medium-sized, multicolored (red and green) pieces of jalapeno peppers at a medium frequency and a medium heat/burn intensity (**Figure 2**). Monterey Jack cheese (42.9) and white Cheddar (42.5) received similar utility scores ($p>0.05$), indicating that either of these cheese options may be appealing to HPC consumers. In contrast, survey participants returned the lowest utility score for orange Cheddar (-66.5) out of all variables presented ($p<0.05$), which suggests that orange Cheddar as a cheese for HPC is less appealing to consumers. It has been previously observed that consumers value intrinsic characteristics of flavored cheeses, smoked Cheddar consumers placed importance on smoking method, smoke intensity, type of wood, and type of cheese (Del Toro-Gipson et al., 2021).

Conjoint results were analyzed using AHC clustering and 3 distinct groups of consumers with different preferences for HPC were identified (**Figure 2**). Age and gender demographic distributions were consistent among all three groups ($p>0.05$). Cluster 1 (n=175), designated the Traditional Consumers, indicated their ideal HPC was a Monterey Jack with a high frequency of medium-sized, multicolored jalapeno pieces and a medium spice/burn intensity which closely aligns with most of the options currently available in grocery stores. Traditional consumers also returned positive utility scores for Colby Jack and white Cheddar cheese, along with chipotle peppers and hatch peppers and a medium frequency of peppers. This result suggests that while these consumers prefer HPC characteristics traditionally seen in HPCs such as Pepper Jack, they are open to new varieties of HPC. This group was the most frequent consumers of HPC, with 42% indicating they consumed HPC at least once per week.

Cluster 2 (n=152) was designated the Mild Consumers, as their ideal HPC was a Monterey Jack with small pieces of multicolored jalapeno peppers at a medium frequency and medium heat (**Figure 2**). This group also returned positive utility scores for low spice/burn intensity and had the lowest utility for ghost peppers (-60.7) (an intensely spicy pepper (Bray, 2013)). A majority of Mild Consumers indicated they generally preferred mild (16%) or medium (58%) spice/burn intensity when consuming spicy foods. This group was the least frequent users of HPC, as only 32% of Mild Consumers reported consuming HPC at least once per week. Cluster 3 (n=183) was designated the Spicy Consumers **(Figure 2).** These consumers' ideal HPC was a white Cheddar with medium-sized, multicolored pieces of habanero peppers at a medium frequency with a medium spice/burn intensity. These consumers also displayed positive utility for mozzarella cheese (21.0), high frequency of pepper pieces (19.5), and a high burn/spicy intensity (19.4). This group reported the highest frequency of spicy foods consumption, with 75% of individuals reporting they consume spicy foods at least once per week. However, only 38% of individuals in the Spicy Consumers group reported consuming HPC at least once per week. This discrepancy may be due to differences between the ideal HPC for this consumer group and the options currently available to them on the market.

Descriptive analysis of hot pepper cheeses

The two replications of cheeses were similar in moisture (40 % ± 0.88), fat in dry matter (51% ± 0.58), salt content (1.8 % ± 0.18) and pH (5.3 ± 0.05). Similarly, trained panel profiles were not distinct ($p>0.05$) for cheese replicates so results are reported as the means of both cheese replications. Based on the results observed during the online survey, HPCs were made using different combinations of hatch peppers, jalapeno peppers, and habanero peppers to create a range of heat/burn intensity and visible pepper color. The HPC were all characterized by mild cooked/milky and whey flavors consistent with young Monterey Jack cheeses (results not shown). As expected, HPCs differed in pepper aromatic flavor and hot pepper burn intensity (**Table 2**). Pepper burn intensity followed an approximately linear pattern across the five HPCs, with Formulation 1 having the lowest pepper burn intensity and Formulation 5 having the highest. With the exception of Formulation 1, which only used green hatch chile peppers, all cheeses contained multicolored (red and green or red, green, and orange) pepper pieces, as this was preferred by all consumer groups in the online ACBC exercise.

Consumer Acceptance Testing

Consumers had the highest overall liking score for Formulations 2, 4 and 5, which were made with a mix of red and green jalapenos and orange habanero peppers with variable pepper flavor and pepper burn (**Tables 2, 3**). Consumer cheese flavor, saltiness and texture liking scores for cheeses were not different ($p>0.05$) (results not shown). Formulation 1 received the lowest appearance liking among the cheeses. This cheese had only green hatch peppers, further indicating that consumers prefer multicolored pepper pieces in HPC which was noted by the survey. The cheeses with the highest hot pepper burn by trained panelists (Formulations 4 and 5) received the highest spiciness and pepper flavor liking scores from consumers **(Figures 3, 4).** Overall, consumers preferred HPCs with more intense pepper burn over less intense HPCs.

Consumer results were segmented using consumer self-reported answers to the same spice/burn preference question used in the online survey. We hypothesized that these groups would perceive actual HPCs differently, as there is a wealth of evidence to suggest that consumer liking for capsaicin and pepper burn is not homogenous. Some consumers dislike any level of capsaicin irritation, while others actively seek higher levels of pungency (Dalton and Byrnes, 2016). Researchers have studied this variety in hedonic response to spicy foods and posited a number of theories about why preference exhibits such variety. It has been documented that sensitivity to capsaicin decreases with age, as younger subjects (<40 years) were observed to have significantly lower threshold scores for capsaicin than older subjects (Just et al., 2007). Several studies have observed that frequent/regular users of spicy products consistently indicated the intensity of oral-induced capsaicin burn lower than non-users (Lawless et al., 1985; Stevenson and Yeomans, 1993; Nolden and Hayes, 2017). No differences have been observed in sensitivity to capsaicin between genders, but Byrnes and Hayes (2015) studied the effect of gender on spicy food liking and intake of spicy foods and hypothesized that men who consumed spicy foods may be more strongly motivated by extrinsic rewards (Sensitivity to Reward), while women displayed stronger motivation by intrinsic rewards (Sensation Seeking). It has also been hypothesized that food neophobia, or avoidance of unfamiliar or novel foods, also plays a role in spicy food liking and perception. Törnwall et al. (2014) grouped participants into "basic" eaters and "adventurous" eaters using The Food Neophobia Scale (FNS) and found that adventurous eaters expressed higher liking for sour and spicy foods and were also less food neophobic (Törnwall et al., 2014). Consumers who indicate they prefer intensely spicy foods enjoy the sensation of pungency/burn (Rozin and Schiller, 1980).

Consumers who reported they preferred mild or medium spicy foods were classified as "Mild" consumers, while participants who preferred hot or extra hot foods were considered "Hot" consumers. Self-reported preference for spicy foods did impact some liking attributes of the HPCs used in consumer testing (**Table 3**). No differences between consumer groups were observed for Formulation 3 for any attribute but significant differences in spiciness and/or pepper burn liking were documented for the other 4 cheeses. As such, mild and hot consumers perceive low burn intensity and high burn intensity cheeses differently and these cheeses may be polarizing for consumer groups. Mild consumers significantly preferred the appearance (as well as spiciness and pepper flavor) of Formulation 1 over hot consumers. However, the color difference between Formulation 1 (green peppers only) and other cheeses (green/red or green/red/orange) may not have been the sole driver of differences in appearance acceptability. By analysis of JAR scores, 89% of hot consumers felt that Formulation 1 had too few pepper pieces compared to only 67% of mild consumers (data not shown), which may also contribute to differences in perception between the two groups for Formulation 1. Pepper color as well as amount of visible peppers may be visual cues to HPC consumers that suggest pepper flavor and spiciness/burn. This is evident when comparing consumer spiciness/burn liking and pepper color liking, as Formulation 1 scored the lowest in both of these categories while Formulation 4 scored the highest (data not shown). However, significant differences in pepper color liking were only observed between cheese samples. No differences in pepper color liking were observed between consumer groups (hot vs mild). Positive consumer responses to pepper color and appearance characteristics may have a halo effect on other HPC characteristics (Lawless and Heymann, 2013).

Penalty analysis of the five HPCs provided further context to consumer liking (**Table 4**). Formulations 1-4 were penalized for having too few pepper pieces, not being spicy enough, and having too much cheese flavor and not enough pepper flavor. Formulation 4 was penalized for both too little and too much cheese flavor, indicating that consumers felt the cheese/pepper flavor balance was not optimal or there was disagreement among consumers regarding the flavor balance of Formulation 4. Further analysis of penalty scores from overall consumers (n=196), mild consumers (n=98) and hot consumers (n=98) (results not shown) indicated that 20.5% of hot consumers and 19.5% of mild consumers felt that Formulation 4 had too much cheese flavor and not enough pepper flavor. In contrast, 37.7% of mild consumers penalized Formulation 4 for having too much pepper flavor and not enough cheese flavor, while only 16.7% of hot consumers responded in the same manner. This discrepancy between the two consumer groups likely resulted in Formulation 4 being penalized for both too much and too little pepper flavor. Overall, Formulation 5 was penalized for being too hot/spicy and having too much pepper flavor. Consumer responses to the spiciness JAR question were also segmented by mild consumers vs hot consumers to better understand how pepper burn intensity was perceived by HPC consumers and to identify an optimal point for hot pepper burn in HPC (**Figure 5**). A majority of consumers (57.4% overall) indicated that Formulation 4 was just about right in spiciness, with 50.6% of mild consumers and 64.1% of hot consumers selecting this option. Formulation 5 was perceived as JAR by 52.9% of consumers overall, 39.8% of mild consumers, and 68.1% of hot consumers. A pepper burn intensity between 3 and 5 on a 15-point universal intensity scale by trained panelists may be the optimal burn intensity for most HPC consumers. HPC consumers who enjoy intensely spicy foods may prefer HPCs that have pepper burn intensities above this range, but cheese manufacturers risk alienating HPC consumers who prefer mild spice if the burn intensity is too high.

The HPC consumers ideal HPC from conjoint analysis (Monterey Jack cheese with medium-sized, multicolored (red and green) pieces of jalapeno peppers at a medium frequency and a medium heat/burn intensity) aligns with acceptance test results. Survey participants (n=510) displayed positive utility scores for both jalapeno and habanero peppers, but significantly preferred jalapenos over habaneros ($p<0.05$). Taste test participants (n=194) preferred the appearance of cheeses with multicolor peppers as well as the flavor of cheeses made with both jalapenos and habaneros (Formulations 4 and 5) over a cheese made with only jalapenos (Formulation 3). Survey participants also indicated that the presence of both red and green peppers in a HPC was more appealing than one pepper color alone. This result was supported by acceptance testing, as consumers returned the lowest pepper color liking and appearance liking scores for Formulation 1 which was made with green hatch chiles. Formulation 4, which was perceived as JAR in spiciness by a majority of taste test participants, was made using a 70% jalapeno pepper mix to 30% habanero ratio and had a pepper burn intensity of 3.1 by trained panel profiling. This study only evaluated the perception of HPCs by self-reported HPC consumers and did not evaluate the opinions of non-HPC cheese consumers. Cheeses that were less liked by current HPC consumers, such as Formulation 1, may be more acceptable to non-users of the pepper cheese category. Utilizing pepper species that have pepper aromatics but low pepper burn, such as hatch chiles (Formulation 1), may present an opportunity for cheese manufacturers to introduce non-users of spicy foods to the pepper cheese category. As such, the appeal of this type of pepper cheese may be under-represented in the current study. From the conjoint analysis, HPC consumers in this study were also interested in nontraditional pepper cheese ingredients such as chipotle peppers. Cheese manufacturers should consider diversifying their HPC offerings to enforce existing HPC consumer liking of HPCs and potentially introduce new users to the category.

CONCLUSIONS

Results of this study illustrate the characteristics of HPC that consumers value and help to identify the ideal HPC that appeals to consumers. The consumer conceptual ideal HPC was a Monterey Jack cheese with medium-sized, multicolored (red and green) pieces of jalapeno peppers at a medium frequency and a medium heat/burn intensity. Consumers consistently demonstrated preference for multicolored pepper pieces in HPC. General spice level/burn intensity preferences impacted liking of spiciness and pepper flavor in HPC. Consumers who self-reported that they preferred mild/medium intensity products were more accepting of lower burn intensity HPCs, while consumers who self-reported preference for higher burn intensity products showed higher acceptance for HPCs with higher pepper burn intensity. A hot pepper burn intensity between 3 and 5 on a trained panel universal intensity scale may be the optimal burn intensity for most current HPC consumers, but consumers who enjoy intensely spicy foods may find HPCs that have pepper burn intensities above this range attractive as well.

ACKNOWLEDGEMENTS

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Table 2.1: Pepper formulations used for manufacture of hot pepper cheeses (HPCs).

Prototype ID	Pepper Type(s)	Dice Size	Ratio
Formulation 1	Green Hatch Peppers	3/8”	N/A
Formulation 2	Green Hatch Peppers Red Jalapenos	hatch 3/8” jalapeno 1/8”	50% hatch peppers, 50% jalapenos
Formulation 3	Red Jalapenos Green Jalapenos	1/8”	27% red jalapenos, 73% green jalapenos
Formulation 4	Red Jalapeno Green Jalapeno Orange Habaneros	1/8”	27% red jalapenos, 73% green jalapenos 70% jalapeno pepper mix, 30% habanero
Formulation 5	Red Jalapeno Green Jalapeno Orange Habaneros	1/8”	27% red jalapenos, 73% green jalapenos 70% habanero, 30% jalapeno pepper mix

Pepper pieces were sourced from Mizkan (Handa, Aichi, Japan) and Edco Food Products (Hobart, WI).

Table 2.2: Mean pepper aromatic and pepper burn intensities from descriptive analysis of hot pepper cheeses (HPCs).

Prototype ID	Pepper Aromatic	Pepper Burn
Formulation 1	2.8^{c}	0.6^{e}
Formulation 2	2.8^{c}	1.3^{d}
Formulation 3	2.7^{c}	2.0^{c}
Formulation 4	3.0^{b}	3.1^{b}
Formulation 5	3.7^{a}	5.7^{a}

Attributes were evaluated using a 0 to 15-point universal intensity scale with trained judges (n=7) evaluating each cheese replication in duplicate. Different letters following means within a column indicate significant differences ($p<0.05$). Most natural cheese flavors fall between 0 and 4 on this scale (Drake et al., 2001).

Table 2.3: Consumer liking means for significantly different attributes of hot pepper cheeses (HPCs) for all consumers (n=196) and consumers grouped by self-reported mild versus hot/spicy food preference (n=98 in each group).

Prototype ID	**Question**											
	Appearance Liking			*Overall Liking*			*Spiciness/burn Liking*			*Pepper Flavor Liking*		
	Overall	Mild	Hot	Overall	Mild	Hot	Overall	Mild	Hot	Overall	Mild	Hot
Formulation 1	5.5^{C}	5.8^{a}	5.1^{b}	5.6^{B}	5.8	5.4	4.0^{C}	4.7^{a}	3.4^{b}	4.2^{C}	4.9^{a}	3.6^{b}
Formulation 2	6.7^{AB}	6.8	6.7	6.4^{A}	6.4	6.3	5.2^{B}	5.7^{a}	4.7^{b}	5.5^{B}	5.7	5.2
Formulation 3	6.6^{B}	6.6	6.7	5.9^{B}	5.7	6.0	5.2^{B}	5.3	5.1	5.2^{B}	5.4	4.9
Formulation 4	7.0^{A}	6.9	7.2	6.6^{A}	6.4	6.8	6.6^{A}	6.2^{b}	7.0^{a}	6.5^{A}	6.1^{b}	6.9^{a}
Formulation 5	6.6^{B}	6.6	6.6	6.7^{A}	6.2^{b}	7.3^{a}	6.5^{A}	5.7^{b}	7.5^{a}	6.4^{A}	5.7^{b}	7.2^{a}

Significant differences between consumer groups were observed for Appearance Liking, Overall Liking, Spiciness Liking, and Pepper Flavor Liking. Different uppercase letters next to overall means within a question indicate significant differences among cheeses for all consumers ($p<0.05$). Different lowercase letters next to Mild and Hot means within a question indicate significant differences between mild and hot consumers ($p<0.05$) for that attribute.

Table 2.4: Results of penalty analysis on hot pepper cheeses (HPCs) from consumer acceptance testing (n=196 consumers)

Variable	**Level**	**Formulation 1**	**Formulation 2**	**Formulation 3**	**Formulation 4**	**Formulation 5**
Amount of Pepper Pieces JAR	Too little	78.1%*	36.8%*	42.9%*	31.0%*	31.0%
	JAR	20.6%	54.8%	51.3%	59.4%	54.8%
	Too much	1.3%	8.4%	5.8%	9.7%	14.2%
Spiciness JAR	Too little	84.5%*	66.5%*	66.7%*	23.9%*	7.7%
	JAR	12.3%	30.3%	32.1%	57.4%	52.9%
	Too much	3.2%	3.2%	1.3%	18.7%	39.4%*
Flavor Balance JAR	Too little	78.1%*	53.5%*	57.1%*	20.0%*	5.8%
	JAR	18.1%	39.4%	35.9%	52.9%	45.2%
	Too much	3.9%	7.1%	7.1%	27.1%*	49.0%*

Consumers were asked to evaluate each attribute on a 5-point scale where 1 and 2=not enough, 3= JAR, and 4 and 5= too much. * indicates significant penalty on overall liking ($p<0.05$).

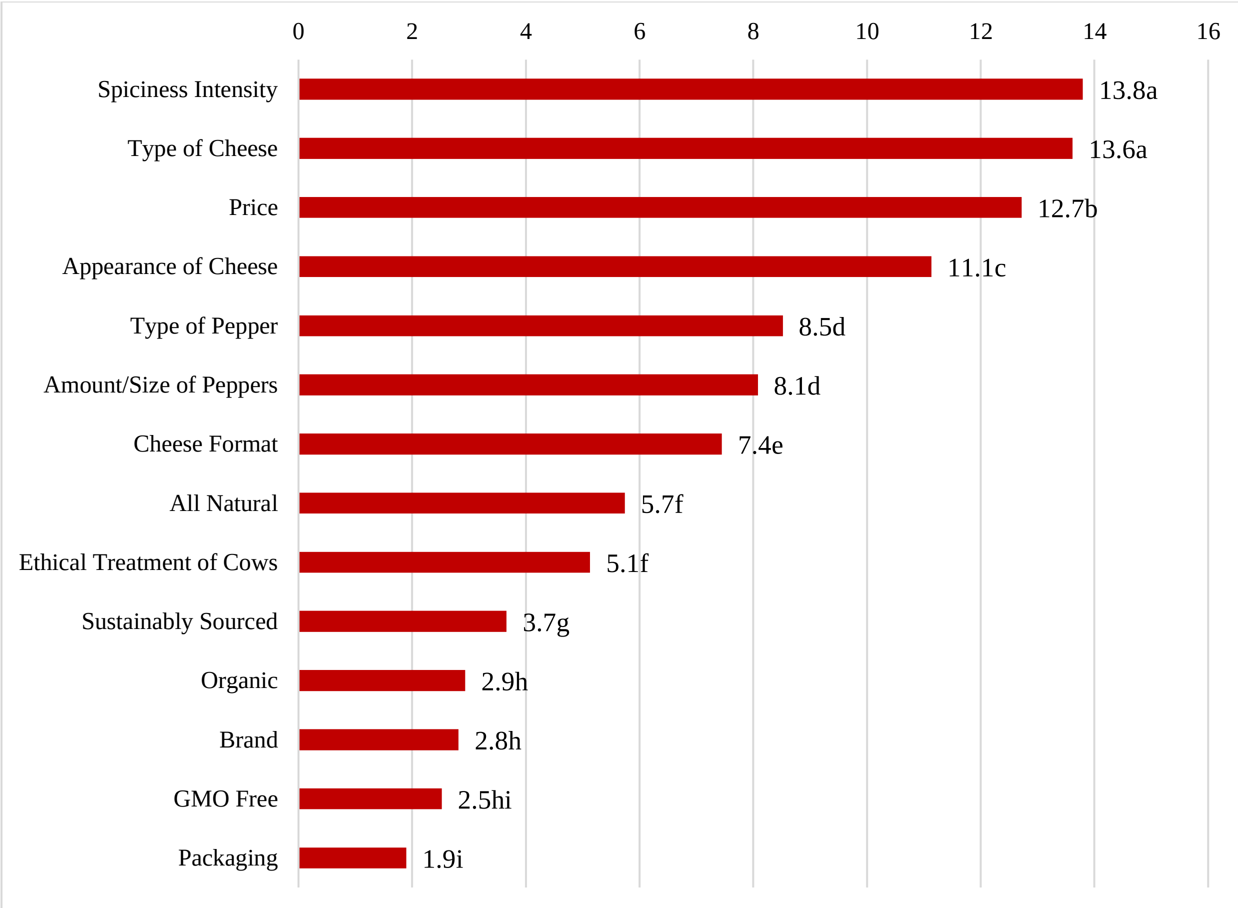

Figure 2.1: Mean Maximum Difference (MXD) scores for important hot pepper cheese characteristics (n=510) Means followed by different letters are significantly different ($p<0.05$). MXD scores have been rescaled to sum to 100. A higher score indicates a more important attribute.

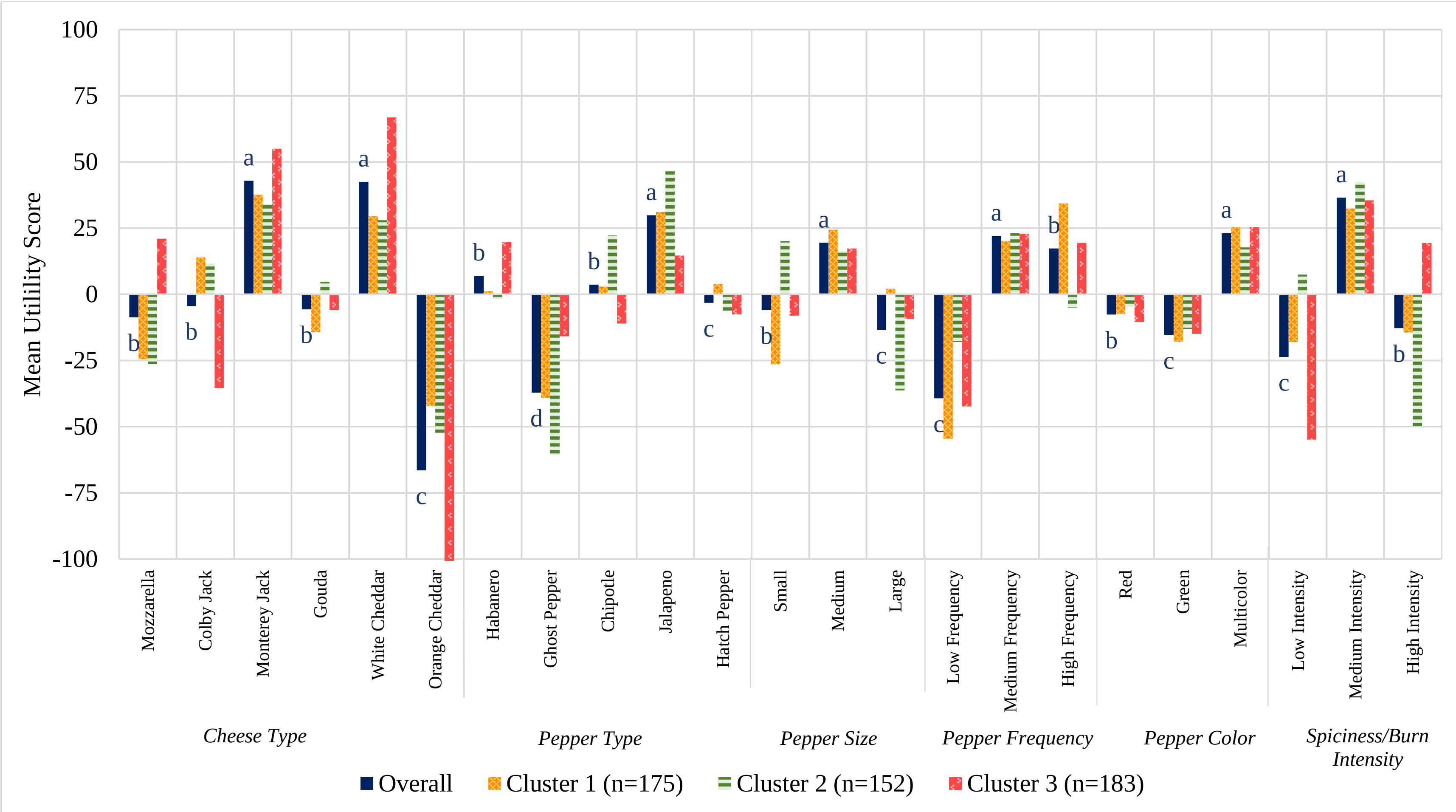

Figure 2.2: Overall and clustered ACBC utility scores for preferred hot pepper cheese attributes from online survey (n=510). Utility scores (zero-centered) and higher (more positive) scores are representative of more appealing levels within an attribute, while lower (more negative) scores represent less appealing characteristics. Means followed by different letters within an attribute are significantly different (p<0.05).

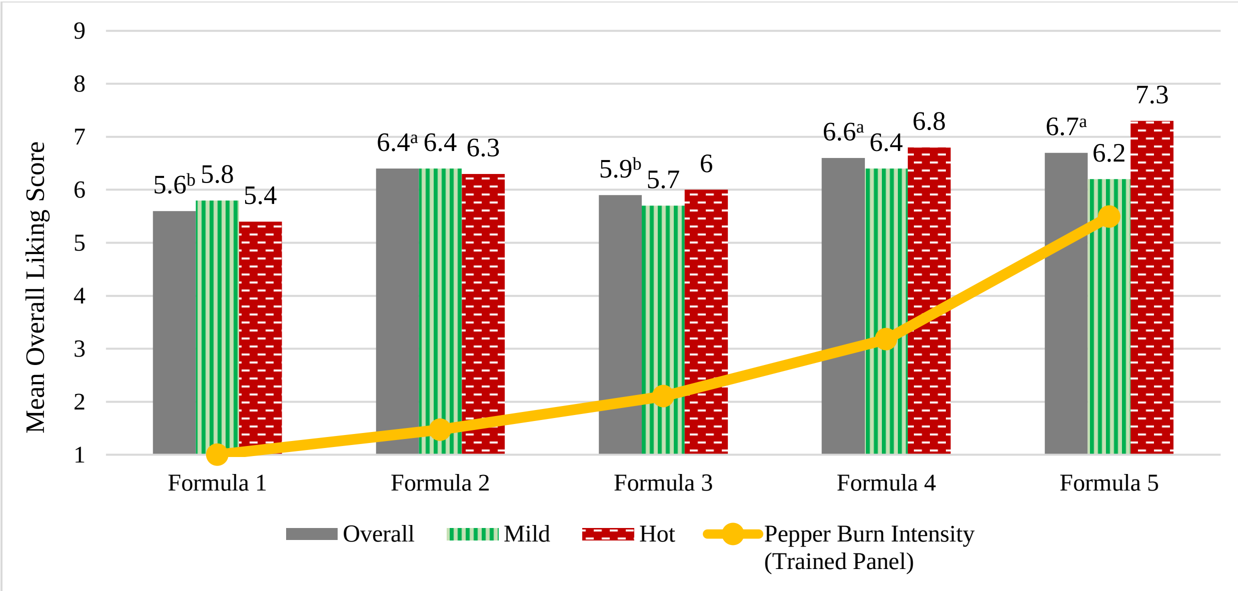

Figure 2.3: Mean overall liking scores for hot pepper cheeses (HPCs) from consumer acceptance testing plotted with pepper burn intensity from the trained panel. Consumers (n=196 total) were self-reported into groups designated "mild" (n=98) or "hot" (n=98) food likers. Letters indicate statistical differences in overall liking ($p<0.05$).

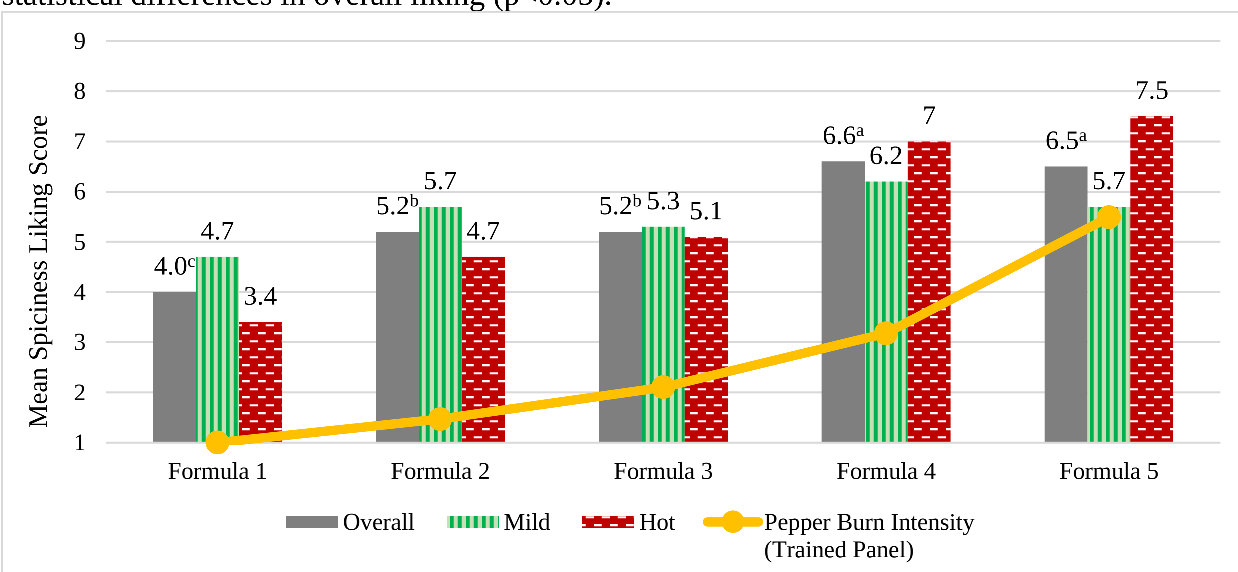

Figure 2.4: Mean spiciness/burn liking scores for hot pepper cheeses (HPCs) by consumer group from consumer acceptance testing plotted with pepper burn intensity from trained panel profiling. Consumers were placed into groups designated "mild" (n=98) or "hot" (n=98) food likers. Letters indicate statistical differences in spiciness liking ($p<0.05$).

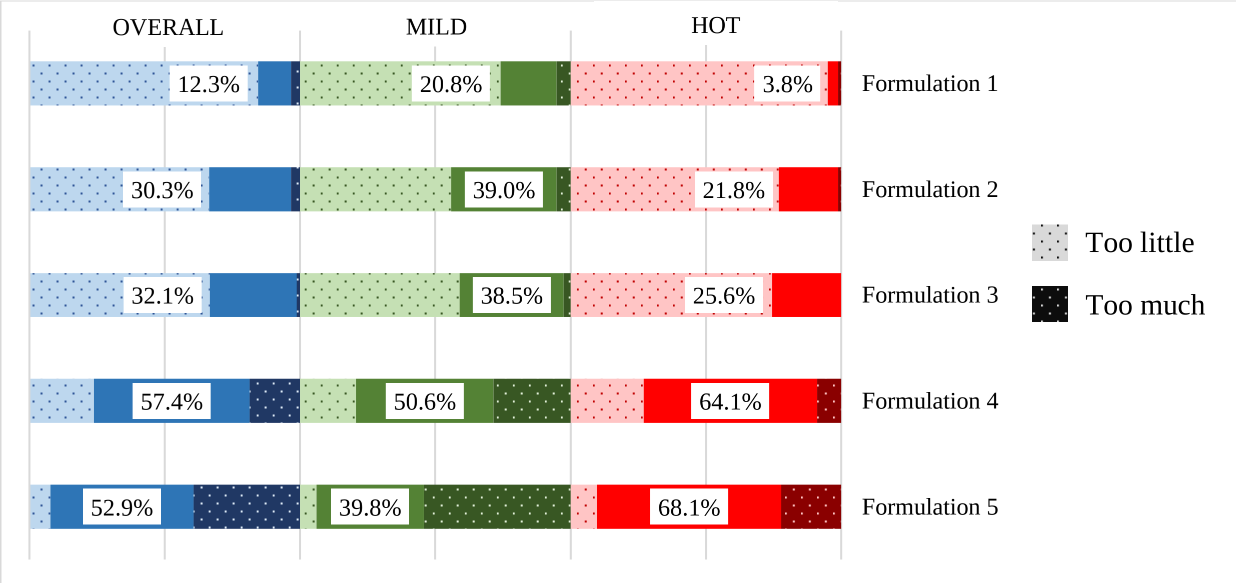

Figure 2.5: Segmented results for just-about-right (JAR) question percentages for spiciness of hot pepper cheese (HPC) consumers. Consumers were asked to evaluate cheese spiciness/hotness attribute on a 5-point scale where 1 and 2=not spicy/hot enough, 3= JAR, and 4 and 5= too spicy/hot. Percentages represent percent of consumers in each group (overall n=196, mild consumers n=98, hot consumers n=98) that indicated the sample was JAR

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CHAPTER 3:

CONSUMER PERCEPTION OF CHEDDAR CHEESE COLOR

Consumer perception of Cheddar cheese color

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INTEPRETIVE SUMMARY

Consumers conceptually preferred light orange color in Cheddar cheese over dark orange or white Cheddar cheese. Most Cheddar cheese consumers consider dark orange Cheddar to be the least natural, but a significant portion consider white Cheddar to be the least natural, which highlights an educational opportunity for the dairy industry. Consumers also associate orange color in Cheddar cheese with more "sharp" flavor.

ABSTRACT

The color of Cheddar cheese in the U.S. is influenced by many factors, primarily the amount of annatto added as a colorant. The U.S. FDA is currently reviewing its definition of the term "natural" on food labels, which may result in the use of colorants being restricted in natural cheeses. The objective of this study was to evaluate how consumers perceive Cheddar cheese color in order to better understand how changes to legislation surrounding colorants in natural Cheddar cheese may affect consumption. We were also interested in determining if a relationship exists between color and other perceived characteristics of Cheddar cheese. Two online surveys on Cheddar cheese color and flavor attributes (n=1226 and n=1183, respectively) were conducted, followed by a consumer acceptance test on six commercially available Cheddar cheeses (n=196). Overall, consumers preferred light orange color in Cheddar cheese over dark orange or white Cheddar cheese, but segmentation was observed for Cheddar color preference. Light orange Cheddar and white Cheddar were perceived as approximately equal in terms of "natural-ness." White and light orange Cheddars were perceived as more natural than dark orange Cheddars conceptually and in consumer acceptance testing. White Cheddar was considered most natural by 50.3% of n=1283 survey participants and 43.4% of n=196 consumer acceptance test participants, while light orange Cheddar was perceived as most natural by 40.6%

and 45.9% of these groups respectively. A bimodal distribution was observed in both the online survey and in consumer acceptance testing for "natural-ness" of Cheddar cheese color, with a subset of consumers (31.4% of n=1183 survey participants and 30.6% of n=196 consumer testing participants) indicating that white Cheddar was the least natural option. Consumers associated orange color in Cheddar cheese with more "sharp" flavor both in an online survey format and consumer acceptance testing.

INTRODUCTION

Consumer interest in "natural" products has been on the rise since the proliferation of the clean label movement in the early 2000s. The push for natural food products and clean ingredient labels emphasizes the elimination of ingredients and processes that are perceived as artificial or unfamiliar. It has been suggested that this desire for familiarity is a countermeasure to greater perceived distance between consumers and food manufacturers as a result of increasingly globalized food systems (Asioli et al., 2017). The term "natural" has been described as a "75 billion dollar word with no clear definition" as consumers increasingly desire natural foods, but the term "natural" is complex and lacks a clear definition from both a regulatory and consumer standpoint (Chambers et al., 2019). Consumers exhibit wide variation in the way they define "natural" foods and there is significant overlap between terms such as "sustainable," "healthy," and "natural." Some consumers define natural foods by their environmental impact and animal/worker welfare practices, while others evaluate the naturalness of foods in terms of the amount of processing and number of unfamiliar ingredients on the label (Schiano et al., 2020). In a 2015 survey conducted by Consumer Reports, 60 percent of respondents believed "natural" labels on foods meant that the product did not contain artificial colors/ingredients or genetically modified materials (Creswell, 2018).

The term “natural” is loosely defined by United States regulatory agencies, including the United States Department of Agriculture (**USDA**) and the United States Food and Drug Administration (**FDA**). The FDA states that “natural” foods are those that “nothing artificial or synthetic (including all color additives regardless of source) has been included in, or has been added to, a food that would not normally be expected to be in that food” (Center for Food Safety and Nutrition, 2018). By this definition, natural colorants would not be allowed in natural cheese. However, this definition of “natural” is informal and not currently enforced, allowing manufacturers who use natural colorants in their products to continue to label their products as “natural”. In November 2015, the FDA put out a call for consumer comments on use of the term “natural” for labeling on human food products and received 7,690 comments from consumers and companies by May 2016 (Creswell, 2018). These comments are still under review as the FDA considers appropriate next steps regarding “natural” labels. The FDA’s decision to enforce their original definition of “natural” as it pertains to labeling would result in significant changes to food manufacturers’ ability to refer to their products as “natural.”

This possible change in the definition of “natural” presents a problem for cheese manufacturers, as many natural cheeses in the United States are made using colorants, most notably Cheddar cheese. Cheddar cheese is one of the largest contributors to the natural cheese category in the United States, with 141.54 million Americans consuming Cheddar cheeses in 2020 (Statista Research Department, 2020). Natural cheese is defined as cheese that is made by coagulating milk, followed by draining, salting, and ripening. Cheddar cheese is defined by the FDA Code of Federal Regulations (**CFR**) in section §133.113. This definition specifies manufacture parameters for Cheddar cheese, including the steps used for manufacture of Cheddar cheese and a list of optional ingredients that may be added to Cheddar cheese. This includes clotting enzymes, calcium chloride, antimycotic agents and enzymes for flavoring, and colorants. At present, the FDA CFR does not address the use of colorants in Cheddar cheese other than stating that coloring may be used as an optional ingredient (Office of the Federal Register, 2021). Dairy products can exhibit some intrinsic yellow/orange coloration as a result of carotenoids from animal feed being transferred into milk. However, the traditional orange color of U.S. Cheddar cheeses is due to the addition of a natural colorant. The most common coloring agent for Cheddar cheese is an extract from the seeds of the annatto plant (*Bixa orellana)*, commonly referred to as annatto. Annatto consists of two carotenoids: bixin and norbixin (Kang et al., 2010). Norbixin is water-soluble and is used in aqueous extracts of annatto. Annatto, both powdered and in an aqueous extract, is an "exempt" color additive, a term which refers to colorants from natural sources. Exempt color additives still require FDA approval for use in food products but are exempt from certification provided they are used in amounts consistent with good manufacturing practices and are listed in the ingredient list of the final product (Center for Food Safety and Nutrition, 2017). If the strict definition of natural is enforced by the FDA, Cheddar cheese with added annatto colorant could not be called natural Cheddar cheese. In 2019, the USDA and the European Organic Certifiers Council approved the first organic certification for natural annatto color (Wyers, 2019). An organic annatto extract allows Cheddar cheese manufacturers to produce a colored Cheddar cheese that is labeled "organic", but if FDA guidelines regarding the definition of natural are enforced, this organic Cheddar cheese could not also be labeled "natural."

The FDA standard of identity for Cheddar cheese does not provide any definition regarding the sharpness of Cheddar cheese flavor or its labeling. The assignation of sharpness labels is therefore at the discretion of the manufacturer. Sharpness is not a defined sensory term and instead refers to the presence or absence of distinctive flavors and texture in Cheddar cheese that result from the process of aging. As such, a mild Cheddar label implies a younger cheese and a sharp Cheddar label implies an aged cheese. However, in the absence of a specific time designation such as “aged for 9 months”, a sharp or extra sharp label can be assigned to Cheddar cheese of any age. Drake et al. (2001) developed a sensory lexicon for Cheddar cheese, including aged flavors such as brothy, catty, and nutty and flavors typically found in younger cheeses such as diacetyl and whey flavor. As Cheddar cheeses age, a wide diversification of possible flavor profiles occurs due to the cascade of cheese ripening reactions that can occur. This includes glycolysis, lipolysis, and proteolysis that serve as a primary step in the degradation of milk constituents to produce flavor compounds (Singh et al., 2003). Consumers can generally differentiate mild and sharp Cheddar cheeses (Meals et al., 2020), but the wide variety of flavors and intensities create a diverse set of expectations (Drake et al., 2008, 2009). For mild Cheddar cheese, cooked/milky, whey, and brothy flavors and sour taste were identified as drivers of liking (Drake et al., 2008) while brothy and sulfur flavors were drivers of liking for sharp or aged Cheddar cheese (Drake et al., 2009).

Previous research has examined consumer perception of color in Cheddar cheeses. Wadhwani and McMahon (2011) studied consumer perception of low-fat Cheddar cheeses with varying levels of annatto added as a colorant and found that consumers preferred Cheddars with an intermediate amount of orange coloring, but consumer preference decreased as the color became too orange or too white. The role of color and perceived Cheddar sharpness was not investigated. Speight et al. (2019) evaluated consumer perception of Cheddar cheese shreds, including color, using qualitative and quantitative consumer research methods. A range of Cheddar cheese colors were represented in the survey using National Cheese Institute (**NCI**)

Cheese Color Standards NCI-1, NCI-6, NCI-8, and NCI-11 (National Cheese Institute, International Dairy Foods Association, Washington D.C.). Cheddar cheese shred color was one of the most important attributes of Cheddar cheese shreds, behind price and nutrition claims. NCI-6 returned the highest consumer utility and NCI-1 returned the lowest, indicating a consumer preference for light orange color in Cheddar cheese shreds (Speight et al., 2019). Meals et al. (2020) studied consumer drivers of liking for Cheddar cheese shreds and identified three distinct consumer clusters for Cheddar cheese shreds with distinct flavor and color preferences. One of these clusters consistently demonstrated preference for white Cheddar cheese shreds and sharp flavors, while other clusters valued other extrinsic characteristics such as shred size (Meals et al., 2020).

While previous studies have evaluated consumer preference for Cheddar cheese color, little to no research exists on how consumers perceive the "natural-ness" of Cheddar cheese color, or whether perceptual relationships exist between color and flavor attributes. Consumer understanding of Cheddar cheeses sharpness labels and their beliefs surrounding a relationship between color and sharpness have not been assessed. In addition, previous work has not established why consumers are drawn to certain Cheddar cheese colors and have lower preference for others. The purpose of this research was to more thoroughly evaluate consumer perception of Cheddar cheese color in order to better understand how changes in the use and labeling of colorants in Cheddar cheese would be perceived by American consumers.

MATERIALS AND METHODS

Experimental Overview

Two online surveys using ethnographic questions and Maximum Difference (**MaxDiff**) scaling were conducted. The surveys were spaced 2 months apart. Survey 1 was conducted to establish consumer familiarity with attributes of Cheddar cheese, including color, flavor, and sharpness, while the objective of survey 2 was to further explore consumer perception of Cheddar cheese color and sharpness specifically. Following completion of both surveys, descriptive analysis and a consumer acceptance test were conducted using six different Cheddar cheeses (white and orange Cheddar, young and aged) to evaluate consumer perception of Cheddar cheese color and the relationship between color and Cheddar cheese flavor intensity (sharpness).

Participants

All testing was conducted in compliance with North Carolina State University Institutional Review Board (**NCSU IRB**) regulations. All participants were contacted using an online database of >10,000 consumers from the greater Raleigh/Durham/Chapel Hill, NC area maintained by the Sensory Service Center at North Carolina State University (**SSC**). Consumers who reported that they did not have any food allergies, intolerances, or dietary restrictions, and who purchased and consumed Cheddar cheese could qualify for this study. Additional qualification criteria for the surveys and consumer acceptance tests are subsequently specified.

Online Surveys

Survey 1

The objective of Survey 1 was to establish a baseline of consumer familiarity with attributes of Cheddar cheese, including color, flavor, and sharpness. The online survey was developed using Lighthouse Studio (Sawtooth Software version 9.8.1, Orem, UT). The survey was uploaded to a database maintained by the SSC, which consists of over 10,000 consumers. Participants who were 18 years of age or older were able to enter the survey (n=1451).

Participants who indicated that they purchased Cheddar cheese and were at least somewhat familiar with different colors of Cheddar cheese (n=1226) completed two MaxDiff exercises. Familiarity was measured on a 5-point scale where 1= completely unfamiliar, 3 = neither familiar nor unfamiliar, and 5 = completely familiar.

The first MaxDiff exercise consisted of 15 different purchase factors for Cheddar cheese, including both extrinsic qualities such as packaging material and an all-natural label, and intrinsic factors such as flavor and color of the cheese. Respondents were asked to indicate which item was "Most Important" and which item was "Least Important" from a list of attributes. Each respondent completed ten sets of best-worst questions with five items in each set. These questions were asked to evaluate which attributes consumers placed the most importance on when selecting a Cheddar cheese and to gain a better understanding of the role of Cheddar cheese color in purchase decisions.

The second MaxDiff exercise consisted of 11 different Cheddar cheese colors ranging from white to dark orange. Color choices were taken from the National Cheese Institute (**NCI**) Cheese Color Standard (National Cheese Institute, International Dairy Foods Association, Washington D.C.). Consumers were asked to select which color was "Most Appealing" and which was "Least Appealing" for Cheddar cheese that they purchased in a series of eight sets of best-worst questions with five color choices per set. This exercise was done to evaluate consumer opinions on a range of possible Cheddar cheese colors.

A series of agree/disagree questions were included at the end of Survey 1 to cross-validate results from earlier survey sections and assess consumer attitudes toward Cheddar cheese characteristics. A 5-point agree/disagree scale was used where 1 and 2 = disagree, 3 = neither agree nor disagree, and 4 and 5 = agree. In addition, consumers were asked to indicate their purchase preference for Cheddar cheese color using a 5-point scale where 1= “I strongly prefer to buy orange Cheddar cheese”, 3= “I do not have a preference” and 5= “I strongly prefer to buy White Cheddar cheese”.

Survey 2

A second online survey was developed using Lighthouse Studio (Sawtooth Software version 9.8.1, Orem, UT) as a means of cross-validating the results regarding Cheddar cheese color and flavor intensity (sharpness) from Survey 1. This second survey was also uploaded to the Sensory Service Center database of over 10,000 consumers. Participants who were 18 years of age or older were able to enter the survey (n=1283). Participants who indicated that they purchased Cheddar cheese (n=1183) completed a series of questions that assessed Cheddar cheese color expectations using the same 11 Cheddar cheese colors implemented in Survey 1. Participants in Survey 2 were first asked to indicate which type of Cheddar cheese (Mild, Medium, Sharp, or Extra Sharp) they purchased most often. Consumers were then asked to indicate which of the 11 colors best represented Cheddar cheeses of different sharpness levels (mild, medium, and sharp), which color best represented Cheddar cheese with the least/most flavor, which color best represented Cheddar cheese that would be the most/least sharp, and which color was the most/least natural. Consumers also answered a series of agreement questions specifically about Cheddar cheese color, including “The color of Cheddar cheese indicates how much flavor the cheese has” and “The color of Cheddar cheese indicates how sharp the cheese is.” These exercises were done to further elucidate consumer trends regarding Cheddar cheese color and sharpness observed in Survey 1.

Evaluation of Cheddar cheeses

Following completion of the two surveys, commercially available national or regional brand Cheddar cheeses were screened to select cheeses for consumer testing. Cheeses were evaluated by two highly experienced and trained cheese experts (each with > 1000 h experience with sensory profiling of Cheddar cheese) to identify cheeses that represented a range of color categories of Cheddar (dark orange, light orange, and white) and flavor profiles (young/mild flavors: mild/medium label and aged flavors: sharp/extra sharp label). A total of six commercial Cheddar cheeses (dark orange Cheddar Cheese (aged flavor), dark orange medium label Cheddar Cheese (mild/medium flavor), light orange Cheddar (mild/medium flavor), light orange Cheddar (aged flavor), white Cheddar (mild/medium flavor), and white Cheddar (aged flavor) were selected for consumer testing. Cheeses were provided in duplicate 4.5 kg lots directly from the manufacturer or purchased from grocery stores in the Raleigh, NC (4.5 kg from different lots). These cheeses were selected to represent a range of commercial Cheddar cheese colors and flavor profiles.

Descriptive Analysis

Seven trained panelists (5 females, 2 males, ages 22-54 y) each with at least 60 h of previous experience with the descriptive analysis of Cheddar cheese flavor evaluated cheeses from each lot in duplicate. An established lexicon for Cheddar cheese (Drake et al., 2001) was applied using a 0 to 15 point universal intensity scale consistent with the Spectrum™ descriptive analysis method (Meilgaard et al., 2007). Each cheese was cut into a 3 cm cube and placed into a lidded 60 mL soufflé cup with a randomly generated 3-digit code and tempered to 15°C. Samples were prepared with overhead lights off to prevent light oxidation. Paper ballots were used for data collection. Each panelist evaluated each lot in duplicate in separate sessions.

Color Assessment

Each of the six cheeses used in consumer testing were evaluated using a handheld colorimeter to instrumentally assess differences in color (Chroma Meter CR-410; Konica Minolta Sensing; Tokyo, Japan). Colors were assessed using the CIELAB color space where L* indicates lightness and a* and b* are chromaticity coordinates that indicate color direction. a* illustrates where the color reading lies on a red/green axis, while b* indicates where the color reading falls on a yellow/blue axis. (Konica Minolta, Tokyo, Japan). Measurements were taken in triplicate for each cheese and the colorimeter was calibrated prior to use. Calibration was performed using the white calibration plate provided by Konica Minolta. An observer angle of 10^{o} was used for all measurements.

For color assessment during consumer testing, participants were provided with a printed paper color standard card that displayed 11 Cheddar cheese color chips labeled with numbers 1-11, analogous to the NCI Cheese Color standards (National Cheese Institute, International Dairy Foods Association, Washington D.C.) The NCI standards utilize the Munsell color system, which uses three values (hue, value and chroma) to assign colors to numeric categories (Munsell, Grand Rapids, MI). In order to most accurately capture the colors used in the NCI standards, Munsell values were converted to RBG values in order to create a color standard card using Adobe Illustrator (Adobe, San Jose, CA).

Consumer Testing

A consumer acceptance test modified for COVID-19 safety was conducted in October 2020 using consumers recruited from the database maintained by the SSC. Consumers aged 18-64 y that purchased and consumed Cheddar cheese at least once a month were recruited. Data was collected using an electronic ballot using Compusense Cloud software (Compusense Inc., Guelph, Canada). Consumers were provided with each of the six cheeses described above. Each cheese was cut into a 3 cm cube and placed into a lidded 60 mL soufflé cup with a randomly generated 3-digit code. Samples were prepared with overhead lights off to prevent light oxidation. For this test, qualified consumers picked up a thermal bag (ULINE, Pleasant Prairie, WI) with coded samples, a Ziploc® bag of unsalted saltines, typed instructions including the color card described in the previous section, and a commercial bottle of spring water. Consumers were instructed to take the samples home and then to click on the provided hyperlink to conduct the test within 4 h of pickup.

Once consumers clicked on the ballot link and initiated the test, before tasting, participants were asked to complete a set of questions using the provided color standards card. Participants were asked to identify the color on the card that looked the most like the color of the Cheddar cheese they typically purchased, the color that looked the most natural, and the color that looked the least natural before tasting any samples. Consumers then proceeded to evaluate cheeses monadically. For each cheese, consumers were first asked to evaluate color liking (no tasting) followed by overall liking on a 9-point hedonic scale where 1= dislike extremely and 9=like extremely. Just-about-right **(JAR)** questions were asked for flavor intensity where 1= not nearly enough flavor and 5= much too much flavor and sharpness where 1=not nearly sharp enough and 5=much too sharp. Participants were also asked to rate the sharpness of each cheese before and after tasting using the scale 1= mild, 2= medium, 2= sharp, and 4= extra sharp. Samples were presented in a Williams design to counteract order effects. Participants were required to rest for three minutes and cleanse their palates with unsalted crackers between cheeses. After completing the test, participants were compensated with a $20 gift card to a local store.

Statistical Analysis

MaxDiff scores from Survey 1 were evaluated using hierarchical Bayesian (**HB**) regression using Lighthouse Studio (Sawtooth Software, Version 9.8.0, Orem, UT). All other analyses were performed with XLSTAT (version 2019.3.1, Addinsoft, Boston, USA) at 95% confidence ($p<0.05$). Cluster analysis of individual importance scores was performed using Euclidean distances and Wards linkage to categorize respondents with similar answers into separate groups. Analysis of variance (**ANOVA**) with means separation performed using Fisher’s LSD with Bonferroni correction was performed on the trained panel attribute intensities and consumer liking data. Consumer JAR questions were analyzed with penalty analysis and chi squared analysis with the Marasculio procedure for multiple comparisons.

RESULTS AND DISCUSSION

Participant Demographics

A total of n=1226 Cheddar cheese consumers responded to Survey 1. A majority (75%) of participants were female and 25% were male. Survey participants represented a wide distribution of ages, with 24% of respondents aged 18-24 years old, 25% of respondents aged 25-34 years old, 18% of respondents aged 35-44 years old, 14% of respondents aged 45-54 years old and 17% of respondents aged 55-64 years old or older. Survey 1 participants indicated minimal familiarity with different manufacturing regions of Cheddar cheese but were more familiar with Cheddar cheese colors, brands, and sharpness labels (**Table 1**).

A similar distribution of Cheddar cheese consumers participated in Survey 2 (n=1183). A majority (73%) of Survey 2 respondents were female and 23% were male. Survey participants represented a range of ages, with 29% of respondents18-24 y, 22% of respondents aged 25-34 y, 16% 35-44 y, 12% 45-54 y and 18% aged 55-64 y. Participants were also asked to indicate the region of the United States they grew up in. Approximately half (56%) of participants grew up in the Southeastern U.S., 6% grew up in the Western U.S., 2% grew up in the Southwestern U.S., 12% grew up in the Midwestern U.S., 16% grew up in the Northeastern U.S. and 8% grew up outside of the U.S. (internationally). Survey 2 participants also showed a variety of Cheddar purchase habits, with 19% of consumers choosing mild, 18% medium, 46% sharp, and 18% extra sharp when asked to select which type of Cheddar cheese they purchased most often.

Participants in consumer acceptance testing were 45% male and 55% female (n=196). Participants in consumer testing represented a similar range of ages to that from the surveys with consumers 18-64 y. Consumers also represented a range of Cheddar purchase habits, with most participants indicating that they purchased multiple types of Cheddar cheese. When asked which type of Cheddar cheese they purchased most often, 13% of participants indicated mild Cheddar, 29% indicated medium Cheddar, 49% indicated sharp Cheddar, and 9% indicated extra sharp Cheddar, similar to the distribution seen in Survey 2.

Consumer Preferences for Cheddar Cheese Color

In all three phases of this study, consumers displayed an overall preference for at least some orange color in Cheddar cheese (**Table 2, Figure 1**). Based on color MaxDiff scores from Survey 1, consumers overall preferred light orange Cheddar cheeses over other Cheddar color options, and preferred dark orange Cheddar cheeses over white Cheddar cheeses (**Figure 1**). NCI

Color 4 received the lowest average score (4.06), while NCI Color 8 received the highest average score (14.68). Preference for NCI Color 1 was higher than NCI Colors 2-4, but lower than NCI Colors 5-11, indicating that a subset of consumers preferred white Cheddar cheese. Color preference generally increased with increasing orange color saturation until Color 8, but decreased again as orange color saturation increased past NCI Color 8, indicating that an optimal point was reached at NCI Color 8. This optimal point varied slightly from previous results with Cheddar cheese shreds in which consumers preferred NCI Color 6 for Cheddar cheese shreds (Speight et al., 2019). However, the trends seen in these MaxDiff results are supported by previous work with block Cheddar cheese (Wadhwani and McMahon, 2012), who observed that consumer liking of Cheddar cheese color was lower for lighter-colored cheeses and very dark orange cheeses and higher for moderately orange Cheddar cheeses. A similar trend was observed by Meals et al. (2020) in which consumers returned the lowest liking scores for white and light yellow/orange Cheddar cheese shreds that were perceived as too light on a 5-point JAR scale.

Three distinct consumer clusters for Cheddar color were identified from survey 1 Color MaxDiff scores (**Figure 2**). Color Cluster 1, designated the Light Orange cluster, (n=309) exhibited a preference for moderate/light orange Cheddar cheeses, with preference increasing as orange color saturation increased until an optimal point was reached at Color 8, after which preference began to decrease. The Light Orange cluster also returned the lowest preference for white Cheddar cheese out of the three identified clusters. Color Cluster 2, designated the White Cheddar cluster, (n=315) showed a strong preference for white Cheddar cheese, with the optimal point at Color 1 and preference consistently decreasing as orange color saturation increased. Cluster 3, designated the Dark Orange cluster, (n=601) was the largest identified cluster. Consumers in this group displayed consistently increasing preference for Cheddar cheese color as orange color saturation increased, with the lowest preference for Color 1 and an optimal point at Color 10. NCI Colors 6 and 7 were the only options acceptable (MaxDiff score above 0) to all three consumer clusters, which supports the supposition that light orange Cheddar is preferred by consumers overall. Questions at the end of Survey 1 provided further evidence that consumers preferred at least some orange color in Cheddar cheese, with 58.3% of survey participants indicating they prefer to purchase orange Cheddar, 20.0% indicating no preference, and 21.7% indicating they prefer to purchase white Cheddar (**Table 2**).

In consumer testing of commercially available Cheddar cheeses, white Cheddar cheeses received the lowest color liking scores, while dark orange Cheddars received the highest color liking (**Appendix Table 1**). Dark orange sharp Cheddar received the highest color liking score, but scored at parity with dark orange medium Cheddar and light orange medium Cheddar (**Appendix Table 1**). These results collectively demonstrate that most consumers prefer at least some orange color in Cheddar cheese. Survey 1 identified NCI Color 8 as an optimal point for consumers overall, but NCI Colors 6 and 7 were found to be acceptable to a wider range of consumers, including those who prefer white Cheddar, light orange Cheddar, and dark orange Cheddar.

Perception of Cheddar Cheese Color and "Natural-ness"

Results from the purchase factor MaxDiff in Survey 1 indicated that flavor, sharpness, and price were the most valued attributes of Cheddar cheese (**Figure 3**). This result is in alignment with the findings of Speight et al. (2019) and Meals et al. (2020) who reported that price and flavor and sharpness of Cheddar cheese shreds were most important to consumers for purchase. In the current study, all-natural labeling and Cheddar cheese color were ranked 5th and

6th respectively out of a list of 15 items in the exercise. This suggests that color and "natural-ness" are less important than intrinsic characteristics such as flavor and sharpness, but are more important than factors such as region or country of origin and other packaging attributes. Cheddar cheese color received a significantly lower average MaxDiff score than an all-natural label, which indicates that overall consumers place more importance on an all-natural label on Cheddar cheese than on the color of the cheese itself. However, survey respondents also indicated unfamiliarity with where Cheddar cheese color comes from (1.8 on a 4-point scale where 1=very unfamiliar and 4=very familiar) **(Table 1)**. All-natural labels have been shown to support consumer desire for familiarity, which may help to explain why Cheddar cheese consumers value these labels over a less familiar subject such as cheese color.

Agree/disagree questions from Survey 1 indicated that consumers believe white Cheddar cheese is more natural and artisanal than orange Cheddar cheese (**Table 3**). These results were supported by agree/disagree questions asked during Survey 2 (**Table 4**) and consumer acceptance testing (**Table 5**), where consumers indicated that white Cheddar cheese or the color of white Cheddar cheese is more natural than orange Cheddar or the color of orange Cheddar. Other questions from Survey 1 and Survey 2 provide further information regarding consumer perception of naturalness as it related to Cheddar cheese color. Survey 1 participants were asked to select which factors they thought influenced the color of Cheddar cheese in a check-all-that-apply (**CATA**) format. Seventy eight percent of survey respondents indicated artificial pigment/colorants influenced Cheddar color, while 56% of respondents thought that natural pigment/colorants impacted color and 36% of respondents indicated that dairy cow feed influenced Cheddar color (results not shown). Survey 2 participants generally agreed with the statements "White Cheddar cheese is made with natural color" and "Orange Cheddar cheese is made with artificial color” but returned a neutral response for the statement “Orange Cheddar cheese is made with natural color” and disagreed with the statement “White Cheddar cheese is made with artificial color” (Table 4). Similar results were observed by Schiano and Drake (2021) in an online survey with n=1210 dairy product consumers. Over 50% of consumers in that study indicated that Cheddar cheese contained natural color but about 40% indicated that it contained artificial color. Consumers in general understand that orange Cheddar cheese is made with added color, but are unsure whether the colorant is natural or artificial. This result may help to explain why consumers indicated low familiarity with where Cheddar cheese color comes from (discussed earlier).

In both Survey 2 and consumer acceptance testing, consumers were asked to select which NCI color standard represented Cheddar cheese that was the most natural and least natural. Both exercises returned a similar bimodal distribution (**Figure 4**). White Cheddar cheese (NCI Colors 1-4) was selected as most natural by 50.3% of participants in Survey 2 and 43.4% of consumers in acceptance testing. Light orange Cheddar cheese (NCI Colors 5-8) was selected as most natural by 40.6% of survey participants and 45.9% of consumer testing participants. Dark orange Cheddar (NCI Colors 9-11) was selected as most natural by 9.1% of survey participants and 10.7% of consumer testing participants. For least natural, dark orange Cheddars were selected by a large majority of Cheddar cheese consumers (69.3% and 67.3% from Survey 2 and consumer testing respectively), while white Cheddar was considered least natural by roughly one-third of participants in the two exercises (31.4% and 30.6% respectively). Most consumers consider white Cheddar and light orange Cheddar cheese to be most natural, but are divided between dark orange and white Cheddar when it comes to which cheeses are least natural. Light orange Cheddar was acceptable to a wide range of consumers. Comment data from Survey 1 (data not shown) indicated that this divide may be influenced by to the erroneous belief that white Cheddar cheese has been artificially bleached or lightened to achieve a lighter color. The statement “White Cheddar cheese is made by artificially lightening or bleaching orange Cheddar cheese” was included in Survey 2 to further explore this trend. Twenty-five percent of respondents strongly disagreed with this statement, 30.6% somewhat disagreed, 31.7% were neutral or unsure, 10.6% somewhat agreed, and 1.7% strongly agreed (data not shown). This distribution of responses indicates that a majority of Cheddar cheese consumers are confused about or unsure of how white Cheddar cheese is related to orange Cheddar, which may help to explain the trends seen in this study.

Consumer responses to NCI color standard questions from Survey 2 were clustered to further illustrate differences in color and perception of natural. Three different clusters of Cheddar cheese consumers were identified. Response distributions for each cluster illustrate differences in perception of “natural-ness” among Cheddar cheese consumers (**Figure 5**). Cluster 1 consumers indicated NCI Color 4 (y=3.69) was the most natural and NCI Color 11 (y=10.75) was the least natural. Cluster 2 consumers indicated that NCI 7 (y=7.08) was the most natural and NCI 2 (y=2.13) was the least natural and Cluster 3 consumers selected NCI 3 (y=2.82) as most natural, while NCI 9 (y=9.20) was least natural. Further differences among these clusters are discussed in the next section.

While differences were observed between white and orange Cheddar in terms of “natural-ness,” both white Cheddar and orange Cheddar were perceived as healthy in Survey 1 and in consumer acceptance testing **(Table 3, Table 5).** Schiano et al. (2020) reported that consumers display cognitive overlap between the terms sustainable, natural, and healthy but apply these terms distinctly when considering dairy products. Consumers disagreed with both the statement

“White Cheddar cheese is healthier than orange Cheddar cheese” and the statement “Orange Cheddar cheese is healthier than white Cheddar cheese” indicating that perception of healthiness for orange and white Cheddar cheese is not different in the mind of the consumer, and that consumers do not relate color to healthiness **(Table 3, Table 5).**

Evidence from this study suggests that consumers value all-natural labels and color of Cheddar cheese while making purchase decisions and perceive white and light orange Cheddars as natural. However, their understanding of the “natural-ness” of Cheddar cheese color is limited by unfamiliarity with where differences in color come from. This issue highlights an opportunity for the dairy industry to educate Cheddar cheese consumers on white and orange Cheddar cheese to support natural perception of these products. Color does seem to affect consumer perception of “natural-ness” but does not affect perception of healthiness of Cheddar cheese. This evaluation of consumer beliefs surrounding Cheddar cheese color and flavor illustrates the potential ramifications of limiting the use of colorants in Cheddar cheese. Removing or changing the colorants used in Cheddar cheese may affect consumer purchase behaviors and acceptance of these products.

Perceptual Relationship between Cheddar Cheese Color and Flavor

Cheddar color affects consumer perception of cheese flavor and sharpness from all three phases of this study. Survey 1 respondents on average agreed with the statements “White and orange Cheddar cheese have different flavors” and “The color of Cheddar cheese indicates the flavor intensity (mild/medium/sharp)” but returned an overall neutral score for statements surrounding aged Cheddar flavor and Cheddar cheese color (**Table 3**). Consumers perceive a flavor difference between orange and white Cheddar, but are unsure if differences in flavor intensity are the same as differences in aged Cheddar flavor.

From Survey 2, consumers selected different optimal color points for each sharpness label and the distribution of responses for each NCI Cheddar cheese color was distinct. Responses for mild Cheddar were approximately normally distributed with a center at NCI Color 6 (**Figure 6**). Responses for medium Cheddar cheese were bimodally distributed with peaks at NCI Color 6 and NCI Color 8 and a slight skew toward the darker orange colors. Responses for sharp Cheddar cheese were strongly skewed toward dark orange with a peak in response frequency at NCI Color 10. However, response frequency decreased after NCI Color 10, which indicates that this color standard may be an optimal point for sharp Cheddar cheese. The overall differences in response distribution shape and center illustrate that consumers believe increasing orange color saturation corresponds with increasing sharp flavor in Cheddar cheese. Response distribution from color expectation questions also indicated that consumers generally conflated sharpness with flavor intensity (**Figure 7**). NCI Color 1 received the highest overall frequency of responses for “least sharp” and “least intense flavor” out of the provided color options. In contrast, NCI Color 11 received the highest frequency of responses for “sharpest” and “most intense flavor.” However, a small subset of consumers (approximately 130 out of 1183) indicated the opposite response, indicating NCI Color 1 would be the sharpest and have the most intense flavor. This trend may be attributed to consumer familiarity with sharp white Cheddar such as those produced in the Northeastern United States. Regionality of Cheddar cheese color and flavor is further discussed later in this section.

Consumer purchase habits of Cheddar cheese (survey 2) influenced their perception of Cheddar flavor and color (**Figure 5**). Cluster 1 consumers thought that NCI 9 represented the sharpest Cheddar with the most flavor (y= 9.31 and y=9.42 respectively). Cluster 2 consumers displayed distinct preferences and expectations for dark orange Cheddar, with NCI Color 10 (y=9.77) being the most flavorful and Color 11 (y=10.59) being the sharpest. Both Cluster 1 and Cluster 2 indicated that mild, medium, and sharp Cheddar are differentiated by increasing orange color. In contrast, Cluster 3 consumers showed clear preferences and expectations for white Cheddar cheese. This group also did not perceive color differences between mild, medium, and sharp Cheddar, indicating that Cheddar of all three types would be NCI Color 5 (y=5.04, 5.50 and 5.23 respectively). Cluster 3 consumers considered NCI Color 4 to be the most flavorful and the sharpest (y=4.13 and y=4.54 respectively).

Consumer acceptance testing also provided further evidence for the perceptual relationship between sharpness and Cheddar cheese color. Trained panelists confirmed that flavor differences were present among Cheddar cheeses selected for use in consumer testing **(Table 6).** Consumers were able to detect visual differences among Cheddar cheeses and were able to effectively describe variation among cheeses using the provided color card (**Figure 8**). Taste test participants were asked to evaluate sharpness of Cheddar cheeses based solely on color/appearance (perceived sharpness before tasting) and on flavor (actual sharpness after tasting) **(Table 7).** Medium cheeses consistently received lower flavor sharpness scores than sharp cheeses in this study, indicating that consumers are able to differentiate between different Cheddar cheeses sharpness levels, consistent with previous studies (Wadhwani and McMahon, 2012; Meals et al., 2020). Dark orange Cheddars received the highest perceived sharpness (based on appearance only) scores and white Cheddars received the lowest. Perceived sharpness scores (based on appearance) were significantly higher than actual sharpness scores (after tasting) for dark orange medium Cheddar ($p<0.05$), but were not significantly different for dark orange sharp

Cheddar ($p>0.05$), supporting the conclusion that consumers expect dark orange Cheddar to have more sharp Cheddar flavor.

Based on overall liking scores, consumers preferred the dark orange sharp Cheddar cheese, which was characterized by sulfur and brothy flavors with a low intensity of free fatty acid flavor (**Table 6**). Drake et al. (2009) reported that brothy and sulfur flavors were preferred flavors for sharp Cheddar cheeses. In contrast, consumers were less accepting of the white extra sharp Cheddar, which was characterized by fruity, nutty, sulfur, and catty flavors. Sixty percent of participating consumers indicated that this cheese was too sharp by sharpness JAR score and this cheese was penalized for being too sharp (results not shown). All of the medium Cheddar cheeses tested were perceived as not sharp enough but penalties in liking for being "not sharp enough" were lower than the penalties for being "too sharp" (results not shown). Consumers in this study were more accepting of Cheddar cheeses that were perceived as too mild than too sharp. Wadhwani and McMahon (2012) also asked consumers to rate Cheddar cheese sharpness on a 5-point JAR scale for both commercially available full-fat Cheddar cheeses and reduced-fat prototype Cheddars. Penalty analysis results were not reported, but the prototype Cheddar that returned the lowest sharpness JAR score received one of the highest overall liking scores and an overall flavor JAR score of 3.1 on a 5-point JAR scale, indicating that while consumers perceived this cheese as not sharp enough, it was still liked and accepted. No cheeses in their study were perceived as too sharp. Sharp and extra sharp Cheddar cheeses used for consumer testing in this study displayed a range of aged Cheddar flavors, including sulfur, fruity, and catty which may have contributed to consumer perception of sharpness (**Table 6**).

Cheddar Cheese Consumers and Color Perception

Regionality of U.S. Cheddar cheese consumers and their purchase behavior also affected perception of Cheddar cheese color. Survey 1 participants disagreed with statements regarding relationships between extrinsic Cheddar attributes and Cheddar cheese color factors such as "The color of Cheddar cheese indicates what region of the U.S. it is from/manufactured in" **(Table 3).** However, consumers also indicated the lowest familiarity with different regions where Cheddar cheese is made (2.3 on a 5-point scale where 1=completely unfamiliar and 5=completely familiar) **(Table 1)** and region-related attributes (Made Locally, Made in the United States, and Made Internationally) were ranked 9th, 11th, and 15th in the Purchase Factors MaxDiff exercise from Survey 1 (**Figure 3)**. When asked to guess which brands of Cheddar cheese were made in which region of the world, 36.8% of n=1226 consumers guessed correctly and 63.2% guessed incorrectly (data not shown). Most consumers do not understand or place value on regionality of Cheddar cheese, which may be why they disagree that Cheddar cheese color indicates region of origin (**Table 3**). Historically, some color differences have been observed in Cheddar cheeses manufactured in different regions of the United States, with many Cheddars from Vermont being white in color, while Cheddars from Wisconsin are more typically orange (Aubrey, 2013).

With this understanding of consumer unfamiliarity with regional differences between Cheddar cheeses (Survey 1), we investigated if consumers that originated from (grew up in) different parts of the U.S. perceived Cheddar color differently. Participants in Survey 2 were asked to indicate the U.S state they grew up in. Responses were then categorized into different regions of origin for analysis. Significant differences in Cheddar cheese color perception were documented based on region the consumer was from (**Table 8**). All regional groups indicated that orange color increased when going from mild to medium to sharp Cheddar. Consumers who were born outside of the United States, designated “International” consumers, expected Cheddar cheese to be lighter in color than other groups, and indicated that the cheese they ate as children was lighter in color. Most Cheddar cheeses made outside of the U.S. do not include colorants which is consistent with international consumer perception of Cheddar color. Consumers who grew up in the Western U.S. indicated the darkest average color for Cheddar cheese they would expect to be the “sharpest” while consumers from the Northeastern U.S. indicated the lightest color for this attribute on average. Cheddar cheese made in the Northeast U.S. is most commonly white in color, which may contribute to differences in perception for Northeast consumers.

Consumer purchase habits for Cheddar cheese also affected their perception of Cheddar cheese color. Survey 2 respondents were asked to indicate which sharpness level of Cheddar cheese they purchased most often, and their responses were used to create purchase groups for analysis **(Table 9).** Similar to the results seen in regionality analysis, all purchase groups indicated that orange color increased when going from mild to medium to sharp Cheddar. Extra sharp consumers expected Cheddar cheese to be lighter in color than other groups and returned a lower color score for sharpest and most flavorful ($y=7.50$ and $y=7.13$ respectively). Survey participants from the Northeastern U.S. were more likely to purchase extra sharp Cheddar ($p<0.05$) than participants from other regions. As discussed previously, white Cheddar cheese prevalence in the Northeast U.S. may have contributed to differences in perception.

CONCLUSIONS

Consumer perception of Cheddar cheese is influenced by the color of the cheese. Consumers value all-natural labeling over Cheddar cheese color when making purchase decisions. Consumers also agreed that white Cheddar cheese is natural, but were neutral or disagreed that orange Cheddar is natural. However, in all three phases of this study, consumers displayed an overall preference for at least some orange color in Cheddar cheese. Color preference generally increased with increasing orange color saturation until NCI Color 8, but decreased again as orange color saturation increased past this point, indicating that an optimal point was reached at NCI Color 8. This indicates that while consumers view white Cheddar as more natural than orange, they prefer to purchase orange Cheddar cheese overall. A subset of the consumer population prefers white Cheddars. This study is limited in that participants in consumer testing were all located in the state of North Carolina and results observed during testing may not be the same for consumers in other areas. In addition, only consumers who indicated they purchase Cheddar cheese participated in this study. Consumers who do not purchase Cheddar cheese may perceive its color and "natural-ness" differently. The trends observed in this study provide further context to the potential ramifications of altering regulations regarding natural labeling and Cheddar cheese.

Table 3.1: Familiarity scores for Cheddar cheese attributes from Survey 1 (n=1226).

Subject	Familiarity Score
Different **sharpness levels** of Cheddar cheese	3.8
Different **colors** of Cheddar cheese	3.7
Different **regions** where Cheddar cheese is made	2.3
Different **brands** of Cheddar cheese	3.4
Cheese color source	1.8

Familiarity was scored on a 5-point scale where 1=completely unfamiliar, 3= neither familiar or unfamiliar, and 5=completely familiar.

Table 3.2: Consumer response distribution from Cheddar cheese color preference question in Survey 1 (n=1226).

Statement	Frequency of Selection
I strongly prefer to buy orange Cheddar cheese.	29.7%
I slightly prefer to buy orange Cheddar cheese.	28.6%
I do not have a preference.	20.0%
I slightly prefer to buy white Cheddar cheese.	12.6%
I strongly prefer to buy white Cheddar cheese.	9.1%

A 5-point agree/disagree scale was used where 1= "I strongly prefer to buy orange Cheddar cheese", 3= "I do not have a preference" and 5= "I strongly prefer to buy White Cheddar cheese".

Table 3.3: Mean consumer responses to agree/disagree questions regarding Cheddar cheese attributes from Survey 1 (n=1226).

Statement	Mean AD Score	Category
White and orange Cheddar cheese have different flavors.	3.6^{a}	Agree
White Cheddar cheese is healthy.	3.6^{a}	
White Cheddar cheese is natural.	3.5^{a}	
Orange Cheddar cheese is healthy.	3.4^{b}	
The color of Cheddar cheese indicates the flavor intensity (mild/medium/sharp)	3.3^{bc}	
White Cheddar cheese is artisanal.	3.2^{c}	
White Cheddar cheese is healthier than orange Cheddar cheese.	3.0^{d}	Neutral
Orange Cheddar cheese is natural.	3.0^{d}	
White Cheddar cheese has more aged Cheddar flavor.	3.0^{d}	
Orange Cheddar cheese has more aged Cheddar flavor.	2.9^{d}	
Orange Cheddar cheese is artisanal.	2.7^{e}	Disagree
The color of Cheddar cheese indicates what region of the U.S. it is from/manufactured in	2.5^{f}	
The color of Cheddar cheese indicates what country it is from/manufactured in	2.4^{f}	
The color of Cheddar cheese indicates if it is organic.	2.2^{g}	

A 5-point agree/disagree scale was used where 1= completely disagree and 5= completely agree. Different letters indicate differences ($p<0.05$).

Table 3.4: Mean consumer responses to agree/disagree questions from Survey 2 (n=1183).

Statement	Mean AD Score	Category
Sharp Cheddar cheese tastes different than mild Cheddar cheese.	4.7^{a}	Agree
The sharpness label on a Cheddar cheese label indicates how intense the flavor of the cheese will be.	4.3^{b}	
The sharpness of Cheddar cheese indicates how long the cheese has been aged.	3.8^{c}	
The sharpness of Cheddar cheese is always related to how long the cheese is aged.	3.7^{c}	
White Cheddar cheese and orange Cheddar cheese taste different.	3.7^{c}	
White Cheddar cheese is made with natural color.	3.5^{d}	
Orange Cheddar cheese is made with artificial color.	3.5^{d}	
The color of Cheddar cheese indicates how sharp the cheese is.	3.3^{d}	
The color of Cheddar cheese indicates how much flavor the cheese has.	3.2^{e}	
The color of Cheddar cheese depends on how long it is aged.	3.1^{e}	
Orange Cheddar cheese is sharper than white Cheddar cheese.	3.1^{e}	Neutral
Orange Cheddar cheese is made with natural color.	3.0^{fg}	
The color of Cheddar cheese indicates what region it is manufactured in.	2.8^{gh}	Disagree
The color of Cheddar cheese indicates the quality of the cheese.	2.7^{h}	
White Cheddar cheese is sharper than orange Cheddar cheese.	2.7^{h}	
White Cheddar cheese is made with artificial color.	2.4^{i}	
White Cheddar cheese is made by artificially lightening or bleaching orange Cheddar cheese.	2.3^{i}	

A 5-point agree/disagree scale was used where 1= completely disagree and 5= completely agree. Different letters indicate differences ($p<0.05$).

Table 3.5: Mean consumer responses to agree/disagree questions from consumer acceptance testing (n=196).

Statement	Mean AD Score	Category
The sharpness label on Cheddar cheese tells you how intense the flavor of the cheese will be	4.1^{a}	Agree
White and orange Cheddar cheese have different flavors	3.6^{b}	
White Cheddar cheese is natural	3.5^{b}	
The color of Cheddar cheese indicates the flavor intensity (mild/medium/sharp)	3.0^{c}	Neutral
White Cheddar cheese has more aged Cheddar flavor than orange Cheddar cheese	2.9^{cd}	
The sharpness label on Cheddar cheese tells you how old the cheese is	2.9^{cd}	
In general, white Cheddar cheese and orange Cheddar cheese taste the same	2.7^{cde}	Disagree
White Cheddar cheese is healthier than orange Cheddar cheese	2.7^{cde}	
Orange Cheddar cheese is natural	2.6^{de}	
Orange Cheddar cheese has more aged Cheddar flavor than white Cheddar	2.5^{de}	
Orange Cheddar cheese is healthier than white Cheddar cheese	2.3^{e}	

A 5-point agree/disagree scale was used where 1= completely disagree and 5= completely agree. Different letters indicate differences ($p<0.05$).

Table 3.6: Trained panel flavor profiles of Cheddar cheeses used for consumer acceptance testing.

Sample	Cooked /milky	Whey	Diacetyl	Milk fat	Fruity	Sulfur	FFA	Brothy	Nutty	Catty	Sour	Bitter	Salty	Sweet	Umami	Sour
Dark Orange Medium	3.7^{a}	2.8^{a}	0.5	3.9^{a}	ND	1.8^{d}	ND	2.5^{d}	ND	ND	3.0^{a}	0.5^{c}	3.6^{c}	2.2^{b}	2.5^{c}	3.0^{a}
Dark Orange Sharp	3.0^{b}	1.0^{d}	ND	3.6^{b}	ND	2.8^{b}	1.7	3.0^{c}	ND	ND	2.7^{b}	0.7^{bc}	4.0^{b}	2.1^{b}	3.0^{b}	2.7^{b}
White Medium	3.9^{a}	2.4^{b}	ND	3.5^{b}	ND	1.2e	ND	1.8^{e}	ND	ND	2.6^{b}	1.0^{ab}	3.5^{c}	2.1^{b}	2.7^{c}	2.6^{b}
White Extra Sharp	3.1^{b}	ND	ND	3.5^{b}	ND	3.3^{a}	ND	3.4^{b}	1.0^{b}	1.9^{a}	2.5^{bc}	1.2^{a}	4.0^{b}	2.3^{b}	3.5^{a}	2.5^{bc}
Light Orange Medium	3.1^{b}	1.4^{c}	ND	3.5^{b}	ND	2.0^{c}	ND	2.7^{d}	1.1^{b}	ND	2.7^{b}	0.9^{b}	4.0^{b}	2.1^{b}	3.2^{b}	2.7^{b}
Light Orange Extra Sharp	3.1^{b}	ND	ND	3.5^{b}	1.2	3.0^{b}	ND	3.8^{a}	3.4^{a}	1.2^{b}	2.3^{c}	1.2^{a}	4.4^{a}	3.0^{a}	3.2^{b}	2.3^{c}

Cheese flavors were scored on a 0 to 15-point universal intensity scale (Spectrum method, (Meilgaard et al., 2007)) Flavors not listed were not detected in cheeses. Most cheese flavors fall between 0 and 5 (Drake, 2004). ND – not detected. Different letters following means indicate significant differences within a column ($p<0.05$)

Table 3.7: Comparison of sharpness perception in consumer acceptance testing (n=196).

Sample	Sharpness Score Before Tasting	Sharpness Score After Tasting	p-value	Conclusion
Dark Orange Medium	3.1	1.9	<0.001	perceived > actual
Dark Orange Sharp	2.7	2.7	0.44	perceived = actual
Light Orange Medium	2.1	1.8	<0.001	perceived > actual
Light Orange Extra Sharp	1.8	2.7	<0.001	perceived < actual
White Medium	2.0	1.9	0.67	perceived = actual
White Extra Sharp	2.0	3.3	<0.001	perceived < actual

*Significance determined using a paired t-test on means. Sharpness was scored on a 4-pt scale where 1=mild, 2=medium, 3= sharp, and 4=extra sharp. Data represents n=196 consumers

Table 3.8: Means of expected Cheddar cheese color questions by region the consumer grew up in (n=1183).

Region Grew Up	N=	Expect Cheddar to Be	Purchase Most Often	Mild Cheddar	Medium Cheddar	Sharp Cheddar	Sharpest	Least Sharp	Least Natural	Ate as Child
SE	668	7.8^{ab}	7.6^{a}	5.9^{a}	6.8^{a}	8.6^{a}	9.2^{a}	2.7^{b}	8.0^{abc}	7.6^{a}
W	71	7.7^{abc}	7.1^{ab}	5.7^{abc}	7.1^{a}	9.0^{a}	9.5^{a}	2.6^{b}	7.3^{bc}	6.8^{b}
SW	21	8.0^{a}	7.4^{ab}	5.5^{abc}	6.6^{ab}	8.1^{ab}	8.6^{ab}	2.9^{ab}	6.2^{c}	7.7^{a}
MW	146	7.8^{ab}	7.6^{a}	5.8^{ab}	6.9^{a}	8.5^{a}	9.2^{a}	2.5^{b}	7.5^{bc}	7.1^{ab}
NE	186	7.1^{bc}	6.5^{b}	5.3^{bc}	6.3^{b}	7.7^{b}	8.2^{b}	3.5^{a}	8.6^{a}	6.6^{b}
International	91	6.8^{c}	6.6^{b}	5.1^{c}	6.2^{b}	8.6^{a}	9.3^{a}	2.6^{b}	8.2^{ab}	5.0^{c}
Pr > F(Model)		0.001	<0.0001	0.022	0.002	0.001	0.009	0.023	0.033	<0.0001

Means represent average response on an 11-point scale where 1=NCI Color 1 and 11= NCI Color 11. Color 1 is the lightest color and Color 11 is the darkest/most saturated orange color. Different letters following means within a column signify significant differences ($p<0.05$). Questions that returned non-significant differences have been removed (Most Flavor, Most Natural)

Table 3.9: Means of consumer responses to Cheddar cheese color questions by Cheddar cheese type purchased most often (n=1183).

Cheddar Type Purchased Most Often	N	Expect Cheddar to Be	Purchase Most Often	Mild Cheddar	Medium Cheddar	Sharp Cheddar	Most Flavor	Least Flavor	Sharpest	Least Sharp	Ate as Child
Mild	219	7.4^{b}	6.5^{c}	6.3^{a}	7.5^{a}	9.0^{a}	8.5^{a}	2.5^{b}	9.6^{a}	2.5^{b}	6.7^{b}
Medium	216	7.5^{ab}	7.0^{b}	5.1^{c}	7.0^{b}	9.2^{a}	8.7^{a}	2.6^{b}	9.7^{a}	2.3^{b}	6.8^{b}
Sharp	540	7.8^{a}	7.9^{a}	5.7^{b}	6.5^{c}	8.4^{b}	8.4^{a}	3.0^{b}	9.2^{a}	2.7^{b}	7.4^{a}
Extra Sharp	208	7.3^{b}	6.8^{bc}	5.7^{b}	6.3^{c}	7.2^{c}	7.1^{b}	4.2^{a}	7.5^{b}	4.0^{a}	7.3^{a}
Pr > F(Model)		0.049	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002

Means represent average response on an 11-point scale where 1=NCI Color 1 and 11= NCI Color 11. Color 1 is the lightest color and Color 11 is the darkest/most saturated orange color. Different letters following means within a column signify significant differences ($p<0.05$). Questions that returned non-significant differences have been removed (Most Natural, Least Natural

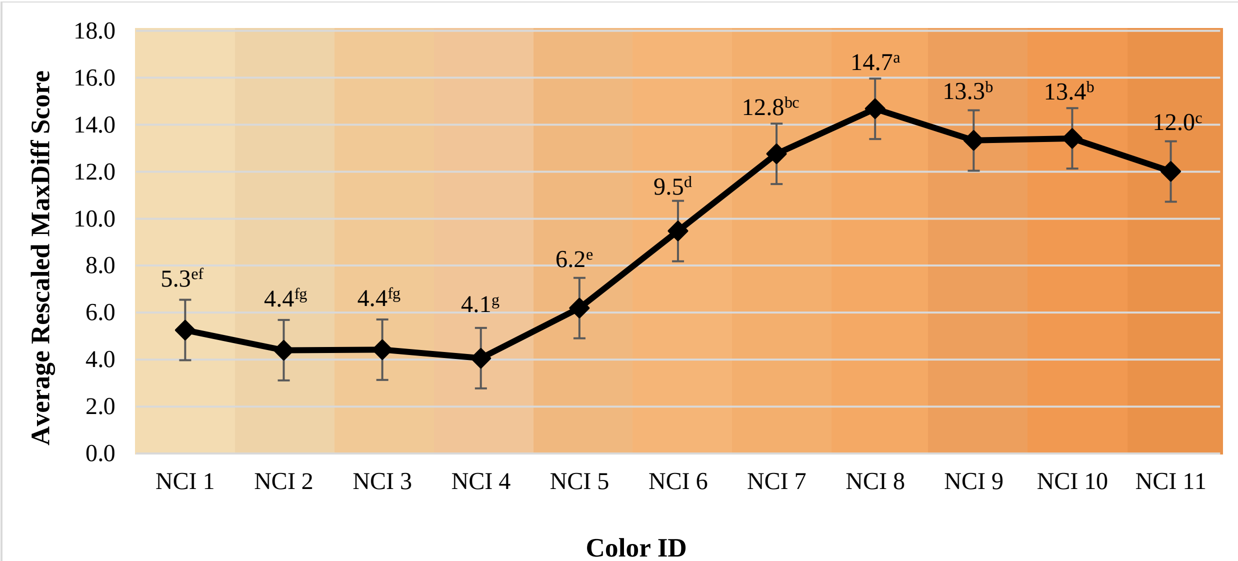


Figure 3.1: Overall consumer MaxDiff scores for Cheddar cheese color from Survey 1 (n= 1226). MaxDiff scores were rescaled to sum to a total of 100. Different letters indicate differences ($p<0.05$). Error bars represent standard error for each color. A higher MaxDiff score indicates a more appealing color.

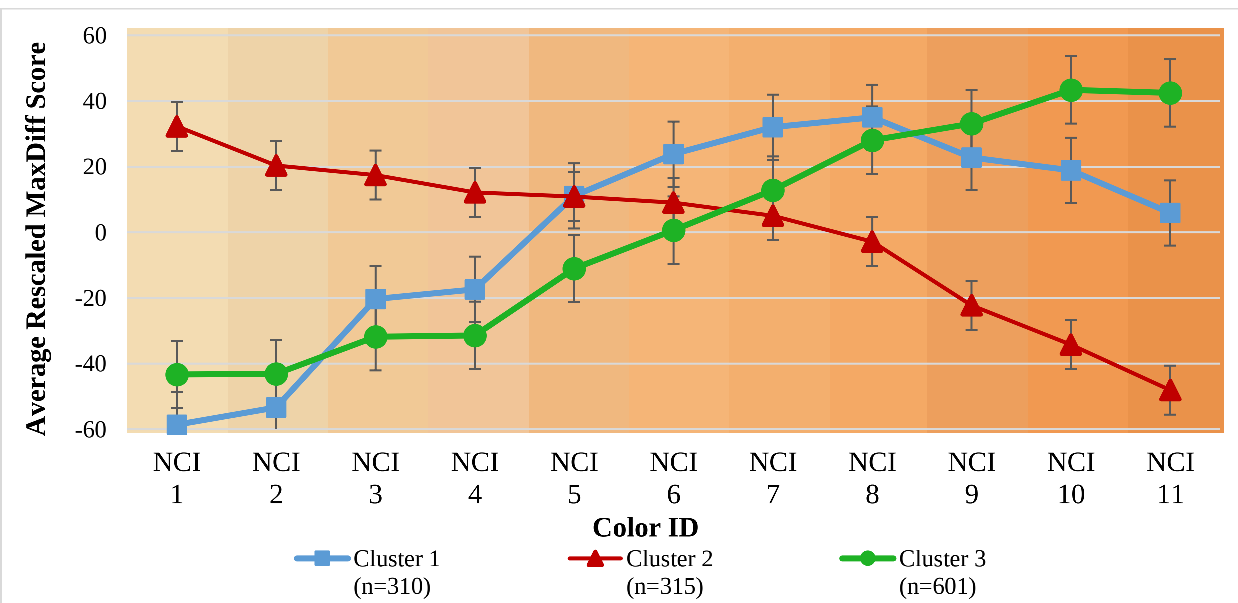


Figure 3.2: Identified consumer cluster MaxDiff scores for Cheddar cheese color from Survey 1 (n=1226). All MaxDiff scores have been rescaled to sum to a total of 100. Error bars represent standard error for each color within each cluster. A higher MaxDiff score indicates a more appealing color.

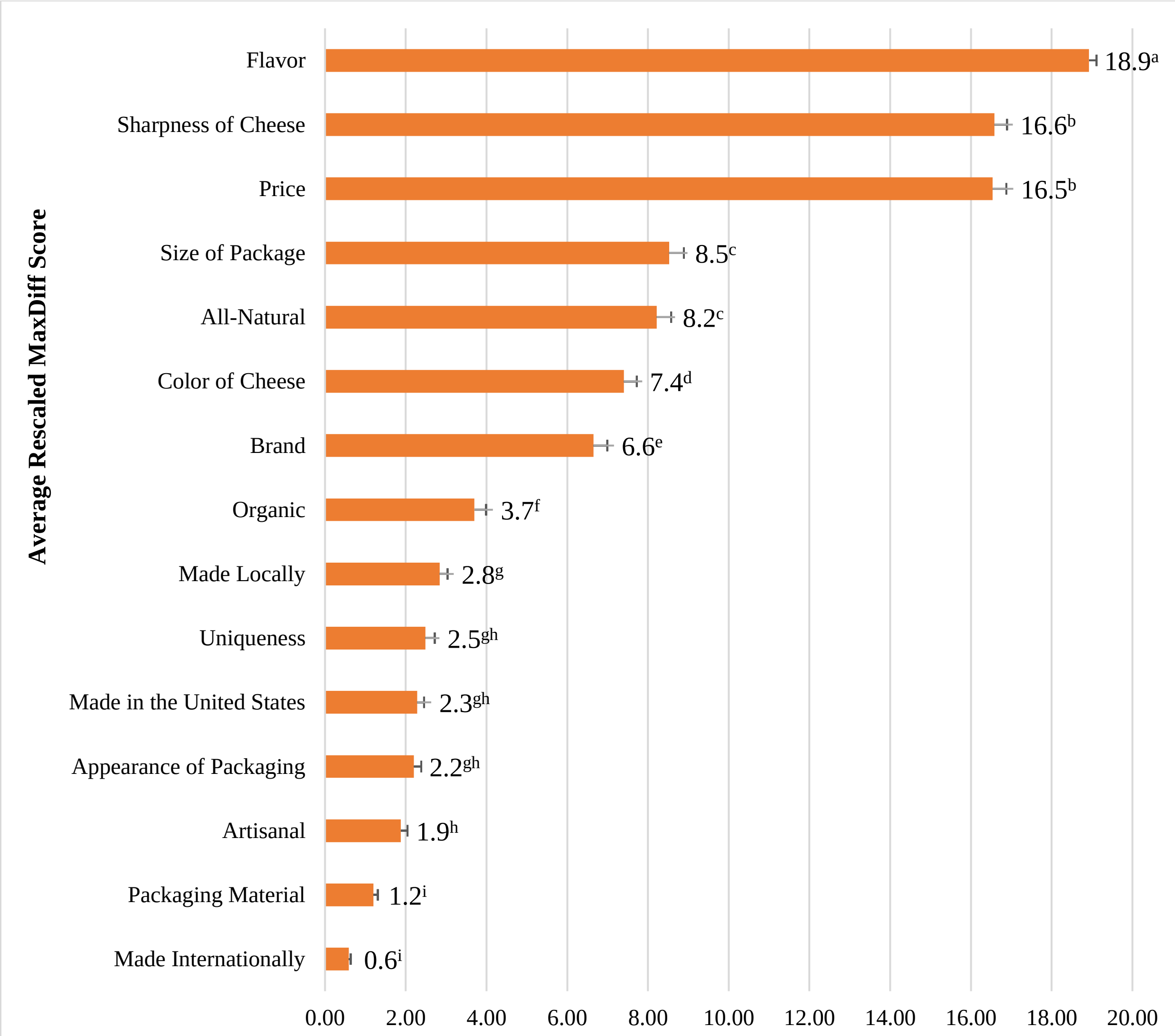


Figure 3.3: Overall consumer MaxDiff attribute scores important for purchase of Cheddar cheese from Survey 1 (n= 1226). MaxDiff scores were rescaled to sum to a total of 100. A higher number indicates greater importance. Different letters indicate differences ($p<0.05$).

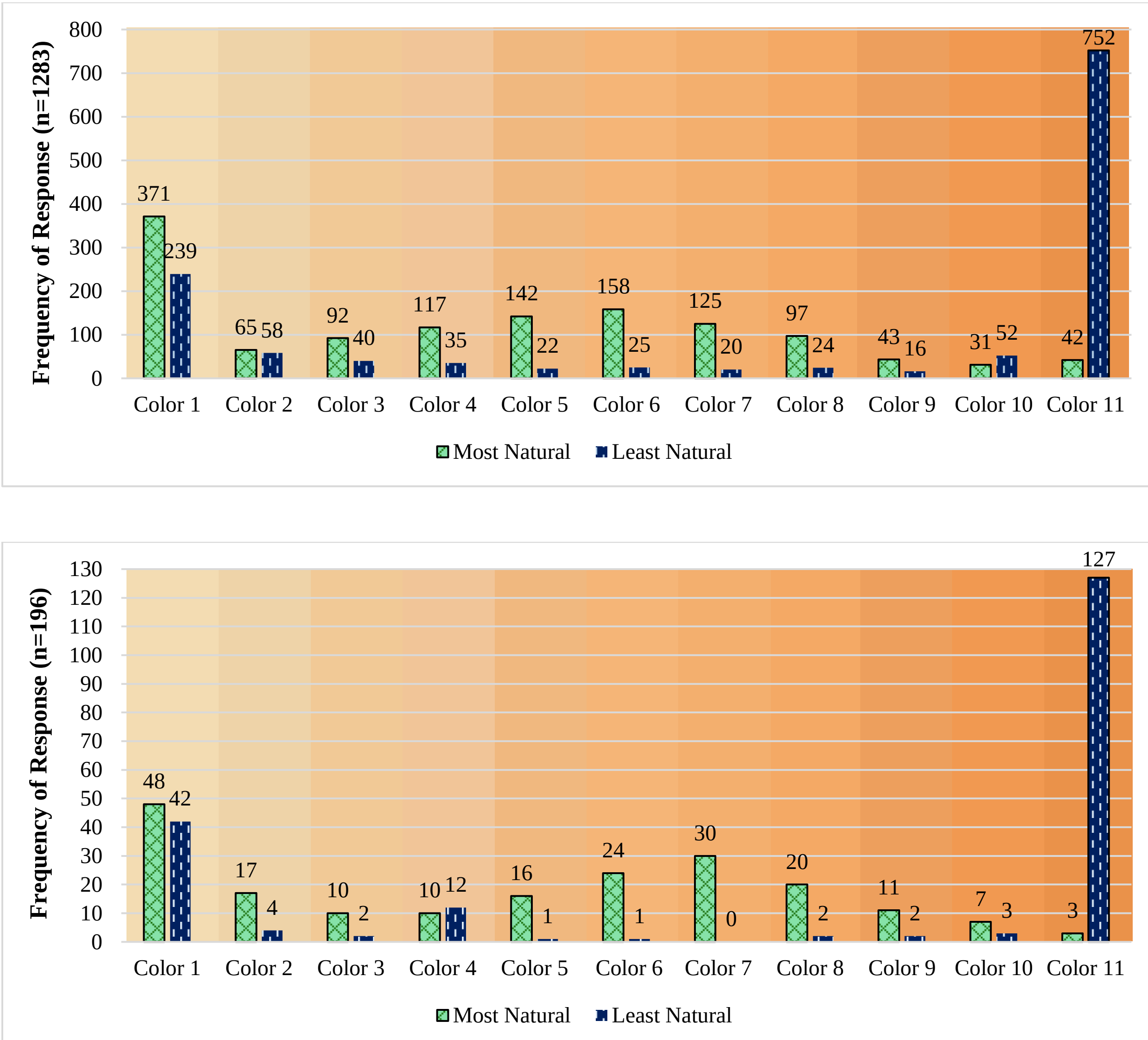
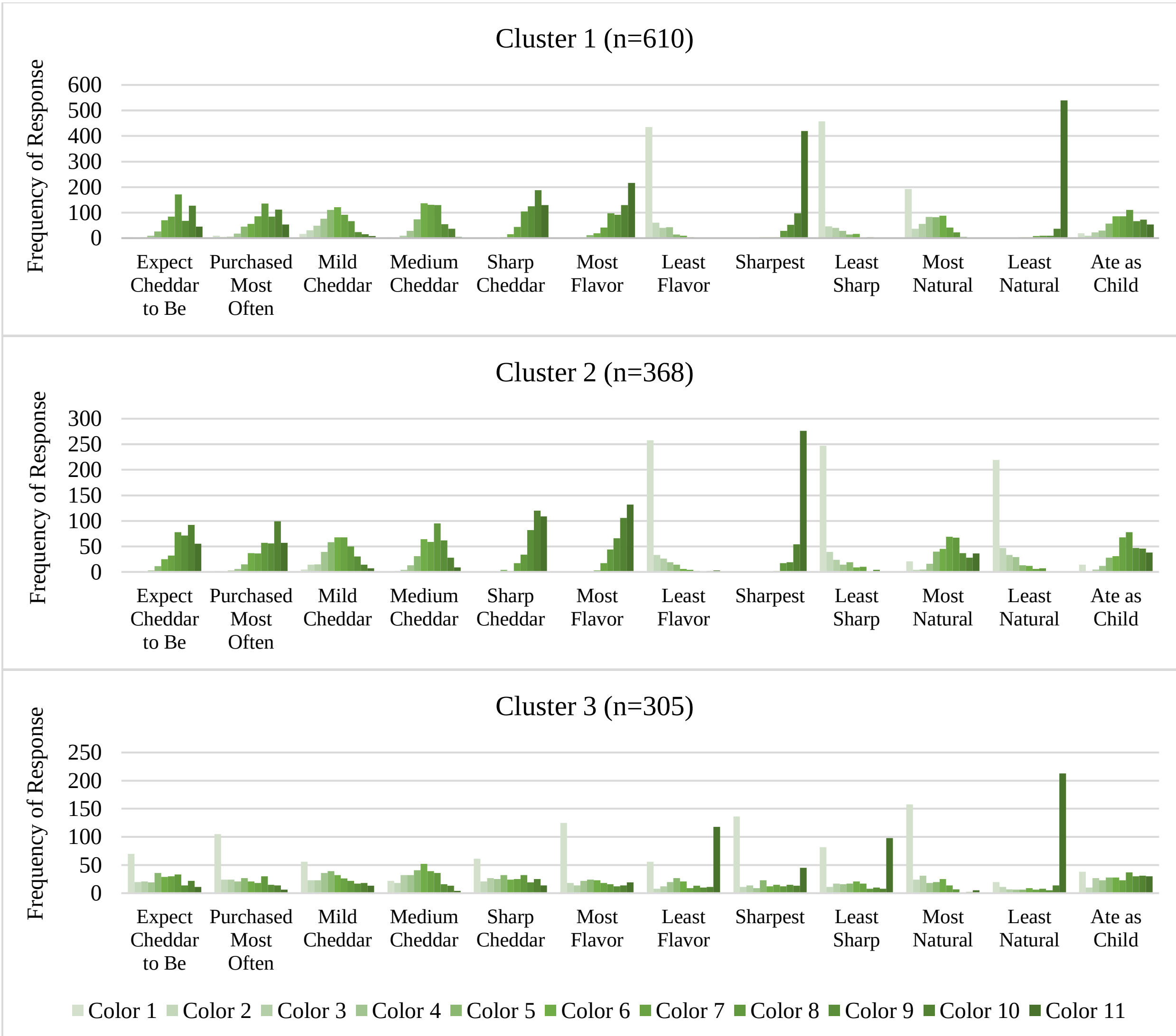


Figure 3.4: Response distributions from Cheddar cheeses consumers from Survey 2 (n=1183) and consumer acceptance testing (n= 196) for perception of "natural" Cheddar cheese color. Participants were asked to select which color represented Cheddar cheese that they thought would be the most natural and the least natural.



	Expect Cheddar to Be	Purchase Most Often	Mild Cheddar	Medium Cheddar	Sharp Cheddar	Most Flavor	Least Flavor	Sharpest	Least Sharp	Most Natural	Least Natural	Ate as Child
Cluster 1	8.1	7.9	5.6	6.9	9.3	9.4	1.7	10.4	1.7	3.7	10.7	7.2
Cluster 2	8.8	8.6	6.2	7.4	9.7	9.8	1.9	10.6	2.0	7.1	2.1	7.6
Cluster 3	5.1	4.2	5.0	5.5	5.2	4.1	6.9	4.5	6.1	2.8	9.2	6.2

Figure 3.5: Distribution of responses and means for identified consumer clusters for Cheddar cheese color expectation questions from Survey 2 (n=1183). For each question, consumers were asked to select which color best represented Cheddar cheese that exhibited each attribute (1= NCI Color 1, 11= NCI Color 11). Clusters were generated based on answers to color expectation questions.

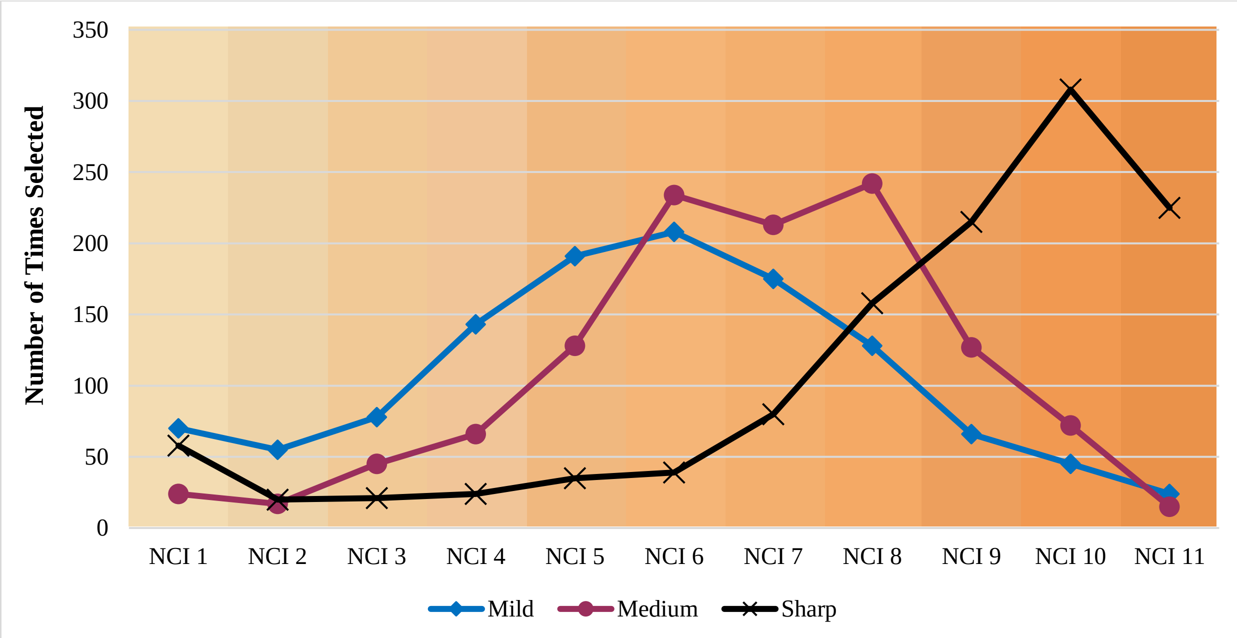


Figure 3.6: Consumer perception of Cheddar cheese sharpness label and Cheddar color from Survey 2. Survey participants (n= 1183) were asked to indicate which color they thought best represents mild/medium/sharp Cheddar.

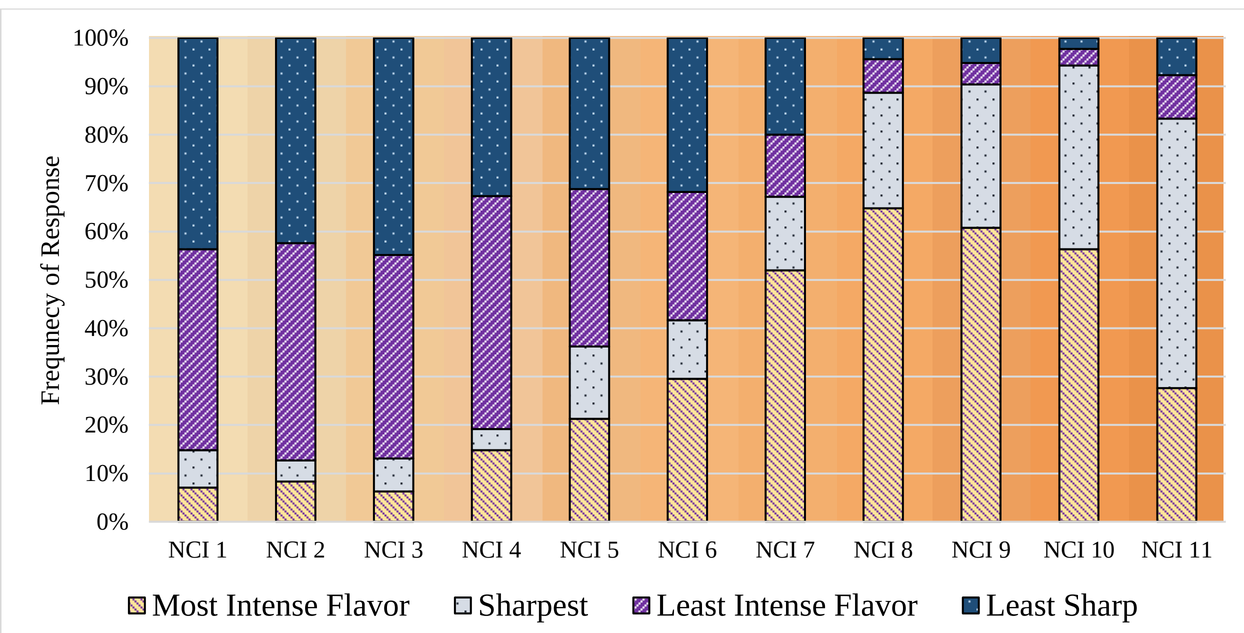


Figure 3.7: Consumer perception of Cheddar cheese sharp flavor, flavor intensity and Cheddar color from Survey 2. Survey participants (n= 1183) were asked to indicate which colors represented cheese that would be the sharpest/least sharp, as well as the colors that represented cheese that would have the most flavor/least flavor.

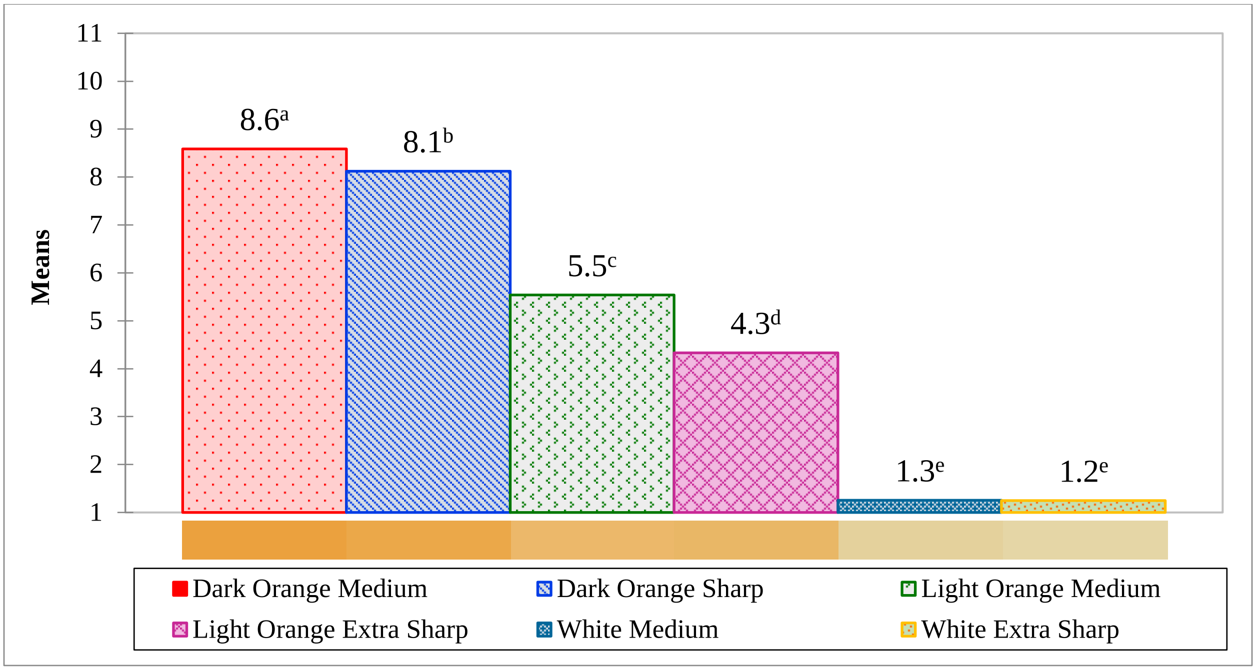


Figure 3.8: Mean color match scores from consumer acceptance testing for perception of Cheddar cheese color (n=196). Participants were asked to select which color on the provided color card best represented the six Cheddar cheeses being evaluated. Different letters indicate significant differences ($p<0.05$).

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SUPPLEMENTAL

Table 1: Color liking scores for different Cheddar colors and sharpness levels from consumer acceptance testing

	Color Liking
Dark Orange Sharp	6.9a
Dark Orange Medium	6.7ab
Light Orange Medium	6.7ab
Light Orange Extra Sharp	6.4bc
White Medium	6.3c
White Extra Sharp	6.2c
Pr > F(Model)	0.0002

CHAPTER 4:

PARENTAL PERCEPTION OF CHILDREN'S SCHOOL LUNCH MILK

Parental Perception of Children's School Lunch Milk

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INTERPRETATIVE SUMMARY

This study evaluated parental understanding and perception of school lunch milk. The ideal school lunch milk for parents was unflavored (white milk) or chocolate, 2% fat, ultrapasteurized, with all-natural and hormone-free label claims, packaged in a cardboard gabletop carton. Parents are largely unfamiliar with the specific attributes and nutritional profile of milk served in schools but believe that schools should offer milk to their children as part of breakfast and lunch.

ABSTRACT

School lunch programs are mandated by the U.S. Code of Federal Regulations (**CFR**) to serve pasteurized milk that is fortified with vitamins A and D and must be skim or 1% fat. In recent years, proposals have been made to alter nutritional requirements for school lunches and school lunch milk, including changes to the milkfat and flavor options available. The objective of this study was to evaluate parental understanding and perception of school lunch milk in order to better understand how changes to school lunch milk are perceived by parents. Four focus groups (n=34) were conducted with parents of school-aged children (5-13 y) who purchased milk as part of a lunch at school. Participants were asked about school lunch milk, including nutritional content, packaging, and flavoring. Focus groups included a build-your-own milk activity and discussion of commercial children's milk products. Two subsequent online surveys were conducted with parents of school-aged children (Survey 1 n=216, Survey 2 n=133). Maximum Difference (MaxDiff) scaling was used to evaluate what beverages parents would prefer their child to drink at school (Survey 1), and which attributes of chocolate milk for children were most important to parents (Survey 2). An Adaptive Choice Based Conjoint (ACBC) activity (Survey 1) included flavor, milk fat, heat treatment, label claims, and packaging type. Both surveys included questions to evaluate knowledge of milk nutrition and attitudes regarding milk and flavored milk. Agree/disagree questions were used in both surveys to assess parental opinions of school lunch milk. Survey 2 also included semantic differential (sliding scale) questions to assess parental opinions of chocolate milk and their acceptance of sugar alternatives in chocolate milk served in schools. Parents were familiar with the flavor options and packaging of school lunch milk, but expressed limited familiarity with school lunch milk fat content. Parents perceived milk to be healthy and a good source of vitamin D and calcium. The ideal school lunch milk for parents was unflavored (white milk) or chocolate, 2% fat, ultrapasteurized, with all-natural and hormone-free label claims, packaged in a cardboard gabletop carton. For school lunch chocolate milk (Survey 2), 3 distinct clusters of parents with differing opinions for children's chocolate milk were identified. Parents are largely unfamiliar with the specific attributes and nutritional profile of milk served in schools but believe that schools should offer milk to their children as part of breakfast and lunch. Parents in both surveys also displayed a preference for 2% fat milk over low-fat options, which provides actionable insight for fluid milk producers seeking to optimize their products intended for schools.

INTRODUCTION

Previous research has established that consumption of dairy milk positively affects child health over a lifetime, beginning with supporting growth and development and later reducing risk of osteoporosis and hypertension (Herber et al., 2020; Sipple et al., 2020). In order to ensure that school-aged children have access to adequately nutritious meals, the United States Department of Agriculture (**USDA**) established the National School Lunch Program (Anonymous, 2020a) and School Breakfast Program (Anonymous, 2020b). These programs provide cash subsidies and reimbursements to school districts for the cost of meals consumed at school. In order to qualify for reimbursement, school meals must meet nutritional standards laid out in the Food and Drug Administration's Code of Federal Regulations (Office of the Federal Register, 2021a). In order to receive subsidies from the NSLP and NSBP, schools must offer their students 1 cup (8 oz.) of milk per day as a component of breakfast and lunch. Students must have at least two milk options to choose from, including one unflavored milk option. Flavored options can include chocolate, vanilla, and/or strawberry milk, but most school districts offer chocolate milk. All milk served in schools must be pasteurized and fortified with vitamins A and D and be either low-fat (1%) or fat-free (skim) (Office of the Federal Register, 2021a). From 2012-2017, flavored milk served in schools was required to be fat-free. On November 20, 2017, the United States Department of Agriculture announced that low-fat flavored milk could be served in schools which resulted in 5,546 public comments from parents and other individuals (Food and Nutrition Service, 2018) Of these comments, 36 comments supported the change in fat content regulation, 69 comments were mixed, and 5,441 were against the change (Gelski, 2018).

Review of public comments revealed a number of central themes. Most notably, parents, nutritional experts, and advocacy groups expressed concern about offering 1% flavored milk instead of fat-free as this could lead to increased sugar, fat, and calorie intake by children in both the short term and long term (Food and Nutrition Service, 2018). However, school districts are required by the CFR to offer meals that meet certain caloric and fat content regulations, meaning that additional fat and calories from 1% flavored milk must be compensated for in other parts of the meal. Skim milk contains 85 calories per serving (half-pint, 8 oz, 236 mL) with 0 g of fat and 0 calories from fat. One percent milk fat milk has 110 calories per 8 oz. serving, with 2.5g of fat (4% daily value), 1.5g of saturated fat (8% daily value), and 25 calories from fat (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015). The difference in calories between skim and 1% fat milk is small, but can be a challenge for school districts to incorporate due to restrictions on calorie and fat content of school lunches. For elementary school (kindergarten through 5th grade) lunches, including milk, must contain on average 550-650 calories. Middle school (6th-8th grade) lunches must contain on average 600-700 calories, and high school (9th-12th grade) lunches must contain 750-850 calories on average. Lunches for all three age groups are required to contain less than 10% saturated fat as a percentage of total calories (Office of the Federal Register, 2021a).

Flavored milk products for children are often a source of controversy due to their higher sugar content compared to unflavored milk. Calories due to added sugar in school lunch chocolate milk are encompassed in the average school lunch total calories addressed previously. An 8 oz serving of milk contains approximately 12 g of carbohydrates due to the native lactose. Chocolate milks can have as many as 18 g of added sugar although current (2020) school lunch formulations have approximately 8 g of added sugar per 8 oz serving in order to have a minimal impact on total calories. In addition, some parents and health groups have expressed concern that increased sugar content may contribute to adolescent obesity and dental caries (Cather, 2019). However, flavored milk was endorsed by the American Academy of Pediatrics over other sugar-sweetened beverages due to its important nutritional advantages, including significant calcium and vitamin D content, which have been shown to support growth (Ballew et al., 2000; Patel et al., 2018). Flavored milk also plays an important role in facilitating child intake of other vital nutrients for growth, such as Vitamin A, calcium, and phosphorus. With increasing concerns about sugar-sweetened beverages from parents and health professionals, scientific authorities have begun to investigate potential associations between flavored milk and negative health effects. A 2018 review of published literature regarding associations between flavored milk consumption and milk intake, added sugar intake, energy intake, and obesity found conflicting conclusions surrounding consumption of flavored milk and negative health effects (Patel et al., 2018). Children who consumed flavored milk have a lower intake of added sugar than children who do not consume flavored milk (Noel et al., 2013). Other researchers studied dairy consumption and obesity and found no correlations between dairy consumption and obesity in adolescents (Phillips et al., 2003; Fayet et al., 2013; Keast et al., 2015). Murphy et al. (2008) studied the association between weight status and milk consumption in American children and found that children who consumed flavored milk reported higher milk intakes than children who only drank plain milk. Researchers reported no adverse effects on BMI measurements for children and adolescents who consumed flavored milk as compared to their peers who consume exclusively plain milk (Murphy et al., 2008). Kling et al. (2016) evaluated factors that affected children's milk intake as part of a school lunch and found that increasing fat content from 1% fat (low energy-density) to 3.25% fat (high energy-density) and portion size (183 g vs 275 g) resulted in a subsequent increase in milk intake for children.

Flavored milk is generally preferred by children, which highlights its importance as a vehicle for delivering important nutrients for healthy growth and development. A national study demonstrated that when flavored milk was removed from school lunch programs, children's milk consumption decreased by 35% on average (Quann and Adams, 2013). Since adult fluid milk consumption is associated with childhood habit, establishing fluid milk consumption in children is a critical activity for lifelong nutrition and fluid milk consumption (McCarthy et al., 2017). Relatively little research has been done on children's sensory perception of milk, though a few studies have evaluated child acceptance of flavored milk with varying milkfat and flavor attributes. Palacios et al. (2010) evaluated child acceptance of lactose-free milks and milk alternatives, including soy milk. Children preferred chocolate-flavored lactose-free 1% dairy milk over all other beverage options in the study, including unflavored 1% lactose-free dairy milk and chocolate-flavored soy milk (Palacios et al., 2010). Other researchers have evaluated child perception of sweeteners in chocolate milk, including monk fruit and stevia, as part of an effort to identify reduced sugar chocolate milks (Li et al., 2015a; Verruma-Bernardi et al., 2015). Li et al. (2015a) studied child acceptance of chocolate milks sweetened with sucrose and or nonnutritive sweeteners (total added sugar ranging from 3.6 g to 12.3 g per serving). Differences in acceptance were observed for older children (8-13 y) and younger children (aged 5-7 years old), with younger children displaying significant preference for samples sweetened with 25% monk fruit or 25% stevia over a 100% sucrose-sweetened control and older children displaying no preference among the three milks. Other studies have sought to understand the effect of packaging on child perception and acceptance of school lunch milk. Sipple et al. (2021) evaluated children's acceptance of 3 types of milk (unflavored skim, unflavored low-fat, and chocolate skim) in 3 types of packaging (polyethylene-coated paperboard cartons, polyethylene terephthalate (PET) bottles, and high density polyethylene (HDPE) bottles). Children preferred the flavor of unflavored milk, regardless of fat content, packaged in HDPE or PET bottles over milk packaged in cardboard cartons, but their preferences were not distinct for chocolate milk. Children also indicated a preference for HDPE bottles over cardboard cartons for their school lunch milk in an online survey, indicating that the cardboard cartons currently used in schools may not meet children's expectations (Sipple et al., 2021).

While much of the research focus has been on child consumption and acceptance of milk, studies have also been conducted to better understand parents' perception of milk. Li et al. (2015a) evaluated parent perception of chocolate milks made with different sweeteners under blinded (no nutritional information) and primed (nutritional information provided) conditions. Nutritional information impacted parent preferences for chocolate milks. “Label-conscious” (n=55) parents preferred a 100% sucrose-sweetened chocolate milk over those partially sweetened with 25% stevia or 25% monk fruit when tasting blinded but preferred milks partially sweetened with 25% stevia when nutrition information was provided. In contrast, “traditional sweetener” parents (n=45) preferred chocolate milks sweetened with 25% stevia or 25% monk fruit when blinded, but preferred a 100% sucrose-sweetened milk when provided nutritional information. Parents also conceptually preferred natural nonnutritive sweeteners or sucrose over artificial sweeteners, and indicated that reduced fat was preferred over full fat or skim. Parents also found the claim “added calcium for strong bones” appealing (Li et al., 2014).

The importance of parental influence on child milk consumption should not be underestimated. By acting as a both a provider of food and a role model, parents’ and caregivers’ decisions regarding food and beverages can have a powerful influence on child eating patterns (Savage et al., 2007). Brett et al. (2016) conducted a cross sectional analysis of participants aged 2–8 y old from a 6 month randomized vitamin D trial to better understand parental attitudes and understanding of milk consumption. Parents’ self-reported intake of milk influenced their children’s intake of milk. A different cross-sectional study conducted using a calcium-intake questionnaire identified three groups of parents with differing perception of milk and provided further evidence that parent perception of milk influences their children’s intake of milk (Reicks et al., 2012). To our knowledge, no studies have specifically addressed parents understanding and perception of the milk that their children drink at school, and little is known about parental opinions on school lunch milk. The objective of this study was to evaluate parental understanding of and familiarity with school lunch milk.

MATERIALS AND METHODS

Experimental Overview

A series of 4 focus groups were conducted with parents to establish parent familiarity with their children's school lunch milk. Qualitative responses from focus groups were used to develop an online survey that assessed the value that parents placed on milk and other beverages served with school lunches, along with the importance and familiarity of school lunch milk attributes. Following the completion of Survey 1, a second online survey (Survey 2) was conducted to evaluate parent perception of sugar claims in chocolate milk served in schools. Surveys utilized psychographic questions, Maximum Difference (**MaxDiff**) scaling exercises, and Adaptive Choice-Based Conjoint (**ACBC**) exercises.

Participants

All testing was conducted in compliance with North Carolina State University Institutional Review Board (**NCSU IRB**) regulations. Participants were contacted using an online database of >10,000 consumers from the greater Raleigh/Durham/Chapel Hill, NC area maintained by the Sensory Service Center at North Carolina State University (**SSC**). Consumers who reported that they had children under the age of 18 y that attended public or private school and consumed milk at school could qualify for this study. Additional qualification criteria for the focus groups and surveys are subsequently specified.

Focus Groups

The objective of the focus groups was to establish a baseline for parent familiarity with school lunch milk. Participants were recruited from a database maintained by the SSC, which consisted of over 10,000 consumers. Participants who indicated in a screener survey that they had at least one child between the ages of 5 and 13 y that purchased fluid dairy milk as part of their lunch at school (n=139) were considered qualified for the focus groups. From the pool of qualified parents, a smaller subset of parents that represented a range of milk purchase habits (n=34) were selected to participate in the focus groups, including parents who purchased dairy milk, plant-based dairy alternatives, and a mix of both for their children to consume at home.

A total of four focus groups were held on the North Carolina State University campus and lasted about 90 minutes each (**Figure 1**). Parents began the focus group by describing their milk consumption as children to establish an understanding of their personal experience with milk. Next, they answered questions about their family's milk consumption, including why they do or do not serve milk to their family at home. The core of the focus group focused on understanding of parent beliefs surrounding school lunch milk, including questions about fat content, flavor, and the importance of other milk attributes.

Parents' familiarity with school lunch milk was assessed by displaying United States Food and Drug Administration (**FDA**) regulations from the Code of Federal Regulations (**CFR**) specifically surrounding flavored milk and milkfat content of school lunch milk on a projector screen in the focus group room followed by a discussion of the information presented. Parents were shown the statement "Schools must offer students a variety (at least two different options) of fluid milk. All milk must be fat-free (skim) or low-fat (1 percent fat or less). Milk with higher fat content is not allowed. Low-fat or fat-free lactose-free and reduced-lactose fluid milk may also be offered. Milk may be unflavored or flavored provided that unflavored milk is offered at each meal service." Regulations were taken from the CFR regarding milk served as part of the National School Lunch Program and National School Breakfast program (Meal requirements for lunches and requirements for afterschool snacks, CFR §210.10). Parents then completed a worksheet that asked them to use a list of provided characteristics to build their ideal school lunch milk for their children, similar to the Build-Your-Own (**BYO**) portion of an ACBC (see below). The attributes included in the BYO section included flavor, fat content, protein content, heat treatment, package, and label claims. For heat treatment, parents were provided with the following information: "HTST (high temperature, short time) pasteurized milk is heated to at least 161°F (72C) for 15 seconds, which kills bacteria that could harm you. This is the milk that you typically buy at the grocery store from the refrigerated section. If refrigerated properly, this milk has a shelf life of 14-21 days. Ultrapasteurized milk is heated to 280°F (138C) for at least 3 sec, which means that this process is able to kill most bacteria, prolonging refrigerated shelf life. Ultrapasteurized milk has a refrigerated shelf life between 60-90 days. UHT (Ultra High Temperature) pasteurized milk is heated to at least 140C for 3 sec and then packaged under a sterile environment. This milk is shelf stable and is typically stored unrefrigerated for 6-9 months." Finally, each group was shown a range of commercially available milks (flavored and unflavored) and asked to discuss their perception of each of them, including package, protein content, sugar content, fat content, and other nutritional attributes. Parents who fully participated in the focus group were compensated with a gift card to an online retailer.

Online Surveys

Survey 1

The objective of Survey 1 was to assess the importance of child milk consumption to parents. The online survey was developed using Lighthouse Studio (Sawtooth Software version 9.8.0, Orem, UT). The survey was uploaded to a database maintained by the SSC, which consists of over 10,000 consumers. Participants who indicated they had children younger than 18 y were able to enter the survey (n=858). Participants who indicated that they had at least one child between the ages of 5 and 13 y that purchased fluid milk as part of their lunch at public or private school (n=216) completed psychographic questions, MaxDiff questions and an ACBC exercise on school lunch milk attributes. Psychographic questions included assessments of familiarity with milk nutrition and attributes of school lunch milk, as well as agreement questions regarding statements about milk served at school. Parents were prompted to answer questions based on their previous knowledge or best guess instead of searching for answers while completing the survey.

The beverage MaxDiff (MXD) exercise consisted of 19 beverages, including milk with different milkfat content and flavor choices as well as water, juice, soda, and similar non-dairy beverages. A MaxDiff or "Best-Worst" scaling exercise allows participants to rank a long list of items with relatively few questions by utilizing simultaneous pairwise comparisons to generate importance scores (Buoye et al., 2018). Parents were asked to indicate which options they would be "Most Interested" (best) and "Least Interested" (worst) in their child consuming as part of their lunch at school. Each respondent completed thirteen sets of best-worst questions with five items in each set. These questions were asked to evaluate which beverages parents placed the most value on for their children's consumption.

The ACBC exercise was used to determine the relative importance of milk attributes to parents and to establish their ideal school lunch milk product for their children. ACBC exercises are designed to examine consumer purchase choices and tradeoffs utilizing a series of product concept builds to generate utility scores, which are commonly zero-centered to sum to 100 (Orme, 2006; Buoye et al., 2018). Higher scores represent attribute levels that are more appealing, and negative utility scores represent levels that are less appealing compared to those with positive scores (Orme, 2006). The exercise consisted of 5 levels with 4 to 6 attributes per level (**Table 1**) that represented extrinsic and intrinsic factors of school lunch milk. Levels included flavor, fat content, heat treatment, label claims, and package type. Parents first completed a build-your-own task by selecting one level within each attribute to create their ideal school lunch milk product for their children, followed by 8 screening tasks in which they were presented with 4 school lunch milk concepts per task and asked to select whether each product concept was "a possibility" or "won't work for me". Next, parents completed a choice task tournament with a maximum of 20 school lunch milk concepts presented. Concepts in the choice tournament were presented in groups of 3 to minimize panelist fatigue. Throughout the ACBC exercise, parents were prompted to consider that they were selecting a milk they might want their child to drink at school. Parents were prohibited from making overlapping selections, such as the label claim "organic" and the label claims "rBST-free" or "GMO-free" since organic milk is required to be free from added hormones and cows producing organic milk may not be fed genetically modified feed (Office of the Federal Register, 2021b). Parents were also prohibited from making conflicting selections, such as HTST-pasteurized milk packaged in a TetraPak® container.

Survey 2

Survey 1 demonstrated the importance that parents placed on chocolate milk for their children's school lunch milk. The objective of Survey 2 was to expand upon results from Survey 1 regarding chocolate milk and to further develop parental understanding of the importance of label claims and nutritional content specifically for chocolate milk. The online survey was developed using Lighthouse Studio (Sawtooth Software version 9.8.0). The survey was uploaded to the same database used by Survey 1. Participants who indicated they had children younger than 18 y were able to enter the survey (n=406). Participants who indicated that they had at least one child between the ages of 5 and 13 y that purchased chocolate fluid milk as part of their lunch at public or private school (n=133) completed psychographic and agreement questions, along with a MaxDiff exercise regarding chocolate milk nutrition and sweeteners. Approximately 90 days passed between Survey 1 and Survey 2. Consumers could participate in both surveys providing that they met the qualification criteria for both.

Parents began the survey with familiarity questions about milk and chocolate milk nutrition, including questions that asked them to guess how many grams of added sugar are in the chocolate milk their children drink at school and at home. Parents then completed a series of 49 randomized agreement questions regarding attributes of chocolate milk served in schools. Next, survey participants completed a series of four sliding scale questions surrounding perception of children's chocolate milk products. The first sliding scale question used the anchor points "It's important that the chocolate milk my child drinks is healthy" (value: -10) and "It's important that my child likes the chocolate milk they are drinking" (value: 10). The next three sliding scale questions assessed parent perception of sugar alternatives. All three used the same format in which the left anchor was valued at -10 and used the text "I would not like to see [ingredient] in the chocolate milk served at school." and the right anchor was valued at 10 and used the label text "I would like to see [ingredient] used in the in the chocolate milk served at school." Ingredients assessed were "sugar alternatives," "natural sugar alternatives," and "low-calorie sugar alternatives." Participants were provided with stevia and agave as examples for natural sugar alternatives and sucralose and erythritol for low-calorie sugar alternatives. The MaxDiff exercise consisted of 28 extrinsic and intrinsic properties of chocolate milk, including fat content, use of alternative sweeteners, packaging, and flavor. Parents were asked to indicate which attributes were "Most Important" and "Least Important" for the chocolate milk their child consumed at school. Each respondent completed twenty-two sets of best-worst MaxDiff questions with five items per question. This MaxDiff exercise was included in the survey to assess the relative importance of different school lunch chocolate milk attributes to parents.

Statistical Analysis

Transcripts of audio from focus groups were manually analyzed for central themes. Data from ideal milk activity and other demographics from focus groups were analyzed for frequency of responses and percentage distribution of demographic information. All statistical analyses were performed at a 95% confidence level ($P < 0.05$). Hierarchical Bayes (**HB**) estimation was performed in Sawtooth Software (version 9.9.0, Orem, UT) and all other analyses were performed using XLSTAT (version 2019.3.1, Addinsoft, New York, NY). Individual utility scores from the ACBC in Survey 1 were calculated by HB estimation, and importance scores for ACBC attributes were calculated as the percentage of the total utility range for each attribute. HB estimation was also used to calculate importance scores for MaxDiff attributes for both Survey 1 and Survey 2. Cluster analysis for Survey 1 was performed using agglomerative hierarchical clustering (**AHC**) with Euclidean distances and Ward's linkage to place similar respondents into clusters based on individual utility scores from the ACBC. Cluster analysis for Survey 2 was performed using the same technique on individual importance scores from the MaxDiff exercise.

RESULTS AND DISCUSSION

Focus Groups

Focus group participants (n=34) were primarily female (82% female, 18% male). Thirty-two percent of participants were 25-34 y, 50% were 35-44 y, and 18% were 45-54 y. Eighty-five percent of participants had 2 or more children in the household and 15% reported one child in the household. Most participants (56%) had at least one child between the ages of 5 and 7 y, 32% had at least one child 8-10 y, and 50% had at least one child 11-13 y. Ninety-five percent of focus group participants' children attended public school and 5% attend private school, charter school, or a magnet school program. All participants indicated that their children consumed fluid dairy milk as part of their lunch at school, and 91.2% (n=31) indicated their children also consumed milk at home. Eighty-seven percent of parents whose children consumed milk at home indicated they served unflavored or white milk at home, and 77% indicated that they served chocolate milk at home. Parents were asked to select the type of milk they served at home from a check-all-that-apply (**CATA**) list of options. Parents indicated skim milk (38%), 1% fat milk (38%), 2% fat milk (84%), and whole milk (42%) were served at home, but 68% of parents also indicated that they served non-dairy milk alternatives at home. A similar distribution of parental purchasing habits was observed in a 2020 Mintel study surrounding milk and nondairy milk alternative consumption in the United States (Bonnett, 2020).

Parents were generally familiar with the flavor of milk that their child consumed at school and the flavor options available to them. A majority of parents (82%) reported that their children consumed chocolate milk at school, and 73% reported their children consumed unflavored or white milk at school. However, parents expressed less familiarity with fat content of milk that their children consumed at school. Prior to displaying USDA regulations surrounding milkfat content of school lunch milk, parents were asked what fat content of milk their child consumed most often at school (participants could make more than one selection). Fourteen percent indicated skim milk, 21% indicated 1% fat milk, 56% indicated 2% fat milk, and 29% indicated whole milk. Parents also indicated limited familiarity with school lunch milk portion sizes. When asked what volume of milk their children consumed as part of a lunch at school, 73% of parents correctly selected 1 cup (8 fluid oz), 9% guessed 2 cups (16 fluid oz), and 18% guessed 0.7 cups (5.7 fluid oz). When presented with school lunch milk regulations, 91% of parents indicated they were not aware of the displayed information prior to their focus group. Most parents (65%) indicated they were surprised by the information presented. Follow-up discussion showed that most parents (>50%) were unaware that 2% and whole milk were not allowed in schools and were surprised by this information.

Parents who participated in the focus group were asked to choose from a list of options to generate their ideal school lunch milk. Overall, the ideal milk for focus group participants was chocolate-flavored, 2% fat, contained 8g of protein, was HTST pasteurized, was packaged in a plastic bottle, and had an all-natural label claim. Parents were split on preferences for milk flavor that children consumed at school: 41% of parents indicated they would prefer their children to drink unflavored (white milk) at school and 53% preferred chocolate. A 2% fat milk was preferred by 47% of focus group participants and 18% chose skim, 18% 1% fat, and 15% whole milk. Parents were less certain of milk protein content per 1 cup serving, with 41% choosing 8g, 24% choosing 10g protein, 12% choosing 12g protein, and 24% choosing "no preference/unsure." An even distribution of responses was observed for heat treatment, with 29% of parents selecting ultrapasteurization as their preferred heat treatment, 32% selecting HTST pasteurization, 24% selecting UHT/shelf stable and 15% indicating "no preference/unsure." Parents also indicated interest in TetraPak® packaging and cardboard cartons for school lunch milk (selected by 26% and 21% of participants respectively), but 41% selected plastic bottles as their preferred package for school lunch milk. Organic and GMO-free label claims were appealing to parents, with 32% and 35% of parents selecting these claims in a CATA format, respectively. The selections made by parents during the focus group were used to generate the list of levels and attributes for the ACBC exercise conducted in the online survey portions of this study.

Overall, focus group participants perceived milk as a healthy choice for their children regardless of its fat content and flavor. Most parents mentioned that milk was important for bone health and development and that they encouraged their children to consume milk for this reason. Approximately 40% of parents mentioned that advertisements regarding the benefits of milk for bone development influenced their decision to serve milk to their own children, such as “Got Milk?” and “Milk Does a Body Good” advertisements. The “Got Milk?” advertisement campaign, which launched in 1993, was at its peak during Millennial and Gen X parent adolescences (Daddona, 2018; Dimock, 2019). Parent familiarity with milk as a component of bone health was also observed by Li et al. (2014), as parents returned a positive utility for the claim “Added calcium for strong bones” in an adaptive choice-based conjoint exercise regarding selection of chocolate milk for their children. Parents preferred milk over other beverages, including water, juice, and soda to be served in schools as part of lunch and breakfast due to its protein and vitamin content. However, some parents (30%) expressed an interest in seeing more non-dairy options to be served in schools out of concern for children with intolerances and allergies. Focus group results from this study may be limited in that sessions only included parents who purchased dairy milk for their children to consume at home and did not include any parents who do not serve milk at home. We also did not ask parents to report their own milk intake. As previously discussed, parent perception and intake of milk has a significant impact on child consumption of milk. Children of dedicated milk provider parents consumed more milk (10.36 oz/day vs 5.64 and 7.16 oz/day for other parent groups, respectively) and less soda and fruit juice products (Reicks et al., 2012). Dedicated milk providers/drinkers also indicated that culture/tradition and health benefits were significantly more important to them compared to parents from other groups (Reicks et al., 2012).

Survey 1

A variety of parents participated in Survey 1. A majority of participants (83%) were female, and 17 % of survey respondents were male. Most (55%) parents were aged 35-44 y, but 18% were 18-34 y, 24% were 45-54 y, and 4% were 55-64 y. Twenty-five percent of respondents self-identified as black/African American, 9% identified as Hispanic/Latinx, 5% identified as Asian/Indian, 63% identified as white/Caucasian, and 2% selected “other”. A range of household incomes was also reported: 12% of parents indicated \$20,000-\$39,999, 25% indicated \$40,000-\$59,999, 15% indicated \$60,000-\$79,999, 17% indicated \$80,000-\$99,999 and 31% of respondents indicated their annual household income was greater than \$100,000. Parents confirmed that they had at least one elementary or middle school-aged child (5-13 y) in their household. Most parents had children that attended public school (86%), 8% attended private school, 2% attended charter school, and 4% attended a magnet school program. Most parents reported that their children purchased lunch, including milk, at school (an average of 3.3 days out of 5). Most parents (69%, n=150) selected “yes” when asked if their children talk to them about the milk they drink at school.

Based on the MXD exercise from Survey 1, parents valued milk as a beverage to be served in schools, as all 8 milk options presented were in the top 10 highest-scoring beverages out of a list of 19 possible options (**Table 2**). Flavored 2% fat milk was preferred overall, followed by 2% fat milk, flavored 1% fat milk, flavored whole milk, and flavored skim milk (**Table 2**). Flavored milk was preferred over unflavored milk for all fat content options, likely due to parent understanding of their children's milk preferences and consumption habits as evidenced by demographic and consumption information collected during earlier parts of the survey. When asked to select which type of milk their child consumed most often at school, 24% of parents selected "unflavored/plain/white milk" while 74% of parents selected flavored milk, including 56% chocolate milk, 10% strawberry milk, and 8% vanilla milk. From MXD results, parents placed value on flavored milk as a beverage for their children to consume at school, as flavored milks were ranked 1st, 3rd, 4th, and 5th out of all beverage choices. Parents also indicated that they valued 2% fat milk as a beverage choice for their children (**Table 2**). Lower-fat milk options were less preferred by parents, with 1% fat milk and skim milk scoring below water as a beverage option for schools. As such, skim and low-fat milk options currently being served in schools may not meet parent expectations.

Survey 1 respondents indicated the most familiarity (3.8 on a 4-point familiarity scale) with the flavor of the milk their children drink at school, and the lowest familiarity (3.0 on a 4-point familiarity scale) with the fat content of school lunch milk (**Table 3**). About one-third of parents indicated that they were familiar with fat content of the milk their children drink at school, while the remaining two-thirds of parents were unsure or unfamiliar. Similar to the trends observed during focus groups, parents who participated in Survey 1 indicated limited familiarity with milk nutrition. Ninety-one percent of parents agreed with the statement "Milk is an excellent source of calcium" and 87% agreed that milk is an excellent source of vitamins A and D (**Table 4**). Seventy-four percent of parents agreed that milk is a source of complete protein. Animal-based products such as dairy milk are complete proteins, meaning that they contain all of the amino acids essential for human growth and metabolism (Hoffman and Falvo, 2004). Nearly 47% of parents surveyed also agreed that milk is an excellent source of dietary fiber, despite dairy milk containing 0 mg of fiber per serving (Singhal et al., 2017). Most parents underestimated the amount of lactose in a serving of milk with 53% of parents guessing 4 grams or 8 grams of lactose per serving of plain milk. An 8 fluid ounce serving of plain milk contains 12-13 grams of lactose (Vaskova and Buckova, 2016). Previous research has shown a general lack of food knowledge and health literacy for dairy foods. Schiano et al. (2021) evaluated dairy consumer familiarity with fluid milk and dairy processing using an online survey and a series of in-depth interviews. A majority (80%) of n=54 interview participants indicated they do not typically read nutrition labels on dairy products, and only 1.8% of n=1210 online survey participants could correctly identify the amount of fat, protein, and lactose in whole milk. Researchers also studied knowledge and perception of milkfat in consumers from Denmark, the United Kingdom, and the United States and found that a large portion of participants were not aware of different types of milk fat fatty acids including omega-3 and trans fatty acids (Vargas-Bello-Pérez et al., 2020). Parent preference for milk over other beverages for their children was also reflected in their responses to agree/disagree statements. Parents most strongly agreed with the statement "Schools should be required to offer milk as part of a lunch at school," returning a score of 4.5 on a 5-point agreement scale (**Table 5**). Similar to the trends observed during focus groups, parents preferred their child to drink plain or flavored milk over other beverage options such as water, soda or juice.

Parents also agreed that schools should offer plant-based alternative beverages as part of a lunch at school (**Table 5**). This item is likely motivated by concerns about allergies and intolerances voiced during the focus groups. An estimated 68% of the world's population experiences lactose malabsorption or intolerance, including 30-50 million Americans (National Institute of Child Health & Human Development, 2006; Messia et al., 2007). In addition, milk allergies account for one-fifth of food allergies observed in US children and one-third of children with a milk allergy experience severe symptoms (Williams, 2013). Due to increasingly diverse household dietary requirements, parents are some of the most frequent purchasers of both the dairy and plant-based milk categories. A Mintel survey of n=2000 consumers reported that 88% of participating parents indicated that they purchased dairy milk and 65% of parents indicated that they also purchased plant-based milk alternatives. Comparatively, 80% of non-parent participants purchased dairy milk and 44% purchased non-dairy milk alternatives (Bonnett, 2020). Previous research has also shown that both plant-based alternative consumers and consumers of both dairy milk and plant-based alternatives place value on a lactose-free claim for beverages, which may be motivating parent desire for plant-based alternatives in the school cafeteria setting (McCarthy et al., 2017; Rizzo et al., 2020). Nondairy milk alternatives must meet specific nutritional requirements in order to be served in schools. Singhal et al. (2017) compared the nutritional value of cow's milk to eight nondairy milk alternative options and found that while plant-based dairy alternatives often contained more calcium and iron due to fortification, they contained significantly less protein (Singhal et al., 2017). Consumers may not be aware of nutritional differences between dairy milk and plant-based alternatives due to limited knowledge of milk nutrition and ambivalence to nutrition labels on milk products as previously discussed (Schiano and Drake).

Survey respondents indicated that flavored milk should be offered as part of a lunch at school and also indicated that they would prefer flavored milk options served at school to be reduced-sugar or sugar-free (3.7 on a 5-point agree/disagree scale) (**Table 5**). This result was also observed in previous research with parents regarding purchase of chocolate milk for their children (Li et al., 2015a). Responses to statements about fat content were more neutral, with the statement “It doesn’t matter to me what kind of fat level of milk the school offers” returning a score of 3.0 on a 5-point agreement scale. This result indicates that there may be differing opinions or confusion among parents regarding school lunch milkfat content. Parents were also less sure about statements regarding alternative sweeteners in flavored milk at school, which prompted the decision to further explore perception of these ingredients in chocolate milk in Survey 2.

Before completing the ACBC exercise, parents were presented with a list of 26 school lunch milk attributes in a CATA format and asked to select which were most important to them for a child’s school lunch milk (**Table 6**). The most selected attributes were unflavored (white milk) (61%), chocolate milk (57%), and 2% fat (53%), followed by cardboard carton (34%) and whole fat (33%). One percent fat was selected by 32% of parents and skim milk was selected by 20% of parents, which further demonstrates that these milkfat contents are less preferred by parents compared to 2% and whole milk. A similar trend was observed by Kim et al. (2013), who reported that 1% and 2% fat chocolate milks were conceptually preferred by consumers over skim chocolate milk in an online conjoint analysis exercise (Kim et al., 2013). Li et al. (2014) also observed that low-fat (1-2%) milks received the highest utility score in a conjoint exercise regarding parent choices for chocolate milk for their children.

In Survey 1, the average ideal school lunch milk for parents from the ACBC exercise was unflavored (white milk) or chocolate, 2% fat, ultrapasteurized, with all-natural and hormone-free label claims, packaged in a cardboard gabletop carton. Parents displayed the highest utility for package, milk fat percentage, and flavoring over label claims and heat treatment (**Figure 2**). Positive utility scores were also observed for 1% fat milk, organic and GMO-free label claims, and plastic bottles. Two clusters of parents were identified from utility scores (**Figure 3**). Cluster

1 (n=141) parent ideal school lunch milk was chocolate, 2% fat, ultrapasteurized, with an all-natural label claim packaged in a cardboard gabletop carton. Cluster 2 (n=75) parent ideal school lunch milk was unflavored (white milk), 2% fat, ultrapasteurized, with organic, all-natural, and hormone-free label claims packaged in a cardboard carton. Chocolate and unflavored milk were preferred by both parent clusters over strawberry and vanilla-flavored milk. A 2% fat milk was preferred over all other milkfat contents by both groups of parents, but Cluster 1 parents indicated significant preference for whole milk to be served in schools and had the lowest utility score for skim milk, while Cluster 2 parents indicated preference for 1% fat and skim milk. Both groups of parents preferred an ultrapasteurized milk product over other heat treatment options. Cluster 2 parents displayed a significant preference for organic and all-natural label claims, while Cluster 1 parents returned a positive utility score for school lunch milk with no label claims. Similar to Cluster 1, a group of parents with a preference for all-natural chocolate milk was also observed by Li et al. (2014) in an online survey of extrinsic attributes that motivated parent purchase of chocolate milk for their children. Cluster 2 parents also returned a positive utility score for glass bottles as a packaging material for school lunch milk, which may indicate that they are sustainability-focused. US consumers are increasingly interested in sustainable packaging options for beverages, and glass and metal are perceived as more sustainable than other package options by most consumers (Feber et al., 2020; Otto et al., 2021). From the current study, groups of parents with distinct preferences for school lunch milk exist, but chocolate and unflavored 2% fat milk are universally appealing for school lunch milk. Parental preference for 2% fat milk observed in this study is supported by data collected by the Agricultural Marketing Service and USDA Foreign Agricultural Service from January to December 2019, whole milk and 2% fat milk were the most-consumed milk types in the U.S. with 13,810 and 12,052 million

pounds sold in 2019 respectively. In contrast, 5,184 million pounds of 1% fat milk and 3,067 million pounds of skim milk were sold during the same period (Shahbandeh, 2021). Parent preference for chocolate school lunch milk likely reflects child preference for flavored milk over unflavored milk. Children consistently display a preference for flavored milk and their consumption of milk significantly decreases when flavored milk options are removed (Quann and Adams, 2013; Hanks et al., 2014; Williamson et al., 2015).

Survey 2

Participant demographics for Survey 2 were similar to those seen in Survey 1 (results not shown). All respondents (100%) indicated their children consumed chocolate milk at school, as this was required in order to participate in the survey. Nearly a quarter of parents surveyed (24%) indicated that their child or children consumed chocolate milk every day at school, and 12% indicated their child consumed chocolate milk every day at home. Forty-eight percent of parents indicated their children consumed chocolate milk about 2-4 times per week at school, and 31% indicated the same response for at-home consumption.

Parents were generally not familiar with the amount of added sugar in chocolate milks served at school and at home. All parents who participated in Survey 2 were asked to guess how many grams of added sugar they thought was in the chocolate milk their children consumed at school using a multiple-choice question format with a provided list of options. Currently, school lunch milk contains approximately 8 g of added sugar. Parents tended to overestimate the amount of added sugar in school lunch chocolate milk, with 69% of parents indicating 10 or more grams of added sugar and only 31% indicating 6 grams or less (data not shown). A much wider distribution of responses was observed for parent responses regarding the amount of added sugar in the chocolate milk they served at home. Only parents who previously indicated their children consumed chocolate milk at home (n=127) were shown this question. Of this group of parents, 20% indicated <6 grams of added sugar, 34.6% noted 6-12 grams, and 44.9% indicated 14-22 grams. Consumers tend to underestimate sugar content in foods that have a perceived “health halo” and overestimate sugar content of foods that are perceived as unhealthy (Dallacker et al., 2018; König et al., 2019). Dallacker et al. (2018) reported that parents underestimated the amount of sugar in products such as orange juice and fruit-flavored yogurt in an online study, but 66.2% of n=224 participants overestimated the amount of sugar in a chocolate-flavored granola bar.

Overall responses to agree/disagree questions supported the trends seen in focus groups and in Survey 1 and provided further context to parent preferences for school lunch chocolate milk (**Table 7**). Similar to the trends seen in focus groups, parents agreed that milk is healthy for children because it contains protein and calcium, and some chocolate milks are healthier than others (4.5 and 4.2 on a 5-point agreement scale, respectively). Health statement results showed that parents perceived unflavored milk and water as healthier than chocolate milk, but chocolate milk was healthier than soda or juice. Overall agreement results showed that parents encouraged their children to drink milk at school (4.6 on a 5-point agreement scale), but self-reported that they preferred their children to drink unflavored milk over chocolate milk (3.7 vs 2.4 on a 5-point agreement scale) and encouraged their children to drink plain milk over chocolate milk at school (3.6 vs 2.9 on a 5-point agreement scale). Parent agreement results in combination with their tendency to overestimate sugar content observed in this study suggest that chocolate milk does not benefit from a “health halo” in most parents’ eyes, despite positive perception of its vitamin and protein content.

Survey 2 respondents most strongly agreed that their children choose the flavor of milk that they want to drink at school (4.6 on a 5-point agreement scale) and indicated that their children liked both unflavored and chocolate milk (4.3) (**Table 7**). Parents also indicated that their child preferred chocolate milk to unflavored milk and agreed that schools should offer both unflavored and chocolate milk as part of lunches (4.3). Overall, survey respondents indicated that nutrition, protein content, vitamin/mineral content, and sugar content of school lunch milk were important to them (4.3, 4.3, 4.2, and 4.2, respectively). Parents were neutral that the only sweetener used in chocolate milk should be sugar (3.4 on a 5-point scale). Previous research has shown that parents are divided when it comes to sugar alternatives in children's chocolate milks, with some parents being acceptors of these ingredients and others preferring their children to consume traditional sweeteners such as sucrose (Li et al., 2015a).

Overall, parents indicated in the MaxDiff exercise that the most important characteristics of chocolate milk served in school were high calcium content and freshness, followed by child consumption of the milk (**Table 8**). Parents also indicated that vitamin D and protein content were important. Parents had a general preference for higher fat chocolate milks, with whole milk and 2% fat milk receiving higher importance scores than 1% fat milk or skim milk, consistently with milk fat content preferences throughout this study. High MaxDiff scores for calcium, vitamin D, and protein content highlight the importance that parents place on the nutritional benefits of chocolate milk, which corroborates what was seen in focus groups. Parent desire for these nutrients may be influenced by advertisement campaigns mentioned by focus group participants that highlighted the benefits of calcium, protein, and vitamin D (Daddona, 2018). Parents also indicated that it was important for chocolate school lunch milk to not contain artificial sugar alternatives, but were more accepting of natural and unspecified sugar alternatives.

Further exploration of parental perception of alternative sweeteners through semantic differential (sliding scale) questions also revealed distinct groups of parents with differing preferences for sugar alternatives and illustrated that most parents are open to these ingredients in school lunch milk (**Table 9**). Overall, parents indicated that it was more important for chocolate milk to be healthy than for their children to like it (-4.0 on a sliding scale where -10=important for it to be healthy and 10=important for my child to like it). Survey participants were neutral toward sugar alternatives in school lunch milk when the type of sugar alternative was not specified (0.3 on a sliding scale where -10= not interested and 10 = interested), but their acceptance of sugar alternatives significantly increased when the sugar alternatives were specified as "natural" (3.9) and decreased when sugar alternatives in school lunch chocolate milk were specified as "low-calorie" (-0.4). These results correlate with those observed by Li et al. (2014) in which the majority of parents indicated preference for natural nonnutritive sweeteners over artificial nonnutritive sweeteners.

Survey respondents were clustered based on their responses to the MaxDiff exercise in Survey 2 (**Table 8**). Three clusters of parents were identified, designated the "Natural" Parents (n=64), the "Vitamins" Parents (n=43) and the "Sugar" Parents (n=16) to represent the core values of each group. Other survey results, including agreement questions and sliding scale responses, were also analyzed by cluster to build a comprehensive consumer profile for these groups of parents (**Tables 7, 9**).

“Natural” Parents (n=74)

“Natural” parents were motivated by freshness, simple ingredients, and an all-natural label in the MaxDiff exercise, as well as chocolate milks that do not contain sugar alternatives, particularly artificial sugar alternatives (**Table 8**). This group’s responses to agreement questions indicate a preference for unflavored/plain milk over chocolate milk, as parents in this group indicated that they viewed chocolate milk as a treat and showed the lowest agreement score of the three identified clusters with the statement “Schools should offer chocolate milk as part of lunches” with a score of 3.7 on a 5-point agreement scale compared to 4.4 for “Vitamins” parents and 4.3 “Sugar” parents. These parents were also neutral regarding the statement “I want my child to drink milk, it doesn’t matter if it’s plain or chocolate” while parents in other groups agreed with this statement. These “natural” parents also agreed that chocolate milk usually has too much sugar, which may help to explain why it is viewed as a treat. Parents were asked to indicate their opinion of sugar alternatives using a series of sliding scale questions (**Table 9**). Sliding scale responses from “Natural” parents indicated a disinterest in sugar alternatives in chocolate school lunch milk unless the alternatives were specified as “natural”. This group was the largest cluster observed in the study.

“Vitamins” Parents (n=43)

“Vitamins” parents valued calcium content, vitamin D content, and freshness of chocolate milk, and indicated that their child(ren)’s acceptance and consumption of chocolate milk was most important to them. This group of parents felt that schools should not offer low-sugar chocolate milks if children like them less and agreed that the nutrient content of chocolate milk was more important than the sugar content (**Table 7**). While this cluster of parents still felt it was important for chocolate milk to be healthy, the level of importance they placed on their children liking the milk was significantly higher than either of the other clusters (**Table 9**). These parents viewed chocolate milk as an important nutrient delivery mechanism for their children and were willing to make compromises on sugar content in exchange for their children's acceptance and consumption of important vitamins and minerals for growth.

"Sugar" Parents (n=16)

These parents were the most accepting of sugar alternatives in chocolate school lunch milk, returning positive sliding scale scores for unspecified, natural, and low-calorie sugar alternatives (**Table 9**). "Sugar" parents valued label claims regarding sugar content above all other characteristics of chocolate milk, placing the highest importance on "no sugar added," "low sugar," and "reduced sugar" label claims, followed by calcium and protein content (**Table 8**). This group of parents agreed more strongly that schools should offer low-sugar chocolate milks even if children like them less, and indicated that the sugar content of chocolate milk is more important than its nutrient content.

Parents' responses to Survey 2 provide further context to the results observed in Survey 1 and suggest that parents value chocolate milk as part of meals at school for its nutritional benefits. This work, along with previous studies (Kim et al., 2013; Li et al., 2014, 2015a) supports the conclusion that distinct groups of parents with different preferences for chocolate milk and sugar alternatives exist. Parental opinions surrounding chocolate milk observed in this study align with previously observed trends that parents value low-fat (1% and 2%) milk options and natural labeling on children's chocolate milk products. It was also observed in both surveys that most parents are interested in reducing the sugar content of children's chocolate milk and are open to the use of sugar alternatives, particularly natural alternatives. Limited studies have been conducted to evaluate sugar alternatives in chocolate milk (Li et al., 2015b; McCain et al., 2018).

Previous work has evaluated children's perception of school lunch milk, including both its extrinsic and intrinsic characteristics, but more work is required to understand how reduced-sugar chocolate milk are perceived by children (Sipple et al., 2021).

Some limitations of this study are that the respondents were generally from the Raleigh NC area and may not be representative of parents nationally. This study is also subject to response bias, as only parents who at least moderately valued their children's milk consumption completed online survey activities. This may have resulted in an over- or underestimation of the value that parents place on school lunch milk attributes (Villar, 2011).

CONCLUSION

Children's consumption of milk as part of lunch of school is important to parents, and milk is preferred over other beverage options for school lunches, including water, juice, and soda. Parents in all phases of this study displayed a consistent and clear preference for 2% fat milk over skim and 1% fat milk and indicated that the calcium, vitamin D, and protein content of children's school lunch milk are important to them. Parents also value flavored milk as a vehicle for delivering important nutrients to their children. Current school lunch milk options, which are limited to skim and 1% plain and flavored milk, may not meet parental expectations for their children. Parents are divided on the use of sugar alternatives in chocolate milk served in schools, with some parents highly in favor of these ingredients and others less so. In order to further bolster parent positive attitudes towards milk and flavored milk, manufacturers of school lunch milk should consider the use of natural sugar alternatives in chocolate milk as a means of reducing the sugar content while highlighting milk's calcium, vitamin D, and protein.

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Table 4.1: Adaptive Choice Based Conjoint (ACBC) levels and attributes for parent importance of school lunch milk attributes (Survey 1)

Flavor	Unflavored (white milk) Chocolate Strawberry Vanilla
Fat Content	Skim 1% fat 2% fat Whole Milk
Heat Treatment	HTST pasteurized[1] Ultrapasteurized[2] UHT pasteurized[3]
Label Claim 1	Organic All Natural DHA Omega-3 Grass-fed Ultra-Filtered (Protein Enriched) No label claim
Label Claim 2	rBST-free GMO free Lactose free Hormone free No label claim
Packaging Type	Plastic Bottle Cardboard Carton Dispenser Glass Bottle Tetra Pak (Shelf Stable)

1. The term "HTST pasteurized" was accompanied by the description "HTST (High Temperature, Short Time) Pasteurized Milk is heated to 72°C for 15 seconds. This is the milk that you typically buy at the grocery store from the refrigerated section. If refrigerated properly, this milk has a shelf life of 18-21 days."
2. The term "Ultrapasteurized" was accompanied by the description "Ultrapasteurized Milk is heated to a higher heat treatment than HTST milk, 138°C for 2-3 sec, which extends its refrigerated shelf life. Ultrapasteurized Milk has an unopened refrigerated shelf life of 60-90 days."
3. The term "UHT pasteurized" was accompanied by the description "UHT (Ultra High Temperature) is commercially sterile milk and does not require refrigeration when unopened. It is typically stored unrefrigerated for 6-9 months."

Table 4.2: Maximum Difference results for parent-preferred beverages to be served in schools from Survey 1 (n=216)

Attribute	Zero-Centered Interval Score
Flavored 2% Fat Milk*	10.5[a]
2% Fat Milk	9.7[b]
Flavored 1% Fat Milk*	9.3[bc]
Flavored Whole Milk*	9.2[bcd]
Flavored Skim Milk*	8.8[cde]
Whole Milk	8.5[def]
Water	8.4[ef]
1% Fat Milk	8.1[f]
Skim Milk	6.0[g]
Flavored Water	5.0[h]
Apple Juice	4.3[i]
Orange Juice	3.6[i]
Lemonade	2.6[j]
Sports Drinks	2.1[jk]
Iced Tea	1.4[kl]
Sugar-Free/Diet Lemonade	1.21[l]
Soda	0.7[lm]
Sugar-Free Soda	0.5[m]
Diet Soda	0.3[m]

Parents were asked to indicate which beverage they were most interested and least interested in their child consuming as part of their lunch at school. Means have been rescaled to sum to 100. A higher number indicates a more preferred beverage.

*Flavored milk was specified as “(Chocolate, Strawberry, Vanilla)”.

Table 4.3: Mean parent responses to school lunch milk familiarity questions from Survey 1 (n=216)

Attribute	Mean Score	Distribution				
		Not at all Familiar	*Slightly Familiar*	*Somewhat Familiar*	*Very Familiar*	*Extremely Familiar*
Fat content of the milk my children drink at school	3.0[c]	19.4%	14.8%	31.9%	16.2%	17.6%
Flavor of the milk my children drink at school	3.8[a]	3.7%	7.9%	22.2%	34.3%	31.9%
Packaging of the milk my children drink at school	3.25[bc]	16.2%	12.0%	25.5%	22.7%	23.6%
Serving size of the milk my children drink at school	3.32[b]	12.5%	14.4%	23.6%	27.8%	21.8%

A 5-point familiarity scale was used where 1= not at all familiar and 5= extremely familiar. Means within a column followed by a different letter are significantly different ($p<0.05$). Percentages represent percentage of Survey 1 participants that selected each option for each row.

Table 4.4: Mean parent responses to milk nutrition familiarity questions from Survey 1 (n=216)

Statement	Mean Score	Distribution				
		Completely Disagree	*Somewhat Disagree*	*Neither Agree nor Disagree*	*Somewhat Agree*	*Completely Agree*
Milk is an excellent source of **calcium**	4.5[a]	2.8%	0.9%	5.1%	25.0%	66.2%
Milk is an excellent source of **vitamins A and D**	4.3[a]	2.8%	1.9%	8.3%	35.6%	51.4%
Milk naturally contains **lactose**	4.3[ab]	2.8%	0.0%	15.7%	30.1%	51.4%
Milk is a source of **complete protein**	4.0[b]	3.2%	7.9%	14.8%	35.6%	38.4%
Milk naturally contains **glucose**	3.7[c]	5.6%	3.7%	33.3%	30.6%	26.9%
Milk is an excellent source of **dietary fiber**	3.3[c]	12.5%	11.6%	29.2%	22.7%	24.1%

A 5-point agree/disagree scale was used where 1= completely disagree and 5= completely agree. Means within a column followed by a different letter are significantly different ($p<0.05$). Percentages represent percentage of Survey 1 participants that selected each option for each row.

Table 4.5: Mean parent responses to agree/disagree questions from Survey 1 (n=216)

Statement	Mean Score
Schools should be required to offer milk as part of a lunch at school.	4.5[a]
I would prefer my child drink plain milk than other beverages, like soda or juice, served at school.	4.4[ab]
I would prefer my child drink flavored milk than other beverages, like soda or juice, served at school.	4.2[abc]
Schools should offer lactose-free milk for lunch at school.	4.0[bcd]
Schools should offer plant based alternative beverages (eg almond milk) for lunch at school	3.9[cd]
Flavored milk should be offered at school as part of a lunch at school.	3.8[de]
I would prefer the flavored milk served at school lunches to be reduced sugar or sugar free.	3.7[de]
Schools should offer ultrafiltered (protein enriched) milk for lunch at school.	3.4[ef]
It doesn't matter to me what kind of milk (white/unflavored, chocolate, strawberry, etc.) the school offers.	3.0[fg]
It doesn't matter to me what kind of fat level of milk the school offers.	3.0[fg]
I would prefer my child drink plain milk than water served at school.	3.0[fg]
I would prefer my child drink flavored milk than water served at school.	2.8[gh]
It doesn't matter to me if there is added sugar in the flavored milk the school offers as long as my child likes and drinks the milk	2.8[gh]
It doesn't matter to me if there are natural sugar alternatives, like stevia, in the flavored milk the school offers to my child	2.7[gh]
It doesn't matter to me if there are sugar alternatives, like stevia or sucralose, in the flavored milk the school.	2.5[h]

A 5-point agree/disagree scale was used where 1= completely disagree and 5= completely agree. Means followed by a different letter are different ($p<0.05$).

Table 4.6: Results of CATA exercise for parents' important school lunch attributes asked in Survey 1 (n=216)

TOP 50% SELECTED ITEMS			BOTTOM 50% SELECTED ITEMS		
Attribute ID	**Attribute**	**Percentage**	**Attribute ID**	**Attribute**	**Percentage**
1	Unflavored (white milk)	60.6%[a]	14	Lactose-Free	17.1%[defghij]
2	Chocolate	57.4%[ab]	15	Ultra-Pasteurized	16.2%[defghij]
3	2% Fat	53.2%[abc]	16	Grass-fed	15.3% [defghij]
4	Cardboard Carton	34.3%[abcd]	17	rBST-free	13.0% [defghij]
5	Whole fat	32.9%[abcde]	18	DHA Omega-3	12.5% [defghij]
6	Strawberry	31.9%[bcdef]	19	Plastic Bottle	9.7% [efghij]
7	1% Fat	31.9%[bcdef]	20	Glass Bottle	9.3% [fghij]
8	Hormone Free	30.1%[bcdefg]	21	Ultra-Filtered (Protein Enriched)	8.3%[ghij]
9	Vanilla	28.2%[cdefg]	22	HTST Pasteurized	6.0%[hij]
10	Organic	26.9%[cdefgh]	23	UHT Pasteurized	5.6%[ij]
11	All Natural	24.5%[defghi]	24	Dispenser	5.1%[ij]
12	Skim	19.9%[defghij]	25	Tetra Pak (Shelf Stable)	5.1%[ij]
13	GMO free	17.6%[defghij]	26	No Label Claim	3.2%[j]

Values represent percentage of Survey 1 participants that selected each option. Means followed by a different letter are different ($p<0.05$)

Table 4.7: Results of agree/disagree questions from parents in Survey 2 (n=133)

Group	Question Text	Overall (n=133)	"Natural" (n=74)	"Vitamins" (n=43)	"Sugar" (n=16)
Children's Acceptance of Milk	My children choose the flavor of milk that they want to drink at school.	4.58^{A}	4.5	4.7	4.5
	My child likes both plain and chocolate milk.	4.29^{ABCDE}	4.3	4.4	4.1
	My child prefers chocolate milk to plain milk.	$4.02^{ABCDEFGH}$	3.9	4.0	4.5
	Schools should offer low-sugar chocolate milks even if children like them less.	$3.82^{CDEFGHIJ}$	4.0	3.3	4.3
	My child prefers plain milk to chocolate milk.	2.69^{OPQRS}	2.7	2.7	2.8
	Schools should not offer low-sugar chocolate milks if it means children like them less.	2.2^{RS}	2.0	2.7	1.8
Health	Milk is healthy for kids because it contains protein and calcium.	4.47^{AB}	4.3	4.7	4.6
	Milk is healthy for kids because it contains calcium.	4.37^{ABC}	4.2	4.7	4.6
	Chocolate milk is healthier for kids than soda.	4.34^{ABCD}	4.3	4.5	4.2
	Milk is healthy for kids because it contains protein.	4.26^{ABCDEF}	4.1	4.5	4.6
	Some chocolate milks are healthier for kids than others.	4.16^{ABCDEF}	4.1	4.3	4.0
	Plain milk is healthier than chocolate milk for kids.	$4.05^{ABCDEFGH}$	4.2	3.9	4.1
	Chocolate milk is healthier for kids than juice.	$3.78^{DEFGHIJ}$	3.5	4.1	4.1
	Lactose-free chocolate milk is healthier for kids than regular chocolate milk.	$2.85^{MNOPQRS}$	2.8	2.9	2.9
	Lactose-free plain milk is healthier for kids than regular plain milk	2.77^{NOPQRS}	2.8	2.8	2.6
	Chocolate milk and plain milk are equally healthy for kids.	2.62^{PQRS}	2.4	2.9	3.1
	Chocolate milk is not healthy for kids.	2.56^{QRS}	2.7	2.2	2.9
	Chocolate milk is healthier for kids than water.	2.19^{RS}	1.8	2.6	2.9
	Chocolate milk is healthier than plain milk for kids.	2.00^{S}	1.8	2.2	2.6
Importance	The nutrition provided by the milk offered at school is important to me.	4.35^{ABC}	4.3	4.3	4.4
	The protein content of milk my child drinks at school is important to me.	4.3^{ABCD}	4.3	4.3	4.6
	The vitamin/mineral content of milk my child drinks at school is important to me.	4.25^{ABCDEF}	4.2	4.2	4.4
	The sugar content of milk my child drinks at school is important to me.	4.17^{ABCDEF}	4.2	3.9	4.7
	The protein content of chocolate milk is more important than the sugar content.	$2.94^{KLMNOPQR}$	3.0	2.9	2.8
	The vitamin/mineral content of chocolate milk is more important than the sugar content.	2.71^{OPQRS}	2.2	3.6	2.8
	The brand of milk my child drinks at school is important to me.	2.17^{RS}	1.7	2.8	2.4
Misc.	Chocolate milk is a treat, not something that my children consume often.	$3.40^{GHIJKLM}$	3.6	3.1	3.3
	I personally consume chocolate milk.	$3.38^{HIJKLMN}$	3.1	3.8	3.5
	The pros of chocolate milk outweigh the cons.	$3.38^{IJKLMNO}$	3.2	3.7	3.3
	The cons of chocolate milk outweigh the pros.	2.72^{NOPQRS}	2.8	2.6	2.8
	My children are interested in the nutrition of the milk offered at school.	2.23^{QRS}	2.2	2.2	2.6

Table 4.7: Results of agree/disagree questions from parents in Survey 2 (n=133) (continued)

Preference and Encouragement	I encourage my children to drink milk at school.	4.15^{ABCDEFG}	3.9	4.5	4.6
	I prefer that my child drink plain milk.	3.73^{DEFGHIJ}	3.9	3.5	3.7
	I want my child to drink milk, it doesn't matter if it's plain or chocolate.	3.60^{EFGHIJK}	3.1	4.4	4.0
	I encourage my children to drink plain milk at school.	3.57^{FGHIJKL}	3.5	3.7	3.4
	I encourage my children to drink chocolate milk at school.	2.92^{LMNOPQR}	2.6	3.3	3.4
	I would prefer my children not to drink chocolate milk at school.	2.65^{OPQRS}	3.0	2.1	2.9
	I prefer that my child drink chocolate milk.	2.44^{QRS}	2.1	2.8	3.1
School Milk Choices	Schools should offer plain milk as part of lunches.	4.50^{A}	4.5	4.6	4.4
	Schools should offer both chocolate and plain milk as part of lunches.	4.35^{ABCD}	4.1	4.7	4.4
	Schools should offer chocolate milk as part of lunches.	4.02^{ABCDEFGHI}	3.7	4.4	4.3
	Schools should offer more flavors of milk than they currently do.	3.00^{KLMNOPQ}	2.8	3.2	3.5
Sugar	Some chocolate milks contain more sugar than others.	4.46^{AB}	4.5	4.4	4.6
	Milk naturally contains some sugar.	4.42^{AB}	4.5	4.3	4.6
	Lactose is naturally found in plain milk.	4.4^{ABC}	4.4	4.3	4.6
	Chocolate milk usually contains too much sugar.	3.93^{BCDEFGHIJ}	4.2	3.6	3.8
	The only sweetener used in chocolate milk served at school should be sugar.	3.36^{JKLMNO}	2.9	4.0	3.8
	It doesn't matter to me if there is added sugar in the chocolate milk the school offers as long as my child likes and drinks the milk	3.31^{JKLMNOP}	3.0	3.8	3.5
	It doesn't matter to me what the sugar content of chocolate milk is as long as my child drinks it.	3.31^{JKLMNOP}	3.4	3.4	2.9

Agreement was rated on a 5-point scale where 1=completely disagree and 5=completely agree. Means followed by a different letter are different ($p<0.05$).
"Natural", "vitamins" and "sugar" are identified clusters of parents from MaxDiff scores for important attributes of school lunch chocolate milk in Survey 2.

Table 4.8: Maximum Difference (MXD) results for parent ideal school lunch chocolate milk attributes from Survey 2 (n=133)

Attribute Category	Attribute	Overall (n=133)	"Natural" (n=74)	"Vitamins" (n=43)	"Sugar" (n=16)
Fat Content	Skim milk	0.85^{LMN}	0.68	0.67	2.16
	1% fat milk	1.40^{L}	1.17	1.06	3.37
	2% fat milk	2.25^{IJ}	2.29	1.98	2.77
	Whole milk	2.95^{H}	1.53	5.25	3.36
Sugar Claims	No sugar added	3.95^{EFG}	4.55	1.23	**8.51**
	Reduced sugar	4.09^{DEF}	4.49	2.05	**7.72**
	Low sugar	4.26^{DEF}	4.79	1.88	**8.21**
	Does not contain artificial sugar alternatives [1]	6.07^{A}	**8.12**	3.88	2.45
	Does not contain natural sugar alternatives [2]	3.68^{FG}	4.82	2.59	1.35
	Does not contain sugar alternatives	4.71^{BCD}	**6.32**	2.93	2.11
Nutrition Claims	High in calcium	**6.46**^{A}	5.50	**8.11**	**6.51**
	High in Vitamin D	**6.19**^{A}	5.10	**8.31**	5.53
	High protein content	**6.14**^{A}	5.16	7.35	**7.40**
	Lactose free	0.95^{LMN}	1.04	0.53	1.62
Label Claims	Fresh	**6.41**^{A}	**5.87**	**7.80**	5.15
	Simple ingredients	4.78^{BC}	**5.80**	3.95	2.26
	Short ingredient list	3.35^{GH}	4.71	1.90	0.95
	Locally farmed	2.08^{JK}	2.54	1.60	1.19
	All natural	5.06^{B}	**6.30**	3.73	2.87
	Organic	2.91^{HI}	3.80	1.46	2.71
Children's Acceptance	My child drinks it	**6.27**^{A}	4.81	**9.22**	5.09
	My child likes it	5.85^{A}	4.47	**8.70**	4.62
	Good chocolate flavor	4.52^{CDE}	3.33	6.75	4.05
Packaging and Shelf Life	Shelf stable	0.82^{LMN}	0.22	1.65	1.32
	Long shelf life	0.72^{MN}	0.30	1.12	1.55
	Easy to open packaging	1.45^{KL}	0.63	2.56	2.24
	Sustainable packaging	1.33^{LM}	1.32	1.18	1.74
	Resealable packaging	0.52^{N}	0.34	0.59	1.19

Parents were asked to indicate which characteristics were most important and least important when considering the chocolate milk their children drank at school. Means have been rescaled to sum to 100. Top 5 most important attributes (highest importance scores) have been bolded and colored to represent the defining characteristics of each group. A higher number indicates a more preferred attribute.

Different uppercase letters next to means in the overall column indicate significant differences between attributes overall ($p<0.05$). "Natural", "vitamins" and "sugar" are identified clusters of parents from MaxDiff scores for important attributes of school lunch chocolate milk in Survey 2.

1. Sucralose provided as an example
2. Stevia provided as an example

Table 4.9: Semantic Differential (Sliding Scale) Results from Survey 2 (n=133)
Health vs. Acceptance

Group	n	Semantic Differential Score
Overall	133	-4.0
“Natural”	74	-5.2
“Vitamins”	43	-1.4
“Sugar”	16	-5.8

Left Anchor (-10): It’s important that the chocolate milk my child drinks is healthy. Right Anchor (10): It’s important that my child likes the chocolate milk they are drinking. “Natural”, “vitamins” and “sugar” are identified clusters of parents from MaxDiff scores for important attributes of school lunch chocolate milk in Survey 2.

No Sugar Alternatives vs. Sugar Alternatives

Group	n	Semantic Differential Score
Overall	133	0.3
“Natural”	74	-0.5
“Vitamins”	43	-0.9
“Sugar”	16	6.8

Left Anchor (-10): I would not like to see sugar alternatives in the chocolate milk served at school. Right Anchor (10): I would like to see sugar alternatives in the chocolate milk served at school. “Natural”, “vitamins” and “sugar” are identified clusters of parents from MaxDiff scores for important attributes of school lunch chocolate milk in Survey 2.

No Natural Sugar Alternatives vs. Natural Sugar Alternatives

Group	n	Semantic Differential Score
Overall	133	3.9
“Natural”	74	5.0
“Vitamins”	43	1.6
“Sugar”	16	5.3

Left Anchor (-10): I would not like to see natural sugar alternatives in the chocolate milk served at school. Right Anchor (10): I would like to see natural sugar alternatives in the chocolate milk served at school. Survey participants were provided with the terms agave and stevia as example of natural sugar alternatives. “Natural”, “vitamins” and “sugar” are identified clusters of parents from MaxDiff scores for important attributes of school lunch chocolate milk in Survey 2.

No Low-Calorie Sugar Alternatives vs. Low-Calorie Sugar Alternatives

Group	n	Semantic Differential Score
Overall	133	-0.4
“Natural”	74	-0.8
“Vitamins”	43	-2.3
“Sugar”	16	6.6

Left Anchor (-10): I would not like to see low-calorie sugar alternatives in the chocolate milk served at school. Right Anchor (10): I would like to see low-calorie sugar alternatives in the chocolate milk served at school. Survey participants were provided with the terms erythritol and sucralose as example of low-calorie sugar alternatives. “Natural”, “vitamins” and “sugar” are identified clusters of parents from MaxDiff scores for important attributes of school lunch chocolate milk in Survey 2.

Figure 4.1: Moderator Guide Used for School Lunch Milk Focus Groups

ICEBREAKER: What is your child's favorite and least favorite food?

Topic 1: Your Childhood Milk Consumption

- Did you drink milk as a child?
- What kind of milk did you drink when you were a child?

Topic 2: Drinking Milk at Home

- How do you serve milk at home?
    - Is it served as a beverage or as part of a meal?
    - Is it for your children or for your entire family?
- Why do you serve milk at home?
    - Probe belief systems
- Do you also serve milk alternatives at home?
    - Are they for you or for your entire family?
    - If not, why?
    - If yes, why?
    - If yes, what types?

Topic 3: School Lunch Milk

All of you indicated that your child drinks milk at school. Confirm. All of your indicated that you thought that was an important part of the school lunch program. Confirm.

Do you know what the school lunch milk looks like in terms of packaging? Have you ever tasted school lunch milk? What fat content is the school milk? How important is the fat content of school lunch milk to you? What volume is school lunch milk served in? Does your child talk to you about the school lunch milk? Do they like it/dislike it?

Talk about white milk first. Is the fat content of school lunch white milk important?

For chocolate milk, is the fat content important? Do any of the other ingredients matter? What about the sugar content?

Probe beliefs regarding fat content- would parents be comfortable increasing fat content if it meant their child drank more milk? Is that specific to flavored/unflavored milk?

Now that we've talked about school lunch milk, how important is the fat content of school lunch milk? Would it matter to you if the milk fat content increased from skim to 1% if it meant your child drank more milk? We've talked about chocolate milk a little bit. Would you be okay with chocolate milk being served to your child if it meant your child drank more milk? Does the fat content of the chocolate milk matter?

Right now, the only milk being served in schools is skim and 1% white milk and skim milk chocolate. Does this surprise you? Did you know this?

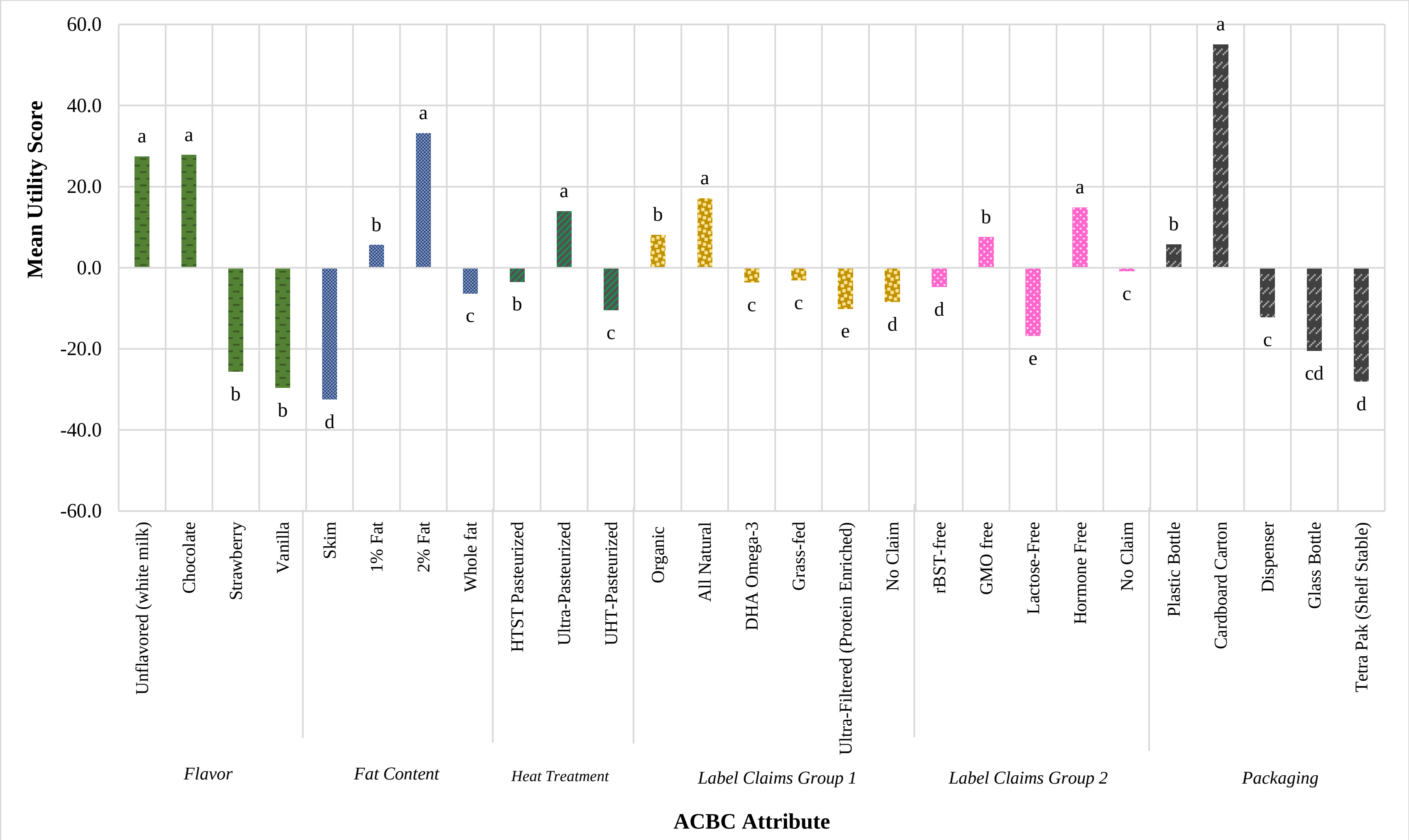
If you were designing a school lunch program, what kind of milk would you want your child to drink? (worksheet)

Topic 4: Analysis of Currently Available Products

For this section, participants will be given examples of milk products that may be offered in school and discuss their perception of each.

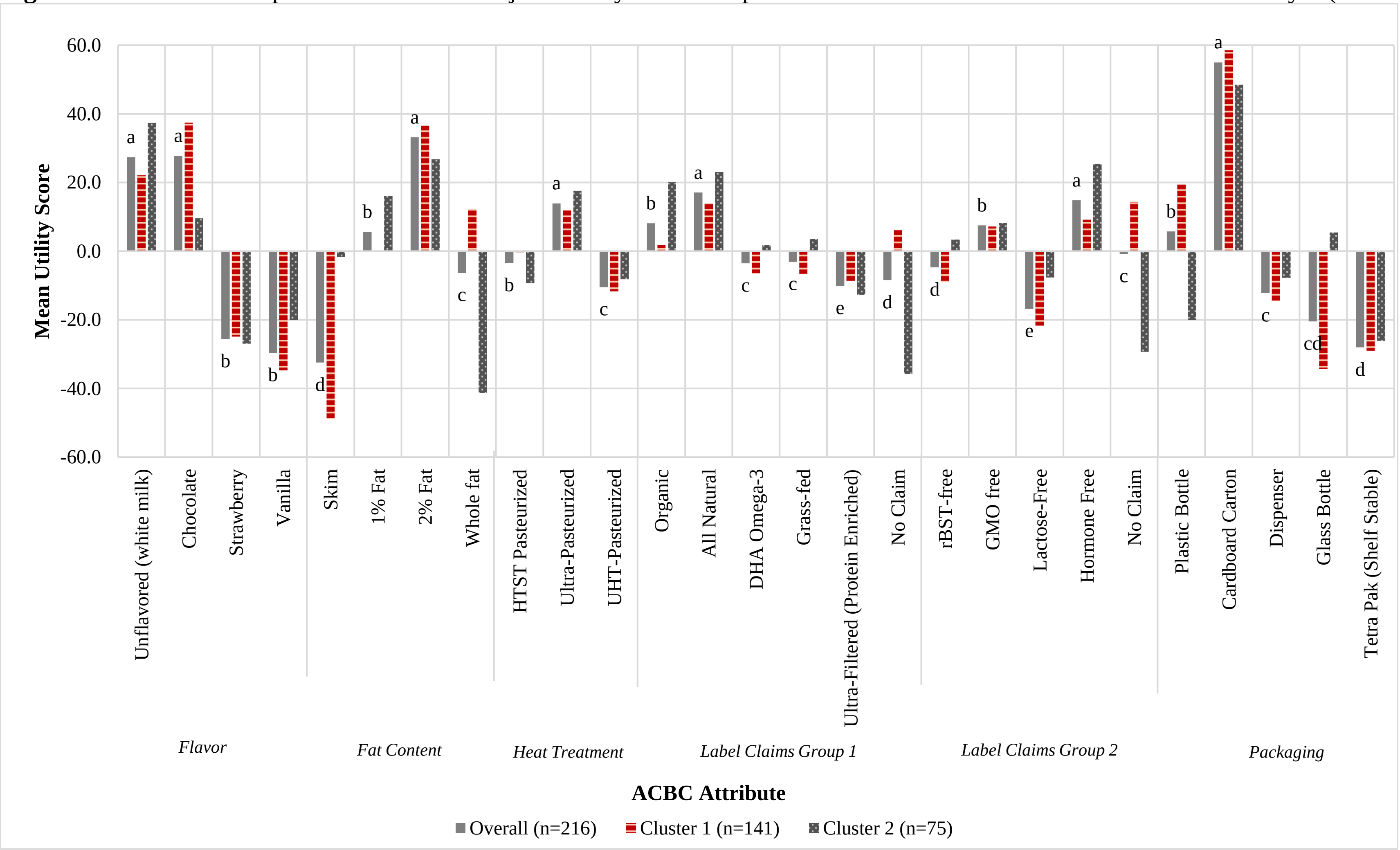
- Packaging
    - Bottles
    - Cartons
    - Dispenser
    - Plastic
    - Tetra packs
- Nutrition
    - Protein Content
    - Sugar Content
    - Fat Content
    - Vitamins/Minerals

Figure 4.2: Overall adaptive choice based conjoint utility scores for parent-desired attributes of school lunch milk from Survey 1 (n=216)



Different letters above bars indicate differences within an attribute ($p<0.05$).

Figure 4.3: Clustered adaptive choice based conjoint utility scores for parent ideal school lunch milk attributes from Survey 1 (n=216)



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SUPPLEMENTAL

Figure 1: Study overview for assessing parents' perception of school lunch milk

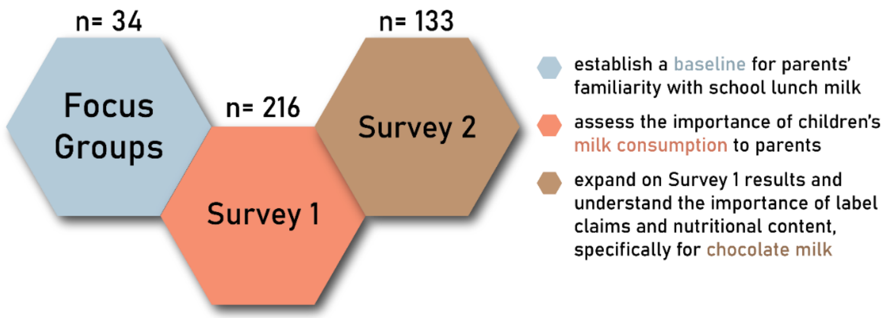

Figure 2: Survey 1 overview for assessing parents' perception of school lunch milk

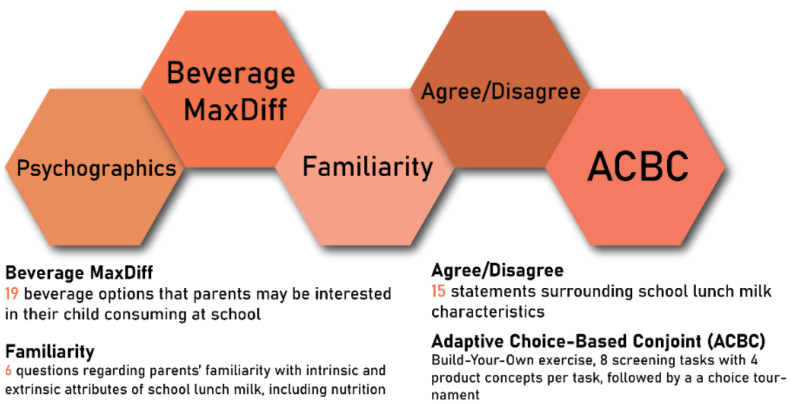

Figure 3: Survey 2 overview for assessing parents' perception of school lunch milk