ABSTRACT

HOMWONGPANICH, KUMPOL. Flavor and Consumer Perception of Dairy and Plant-based Cheese (Under the direction of Dr. MaryAnne Drake).

Cheese consumption and demand continue to rise. Concurrently, so does consumer interest in plant-based foods. A new plant-based category, plant-based cheeses, rose in popularity due to the increase in demand for plant-based foods. The plant-based cheese market remains small when compared to the dairy cheese market in the U.S. An objective sensory tool to document sensory properties of plant-based cheeses is necessary to facilitate product development and communication. In the first study, the first study, a sensory language to characterize and quantify attributes of plant-based cheeses was identified. The overall perceived sensory similarity/difference between plant-based mozzarella and Cheddar cheeses compared to the dairy counterparts was determined with projective mapping. In total, three lexicons were identified for plant-based cheeses including cold flavor, cold texture, and melted texture. The lexicons were validated by sensory evaluation of twenty-one commercial plant-based cheeses. Projective mapping determined that plant-based cheeses were different from each other and remained distinct from dairy counterparts.

The second study determined the impact of extrinsic attributes on consumer desires for block mozzarella cheese. An online survey and focus groups were conducted to achieve this goal. The online survey (n=437) utilized adaptive choice-based conjoint (ACBC), maximum difference (MXD) scaling, and kano modeling. Excluding price, milk fat and label claims were the most important attributes to consumers ($p<0.05$). The ideal block mozzarella for U.S. consumers was whole milk, firm texture/shreds well, block/bar shape, with resealable packaging and farmer owned labeling. Twenty-three label claims were investigated, and two consumers clusters were

identified. Cluster 1 (n=249) was named the Natural cluster because they placed high importance on label claims such as produced without added hormones, all natural, organic, rBST free, and natural cheese. Cluster 2 (n=188) was identified as the Flavor cluster because labels such as farmer owned for more than 75 years, made locally, made with milk from our pasture-raised cows, established business for more than 75 years, and #1 in Italy were of importance to them. The flavor cluster also valued labels such as premium taste, artisan quality, Italian style, traditionally cultured, and natural cheese. Price had the most influence on block mozzarella selection for everyday use, however, extrinsic attributes played an important role for special occasions as consumers look to those attributes as indicators of quality.

Flavor and Consumer Perception of Dairy and Plant-based Cheese.

By
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BIOGRAPHY

Kumpol Homwongpanich was born in 1997 to Rada Loetpunnarom and Weerasak Homwongpanich in Chainat, Thailand. He was raised by his loving grandmother, mother, and aunt. Since a young age of 6 months, Kumpol has always experienced health complications due to a genetic disorder called E-beta Thalassemia, which motivated his father to move abroad to the United States of America for a better job opportunity that could support his medical expenses. Later on, his family relocated him to Bellflower, California at the age of 10 with the hope of providing him with a better education. Kumpol graduated from Mayfair High School in 2016 and continued on with his education at California Polytechnic State University San Luis Obispo (Cal Poly SLO) majoring in biology. After two years of undergraduate study, he made a difficult decision to pivot to food science. Kumpol came across a lab assistant position for the Sensory Team with Dr. Amy Lammert conducting sensory research at Cal Poly SLO which immediately caught his interest. The lab assistant position, the class lecture, and frequent conversations with Dr. Lammert sparked his interest in the field of sensory and consumer science. He went on to pursue a Master’s degree in Food Science under the advisement of Dr. MaryAnne Drake with the goal of becoming a better sensory scientist.

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INTRODUCTION

The consumption of plant-based food alternatives has been on the rise in the United States and globally with the U.S. retail sales alone rising from $5.5B in 2019 to $8.0B in 2022 (Plant Based Foods Association, 2023). The dramatic rise and growth of this category, stemming largely from the health and sustainability halo, instigated food company giants and startup investors to initiate product launches into retail stores and the introduction of plant-based menus in the restaurant industry. However, a few plant-based categories, notably plant-based meat, plant-based ice cream, and plant-based cheese experienced a decline in growth for the first time following the 2022 end-of-the-year report (Plant Based Foods Association, 2023). Market research reports and peer-reviewed literature agreed that some of the shortcomings of plant-based food products are flavor and price (O'Donnell et al., 2023; Plant Based Foods Association, 2023; McClements and Grossmann, 2022; Falkeisen et al., 2022).

Meilgaard et al. (2016) stated that prosperous companies tend to excel in obtaining and understanding their consumers. Sadly, many food products in general failed because of the failure to assess consumer desires before launching. The plant-based market is a fast-evolving market that went from a few large players to a highly saturated and competitive market in less than a decade. The question is "will this market continue to grow"? The goal of this review and the following research is to investigate and contribute to the limited published peer-reviewed papers on consumer perceptions, desirability, and acceptability of plant-based cheeses.

PLANT-BASED CHEESE MARKET OVERVIEW

McClements and Grossman (2022) coined the term “next-generation plant-based foods” as “foods that are specifically designed to mimic the properties of existing animal-based foods”. This literature review will focus on commercially available plant-based products that are designed to serve as alternatives to their traditional counterparts, especially plant-based cheeses. The term next-generation plant-based food (hereafter referred to as plant-based food) in this review does not include the unique category of plant-based products with their own identities such as tofu, tempeh, or whole fruits and vegetables such as broccoli, pea, or apple for example. Plant-based foods have experienced drastic growth within the past few years. Notably, the Plant Based Foods Association reported that the total U.S. plant-based foods sales increased by 27.9% from 2019 to 2020. In 2022, the plant-based foods market concluded the year with a total U.S. sale of $8B. The largest contributor of sales was plant-based milk which accounted for $2.8B of the total U.S. plant-based foods market (Plant Based Foods Association, 2023a). Since the massive sales increase in the year 2019, many food companies have been eager to capture a portion of this growing market with new products constantly being launched into the market. In 2022 alone, many major food companies launched their new lines of plant-based products; for example, Nestlé launched the plant-based Kit Kat, and Kraft-Heinz introduced a dairy-free alternative to their iconic Philadelphia brand cream cheese (O’Donnell et al., 2023). Moreover, quick-service restaurant giants caught on to the trend and partnered with plant-based food companies to offer an alternative to their regular menu to the customers. Two such examples are KFC which partnered with Beyond Meat and Lightlife to bring plant-based chicken to their menu in the U.S., Canada, and Europe, and Starbucks with their plant-based menu expansion after partnering with JUST Egg and Daring Chicken on top of their existing plant-based items such as the plant-based breakfast sandwiches which utilize plant-based sausage from Impossible Foods

The plant-based dairy category is the best growing category in the plant-based market with plant-based milk accounting for 15% of all fluid milk beverages sold in the U.S. (Plant Based Foods Association, 2023a). Fluid dairy milk sales have experienced fluctuations with the total U.S. sales decreasing by 22% between 2014 to 2018; with slight spike increases from 2019 to 2020 and 2021 to 2022 (Franz, 2019; Mills, 2023). While the rising popularity of plant-based milk may not be the only reason for the decline in dairy milk consumption, their presence provides direct competition to the dairy industry. Stemming from the popularity of plant-based milk, the plant-based market has swiftly expanded into other product categories. The notable plant-based dairy categories include creamer, ice cream, yogurt, and cheese. Unlike dairy milk, the dairy cheese market has gained momentum in growth. The dairy cheese market experienced a giant 17.1% jump in growth in 2020 (Riebe, 2023). Mintel U.S. Cheese 2023 report suggested that consumption across all cheese categories is expanding and that consumers are increasingly adding cheese to their casual consumption occasions. In 2022, the U.S. dairy cheese market concluded an impressive total U.S. sale of nearly 30B in dollar amount and 4,582M lbs in volume (Riebe, 2023; Dairy Management Inc., 2023). Looking at the plant-based cheese market, the total sales in 2022 was $233M which totaled to only about 0.77% of the total cheese sold in the U.S. (Ignaszewski and Pierce, 2023). With the growing consumption in the cheese market, there is a large opportunity for plant-based cheese to gain market share and establish itself as a major competitor in the category.

One component of a successful marketing strategy is to understand the core consumers for the product and potential consumers who may be interested in the product. According to the

Good Food Institute (2023), flexitarians are the main adopters of plant-based foods. However, a large untapped market is omnivores. Omnivores have positive attitudes toward meat, associating meat with luxury, status, taste, and good health (Ruby, 2012). However, there has been an attitude shift with a trend towards the reduction of overall meat consumption (Richardson et al., 1993). Similarly, a more recent study (Bryant, 2019) found that most meat-eaters agreed with the benefits regarding the ethical and environmental factors of vegetarianism and veganism. Despite those benefits, meat-eaters are unwilling to partake in the diets due to taste, price, and convenience barriers (Bryan, 2019). A study by Michel et al. (2021) suggested that meat eaters were more likely to purchase meat alternatives with similar taste, texture, and ease of preparation to real meat. Due to these barriers, it has been suggested that plant-based foods should mimic the sensory qualities of the product it is replicating as much as possible to reduce the barrier of entry for omnivores (McClements and Grossmann, 2022).

There are many possible explanations for the increasing interest in plant-based foods by consumers. The most common reasons for the support of plant-based foods are sustainability and health. Schiano et al. (2020) conducted an online survey on dairy food sustainability and reported that 77% of respondents agreed that sustainability "should be promoted for the greater good, rather than personal benefits" and consumers are more likely to agree that "they purchased sustainable products for reasons focused on others (the greater good, the wellness of people and animals, and the wellness of the planet) rather than reasons focused on themselves (a better experience or better/safer products)". In the same study, a check-all-that-apply exercise on traditional dairy and plant-based dairy product images, plant-based, animal-free, nut-based, and coconut-based fluid milk alternatives were considered more sustainable than traditional dairy milk. Furthermore, fifty-five percent of respondents were willing to pay more for sustainable foods (Schiano et al., 2020). Sucapane et al. (2021) found that products described as plant-based were perceived to be more eco-friendly than the same product described as a meat alternative.

According to Ostfeld (2017), a plant-based diet can be defined as a “diet that consists of all minimally processed fruits, vegetables, whole grains, legumes, nuts, and seeds, herbs, and spices and excludes all animal products, including red meat, poultry, fish, eggs, and dairy products”. This begs the question of whether new-generation plant-based foods could fit into the plant-based diet definition based on Ostfeld (2017). Whole plant-based food alternative products do contain plant-based ingredients but may fail to meet the definition of minimally processed food. Williams and Patel (2017) described the health benefits of plant-based diets in their publication but questioned if all plant-based diets are equally beneficial for health. Most plant-based milks have been shown to be nutritionally inferior to traditional dairy milk; fortifications are necessary to improve nutrition (McClements, 2020). Another example is plant-based eggs which have been shown to lack vitamins and minerals commonly found in real (chicken) eggs, thus fortifications of those micronutrients are necessary to bring plant-based eggs up to par with traditional eggs (McClements and Grossman, 2021). The objective to confirm or debunk the health benefits of plant-based foods is outside of the scope of this literature review. Whether the health benefits are justified or incorrectly extrapolated, it is clear that plant-based alternatives have benefited from the push for plant-based diets and that many consumers believe plant-based alternatives to be nutritionally beneficial to their health. Products labeled as plant-based were perceived as healthier than the same products labeled as meat alternatives (Sucapane et al., 2021). The consumer insights report on plant-based proteins in restaurants by Varchasvi (2023) showed that 26% of carnivores and 32% of omnivores believed plant-based proteins were healthier than traditional meat. The Plant Based Foods Association (2023b) also reported that health benefits followed by animal welfare were key consumer desires in regard to plant-based foods. McCarthy et al. (2017) also noted that aside from environmental factors, non-dairy alternative consumers sought plant-based beverages because of health concerns and animal welfare concerns. Research insights from Meticulous Research (2022) suggested that a few other reasons for the rising growth in the plant-based foods market could be attributed to the increasing self-diagnosis of animal protein intolerances, the increasing vegan population, and growing venture investments.

Plant-based Milk

Much recent research has addressed plant-based milk alternatives. Hass et al. (2019) found that taste/flavor was the most important attribute of milk consumption but the motives to consume plant-based milk were multi-faceted including to indulge, to feel good, to achieve a healthy diet, environmental protection, animal welfare, flexibility, convenient lifestyle, and to increase a variety in a diet. Also, food curiosity is a good predictor for willingness to try novel plant-based milks. Product familiarity also played a significant role in consumer perception of plant-based beverages (Hass et al., 2019). Jaeger and Giacalone (2021) investigated barriers to the consumption of plant-based beverages using a combination of emotional responses, conceptual responses, and behavioral responses to map a more complete picture of product perceptions of plant-based users and non-plant-based users. Overall, non-plant-based users experienced a significant multitude of barriers, one of which was food neophobia. Furthermore, non-users of plant-based foods may have issues coming up with ideas on how to incorporate plant-based beverages into their diet due to unfamiliarity (Jaeger and Giacalone, 2021). The Plant Based Foods Association (2023b) reported consistency/texture followed closely by high price are the top two factors that consumers dislike the most about plant-based foods. High price is a trade-off of sustainable products and flavor, or product quality trade-offs have also been suggested as a deterrent for consumer purchase of sustainable foods by Schiano et al. (2020). Aspects that directly impact the dining experience such as taste, texture, and value for money are negatively associated with plant-based proteins (Varchasvi, 2023). Consumers noted that alternative dairy products are high in price and assumed that they were two to five times that of traditional dairy products (Adamczyk et al., 2022). Plant-based milk alternatives have a relatively high price point which may impact consumer willingness to purchase, but consumers noted reasons/justifications for paying more which included animal welfare concerns, environmental friendliness and sustainability (Rombach et al., 2023).

Moss et al. (2022) conducted an online survey that captured 323 Canadian participant opinions on plant-based milk. The word association task showed that the most frequently cited category term was healthy/nutritious suggesting that plant-based milk was associated with health benefits. The rest of the word-associated terms were characteristics of plant source (almond, soy, oat, milk alternatives), sensory attributes (watery, nutty, creamy, bland, sweet), not containing dairy (lactose intolerance, dairy-free, alternative to milk, no animal involved), sustainability (environmentally friend, sustainable), and expensive. A consumer acceptance test of unflavored and flavored plant-based milk found that oat milk had a significantly higher overall liking than coconut, soy, and cashew, but not almond and pea. Consumers were able to relate sensory properties to the main ingredient in plant-based milk and were able to identify different flavors, textural attributes, and appearances using a CATA task. Consumers associated plant-based milk with health benefits and sustainability but were concerned with price, ingredients, and sensory properties.

Cardello et al. (2022) conducted acceptance testing on three dairy milks and seven plant-based milks. The most-liked products were regular full-fat and full-fat lactose-free dairy milk followed by blended plant-based milks (oat, rice, coconut), regular soy milk, and reduced-fat soy milk respectively. Milks were discriminated by sensory, emotional, and situational uses. Highly liked full-fat dairy milk was characterized by 'white appearance' and 'milk-like flavor'. The blended plant-based beverage produced with oat, rice, and coconut was described as having a coconut-like flavor, creamy mouthfeel, and thick/viscous. In general, plant-based beverages were associated with similar attributes such as 'bean-like flavor', 'grain/wheat flavor', 'nutty flavor' and 'cardboard-like' which resulted in decreased liking scores. However, the authors uncovered four different segments of consumers including full-fat dairy likers, plant-based likers, dairy and tri-blend likers, and full-fat dairy, tri-blend, and soy likers.

Amyoony et al. (2023) conducted acceptance testing with 104 participants to investigate consumer perception of the aftertaste of plant-based beverages using a 9-point hedonic scale and word association tasks. Five plant-based beverages were chosen for the study to cover a wide variety of ingredient representations (oat, almond, coconut, soy, pea). Flavor, texture, and aftertaste had strong correlations with overall liking. Plant-based beverages made from oat, almond, and coconut scored significantly higher than soy and pea in terms of flavor and aftertaste, consistent with other studies. However, only oat and almond had a significantly higher overall liking than pea and soy.

Plant-based yogurts

Positive consumer attitudes towards plant-based yogurt alternatives are environmental, sustainability, and health which is similar to the overall trend of plant-based foods (Pandey et al., 2021). A negative issue commonly associated with plant-based yogurt is texture as commercial plant-based yogurts tend to have lower protein concentrations and different gelation properties due to the lack of casein (Giacalone et al., 2022). Grasso et al. (2020) observed no correlation between texture and protein content due to the low protein content of plant-based yogurts. A few of the commercial plant-based yogurts tested by Grasso et al. (2020) were not different in instrumental firmness, consistency, cohesiveness, and index of viscosity to the dairy product reference. The acceptance test by Grasso et al. (2020) was conducted with only 25 participants meaning that all of their results as they pertain to consumer testing are likely incomplete at best, and no descriptive (trained panel) data were collected so the actual sensory properties of the yogurts in this study remain unknown. Greis et al. (2020) conducted a temporal dominance of sensations (TDS), hedonic scores and penalty lift analysis on five plant-based yogurts and two dairy yogurts. Two plant-based yogurts were similar to the two dairy products, and those four samples were associated by consumers with thickness, creaminess, and foaminess. The rest of the plant-based products that were not similar to the dairy yogurts were associated with wateriness and thinness. All plant-based yogurts performed worse than the two dairy yogurts in overall liking and the plant-based products had a much larger variability in liking scores compared to the two dairy yogurts. Furthermore, TDS evaluation also indicated more variability in the perceived attributes of plant-based products. Overall, dairy yogurts were higher in the dominance of creamy while plant-based yogurts were dominated by thinness and wateriness (Greis et al., 2020).

A study of plant-based and dairy yogurts reported that plant-based yogurts were perceived as novel and sustainable in focus groups (Gupta et al., 2022). The authors stated that yogurt liking was largely impacted by texture because of the observed positive correlation between the terms “good texture” and “smooth” with the “cheerful” emotion and the term “bad texture" with "nasty" emotion. Coconut yogurt was associated with the terms "artificial" and "indifferent" while soy yogurt in this study was associated with "good texture" and "smooth" attributes. The soy yogurt in this study received a similar rating to the reference dairy yogurt; however, the authors noted that the dairy yogurt used in this study was not typical of a dairy yogurt due to the large and coalesced fat droplets that were unevenly distributed in the protein network. Lastly, the study showed that the overall liking was positively correlated with the protein content probably because higher protein content resulted in a higher consistency and better gel firmness (Gupta et al., 2022).

Recently, Jaeger et al. (2023) published a study investigating consumer acceptance of eight plant-based yogurts commercially available in the New Zealand market using a multi-response approach. Consumer liking of plant-based yogurts was generally low ranging from 4 to 5 on a 9-point hedonic scale. Low sensory acceptability was likely the reason for poor attitudes towards plant-based yogurts. Plant-based yogurts made with blends (oat, rice and coconut) were liked more than yogurts made from one protein such as cashew and soy. Attributes that positively impacted liking were 'smooth/creamy mouthfeel', 'sweet', and 'vanilla' while 'sour/acidic taste' negatively impacted liking. The most liked sample was cited as 'energetic/excited', 'enthusiastic/inspired', 'secure/at case', and 'relaxed/calm'. Negative terms that impacted mean liking were 'tense/bothered', and 'jittery/nervous'.

Plant-based cheese

Plant-based cheeses face a similar problem to plant-based yogurt in that the category is in its infancy and more research is needed to further understand consumer perception of this product category (Giacalone et al., 2022). To truly understand the product acceptability of plant-based cheeses, it is necessary to investigate the sensory properties of plant-based cheese specifically. Short et al. (2021) conducted a systematic review of sensory evaluation studies for plant-based cheeses. In the published review, twelve articles were found with some form of liking evaluation of plant-based cheeses. Short et al. (2021) noted that several studies had limitations such as small participant numbers, choice of control, and usage of trained panelists instead of consumers. The lack of valid sensory research (objective and subjective) on plant-based cheeses represents a real need in the literature. A few recent studies have been published to address the lack of consumer research in the plant-based cheese category.

Falkeisen et al. (2022) investigated consumer acceptability of commercially available plant-based Cheddars as well as emotional responses to plant-based cheeses with consumers in Nova Scotia, Canada. Two different consumer tests conducted in this study were cold plant-based Cheddars (n=100) and melted plant-based Cheddars (n=93). The study concluded that plant-based Cheddars in this study were not well-liked by consumers, citing mouthcoating, rubbery, off-flavors, and pungency as attributes that negatively influenced overall liking. However, a plant-based Cheddar made with coconut oil was liked more than other plant-based Cheddars, and plant-based Cheddars with higher overall liking scores were associated with positive emotions like loving, good-natured, free, joyful, understanding, happy, satisfied, and warm. Overall, participants indicated that plant-based cheeses do not taste similar to traditional dairy cheese. Despite the poor hedonic responses from consumers, the authors stated that interest in plant-based cheeses was relevant as consumers become more concerned about health benefits, sustainability, and ethicality and emphasized the need for further investigations into this category.

In the same publication as a plant-based beverage consumer test, Amyoony et al. (2023) also conducted an acceptance test on five commercially available pre-sliced plant-based cheeses.

Similar to plant-based beverages, the overall liking score of plant-based cheeses was negatively correlated with the aftertaste intensity. The participants in this study mainly consumed plant-based beverages and only rarely consumed plant-based cheeses, so the lack of familiarity could be the main contributing factor to the low hedonic ratings and descriptors such as strange and weird in the word association task. Plant-based cheeses with higher overall liking scores were associated with terms such as salty, sweet, fatty, and cheese-like while samples with lower overall liking scores correlated with terms such as disgusting, lingering, sour, strong, nutty, bitter, and off-flavor.

While studies that focused on understanding plant-based cheeses and consumers have recently been published, there are still gaps within research to fulfill. One such example is the lack of a language that could be used to describe and quantify attributes associated with plant-based cheeses. Plant-based cheese is a relatively new product category in a volatile market with high competition. With constant introductions of new plant-based cheeses, the development of an objective sensory language is imperative to provide product developers with tools to help them understand the characteristics of plant-based cheeses in the market.

DESCRIPTIVE ANALYSIS AND LEXICON DEVELOPMENT

Product research and formation is a complex process that involves multiple personnel from different areas of expertise. The role of a sensory scientist is to effectively communicate consumer preferences while having a thorough understanding of the characteristics of the products. In the 1920s, the need for scientific food analysis for production phases and food-acceptance research to test for consumer preference emerged (Caul, 1957). Caul (1957) described two polar opposite solutions as the objective method entailing the use of the scientific method to analyze and measure the flavor of foods in an accurate and precise manner and the subjective method described as acceptance research of foods focused on preference tests. To achieve the goal of accurate and precise measurements of foods, descriptive analysis methods were developed. Descriptive analyses are the most sophisticated tools in the sensory science toolbox (Lawless and Heymann, 2010). The first descriptive analysis technique, the Flavor Profile (FP), was developed by Arthur D. Little and Co., Cambridge MA. In the 1940s (Lawless and Heymann, 2010). The FP was described as a descriptive analysis of the characteristics notes of aroma and flavor in order of appearance, intensities, and amplitudes expressed in a language which enables differences to be detected and used in the steps of flavor improvement (Cairncross and Sjöström, 1950). To elaborate, panelists would first focus on the overall impression of the aroma amplitudes scoring it as either very low, low medium, or high then individual detected characteristics are listed in chronological order of when they are perceived and scored as either not present, threshold, slight, moderate, or strong (Caul, 1957). Once all characteristics of the aroma have been recorded, the same process repeats for flavor attributes. Aftertaste attributes are also recorded after swallowing, if present, but are often not scored on intensities except for when aftertaste is the focus of the study (Caul, 1957). The FP method set the standards for the development of descriptive analysis methodology and paved the way for alternative techniques. Since then, many descriptive analysis techniques have been developed and used in the attribute quantification of foods. The two major approaches to descriptive analysis today include Quantitative Descriptive Analysis (QDA) and Spectrum™ Descriptive Analysis Method (Spectrum™).

Quantitative Descriptive Analysis (QDA) was introduced in 1974 by Stone et al. to propose a method with a continuous scale which allowed for the application of statistical analysis (Gacula, 1997). The method relies on intensity scoring of each attribute on a 6-inch line scale with end anchor points ½ inch from each end and an optional third anchor at the middle of the line (Stone et al, 1974). Panelists are directed to place a mark on the line to represent the intensity of the attribute perceived which yields an interval scale data appropriate for analysis of variance. Another big variation from FP is the elimination of product experts as noted in Stone et al. (1980) that QDA should be independent of the individual panelist meaning no experts as individuals familiar with a particular product or experimental conditions may contribute biased responses. A group consensus aspect is only applicable during the language development stage and not the data collection stage meaning that each panelist individually evaluates the products and contributes data points of their own rather than a group agreeing on a single set of outcomes. Since the evaluation by each panelist results in interval scale data, analysis of variance can be applied to not only determine the significance of product differences but also the performance of each panelist. The vocabulary generated by QDA panels is product-specific and often only are terms that the panelists could detect without extensive training. The upside of this method is that QDA requires less training compared to methods like FP or Spectrum and that the terms are more likely to be similar to consumer vocabulary. However, the results from QDA should be considered as relative not absolute (Lawless and Heymann, 2010). Lawless and Heymann perfectly depicted an example in their book describing a scenario in which the crispness of potato chip 1 was scored an 8 by judge A while judge B scored a 5 on the same potato chip; however, both judges scored potato chip 2 two points lower than potato chip 1 meaning that they both perceived the difference in crispness at equal magnitude but both judges used the different part of the scale (2010).

Another important method that stemmed from the FP was the Texture Profile Method (TPM). The TPM, modeled after the FP method, was introduced by Brandt et al. in 1963 based on the texture characteristics classification work by Szczesniak (1963) and texture rating scales work by Szczesniak et al. (1963). The purpose of developing the method was to introduce a technique that allows for chronological characterization and scaling of food textures from the first bite through mastication. While this review will not explain the TPM method thoroughly, it is important to note that TPM served as a crucial building block that led to the development of the Spectrum method. The method of interest in this review is the Spectrum Method; therefore, the remainder of this literature review will focus on investigating this particular technique.

Gail Vance Civille developed the Spectrum™ Method in the 1970s using the foundations from the Flavor Profile Method and Texture Profile Method (Dus et al. 2018). The method expands on the rigorous training structure of FP and TPM and introduces the use of an absolute 0-15 point scale, with tenths, that have a much better discriminating ability than FP and TPM (Civille and Osdoba, 2020). The three foundations behind the Spectrum™ method include a universal intensity scale for quantitative ratings, the use of clear qualitative references, and the use of highly trained panelists (Civille and Osdoba, 2020). A universal intensity scale is considered by Spectrum™ proponents to be an absolute scale that allows for intensity comparisons across attributes. For example, the sweetness attribute scored as a 2 has an equal intensity as the bitterness attribute scored as a 2. One advantage of this is the ability to compare a large number of products across multiple time points because the philosophy suggests that it is possible to compare the data from one experiment with data derived from a different study (Lawless and Heymann, 2010). Attributes may also be compared across product categories because all products are rated relative to the universal scale and not each other (Civille and Osdoba, 2020). The implementation of an absolute scale is made possible by the references that anchor them. To elaborate, the reference anchor for the sweet taste attribute scored as a 2 on the scale is a 2% sucrose solution in water while the sweet taste attribute scored as a 15 is anchored by a 16% sucrose solution (Meilgaard et al., 2016). The presence of these standardized references allows panelists to familiarize and calibrate themselves to become experts with an accurate and precise product-discriminating ability. The success of the Spectrum™ descriptive analysis panel heavily relies on the panelist recognition and discrimination abilities, thus the method required much more extensive training than any other methods. Spectrum™ panelists should complete a minimum of 100 hours of training for each sensory modality before starting product evaluations (Civille and Osdoba, 2020). Panelists are also required to stay calibrated to the references and tuned with each other due to the complexity of such rating methods. One downside of all descriptive analysis methods has always been training time requirements. Cairncross and Sjöström (1950) described that flavor analyses are no different from other laboratory analyses in that time is required for developing the technique and training the fundamentals which often required members to squeeze evaluation sessions into their crowded schedule and remove them from work that they may deem more important. This problem is true for all descriptive analysis methods, but it may be especially problematic for the Spectrum™

method due to the extensive time requirement for training to maintain panel acuity. However, the outcome of successfully training such a panel could lead to a much better understanding of product characteristics and the technique can be applied to a wider range of products compared to other available methods. The accuracy and reproducibility of the panel should resemble results from other trusted laboratory methods and allow for similar business decisions to be made (Dus et al., 2018).

Another crucial aspect that is required for a successful evaluation is the qualitative descriptors and references. The qualitative descriptors/terms/attributes that are used to characterize a category of product are known as a lexicon. For the Spectrum™ method, the lexicon used for a product category is chosen priori and remains the same for all products over time (Lawless and Heymann, 2010). The lexicon requires three crucial components including a name that accurately describes an attribute, a definition to describe attributes, and specific references to help panelists recognize the intensity of each attribute on the scale (Dus et al, 2018). Lexicon developments can be summarized into five steps: category survey, term generation, use of references, examples, and refinement (Dus et al., 2018; Civille and Osboda, 2020). The process begins by conducting a category survey meaning that a large range of products is collected and sampled to develop an understanding of the variability within the product category of interest. Once representative samples, generally between 6-12, have been identified, the panel can taste the samples and generate initial terms as they are perceived to be relevant to the products (Civille and Osboda, 2020). During this stage, the panel generally relies on consensus among panelists to keep and eliminate terms. However, an experienced panel leader is crucial for term conglomeration/division to determine only relevant primary terms. One such example is the confusion around the term creaminess. Creaminess is a term often used by consumers but Lawless and Civille (2013) noted that the term creaminess is a combination of thickness, smoothness, and dairy fat and thus should be divided properly into individual terms to help product developers understand what specific adjustments are necessary. This is another advantage that is achievable using the combination of a highly trained panel and the Spectrum™ method and may be a challenge to another method such as QDA™ because QDA™ panelists often lean on consumer-oriented terms. Following initial term generations, a thorough clarification of the meaning of each term (definition) and identification of references is required. As mentioned earlier, Spectrum™ panelists rate the terms relative to the scale and not the samples; therefore, panelists must understand the characteristics of each term and be able to score the intensities accurately. To help facilitate panelists rating acuity, references must be identified either using existing published standard references or identifying new references for attributes that do not exist in the literature. References could be in the form of food products or chemicals (Drake and Civille, 2003). Step 4 is the identification of an example for each generated term that is similar to the references. Examples are often food products that have a predominant characteristic of a certain term, but they are different from references in that they encompass multiple sensory characteristics to help panelists understand an attribute in the context of a complex matrix (Dus et al., 2018). For example, a generic brand of vanilla could be used as an example of vanillin but would not be a good reference for vanillin (Lawless and Civille, 2013). Lastly, the developed lexicon can be refined by further elimination of any irrelevant terms and validated by using the terms to compare products in the category to determine if differentiation occurs. However, it is important to note that lexicons are working models that can evolve with new discussions and new samples (Dus et al., 2018). This is a worthwhile note especially for the plant-based food category as it is relatively a new category with constant product introductions to the market, elimination from the market, and developments of ingredients and processing methods.

Due to the implementation of a quantitative scale, Spectrum™ descriptive analysis data can be subjected to statistical analysis using ANOVA to determine the significance of product attribute intensities. Furthermore, a relationship between descriptive analysis data and instrumental analysis or consumer acceptance data can be established using a technique called preference mapping. External preference mapping, specifically, is when data obtained from two different sets of measurement methods are connected via multivariate techniques. By combining descriptive analysis data and consumer acceptance data, the relationship between consumer likes/dislikes of a sample can be explained by attributes derived from trained panelists.

There are many published lexicons for dairy and plant-based products that are relevant to this review. Definitions and references for the five basic tastes including sweet, sour, salty, bitter, and umami are published in Meilgaard et al. (2016). Heisserer and Chambers (1993) surveyed 42 hard natural cheeses to develop a lexicon for the sensory flavor attributes of aged natural cheese. The groundwork of that study was then narrowed down to the development of a flavor lexicon for Cheddar cheese by Drake et al. (2001). In 2010, the sensorial properties of processed and imitation cheeses were investigated, and a flavor lexicon was developed (Drake et al., 2010). A sensory lexicon containing flavor and appearance attributes was developed for whey and soy proteins by Russell et al. (2006). Oliver et al. (2018) developed a sensory lexicon with multiple modalities including appearance, aroma/flavor, texture, and mouthfeel to describe strawberries at different maturation stages. Vara-ubol et al. (2004) identified primary terms associated with beany aroma. An extensive 59 attributes flavor lexicon was developed by Cherdchu et al. (2013) in the English language and Thai language to describe soy sauce in the U.S. and Thailand. Drake et al. (1999) compared hand evaluation and mouth evaluation for the texture of cheeses and found that both techniques similarly discriminated cheese texture. The terms to describe the sensorial textural properties of cheese were compiled by Drake et al. (1999) and expanded by Brown et al. (2003). Meals et al. (2020) applied the sensory languages developed by previous researchers to determine the differentiating attributes and drivers of liking for the flavor and texture of cold and melted Cheddar cheese shreds and found color, whey, diacetyl, sulfur, nutty, and brothy flavors to be the main product differentiators. Liu et al. (2023) compiled languages from multiple sources mentioned to identify predominant aroma components of dried pea protein concentrates and isolates and found that distinguishing attributes included cheesy, doughy, sulfur, pyrazine, fecal, and sweet aromatic flavors, and salty taste. As it currently stands, there is no published lexicon specific to describing sensorial attributes for plant-based cheeses. Using the lexicon development guidelines and existing literature, such a language can be developed to provide the industry with a proper tool to characterize and quantify their products and potentially determine drivers of likes/dislikes to assist with further developments of plant-based cheeses that can meet consumer needs.

PROJECTIVE MAPPING

One of the objectives of this study was to evaluate the similarity (or lack of) between plant-based cheeses and traditional dairy cheeses. During the lexicon development, it was noted that very few sensory attributes overlapped between the two categories; therefore, it was not feasible to directly compare these two categories using descriptive analysis. Two popular alternative solutions that could assist in obtaining perceptual maps of the overall similarity are sorting and projective mapping. The sorting exercise is a pairwise categorical measurement that requires panelists to group samples together based on similarity into at least two groups (Nestrud and Lawless, 2010). Sorting is a widely accepted method in sensory evaluation and has been applied to multiple product comparisons to obtain perceptual maps. Lawless et al. (1995) applied the sorting technique to sixteen commercial cheeses to determine the feasibility of applying multidimensional scaling (MDS) to sorting data to create perceptual maps. It was concluded that MDS served as a viable tool to construct perceptual maps of sorting data and that sorting data was a rapid and simple task that could differentiate cheeses based on their perceived similarity/dissimilarity (Lawless et al., 1995). King et al. (1998) compared sorting and projective mapping on similarly-of-use of snack bars and found that projective mapping combined with MDS provided a more meaningful spatial representation than sorting. Panelists also found it easier to change their minds using the projective mapping procedure (King et al., 1998). Nestrud and Lawless (2010) compared the perceptual maps from sorting (with MDS) to projective mapping (with multiple factor analysis) from untrained consumer evaluations of ten apples and ten cheeses. The authors suggested that projective mapping has an advantage over sorting when products have small differences such as when comparing different Cheddar cheeses rather than comparing all cheese types. It has also been suggested that data from projective mapping provides more information than sorting because it contains scaled distance measurement rather than categorical 0 and 1 data obtained from sorting (Lawless and Heymann, 2010).

Projective mapping, also known as napping, was initially introduced by Risvik et al. in 1994 to offer an alternative approach to descriptive analysis when investigating the overall differences between products. The method requires presenting participants with a 2-dimensional rectangle either on paper or using a software and asking them to evaluate the samples based on how similar or different they are to each other by placing the samples they perceived as similar closer together and the samples they perceived to be different further away from each other.

The published study by Risvik et al. (1994) utilized nine trained panelists to complete the projective mapping activity, but it is generally agreed upon that projective mapping is also viable with untrained panelists (Lawless and Heymann, 2010; Risvik et al., 1997) granted that studies generally utilized 15-50 untrained panelists (Nestrud and Lawless, 2008; Ares et al., 2010) compared to 9-15 trained assessors (Risvik et al., 1994; Perrin and Pagès., 2009). For data analysis, multiple factor analysis (MFA) was an important addition to projective mapping and was first used by Pagès (2005). MFA allows more dimensions to be uncovered from projective mapping data if panelists pay attention to different attributes (Lawless and Heymaan, 2010).

Risvik et al. (1994) argued that the perceptual map derived from projective mapping was similar to that of the map derived from sensory profiling utilizing unstructured line scales when used to evaluate five chocolate samples. Albert et al. (2011) suggested that projective mapping could be used as a quick alternative to QDA™. Further advantages of projective mapping over traditional descriptive analysis methods include lower cost of assessment, fast, and less product required (Moss and McSweeney, 2022). On the contrary, some studies also suggested that projective mapping does not outperform descriptive analysis in discriminating samples (Antúnez et al., 2017; Perrin and Pagès, 2009). However, the combination of projective mapping and descriptive analysis is suggested to obtain a more complete visualization of data and avoid data misinterpretation (Nestrud and Lawless, 2010).

Overall, projective mapping is a method that can serve as a faster and less expensive preliminary substitution for descriptive profiling or serve as an alternative to visualize overall perceived similarity when classical profiling methods are not viable and can be conducted with participants with various levels of training (Jervis and Drake, 2014). For our study, the objective is to investigate the overall perceived similarity between plant-based cheeses and dairy cheeses, thus projective mapping is a quick and viable technique that can serve as an alternative to descriptive analysis for this particular goal.

METHODS TO ASSESS CONSUMER PERCEPTION AND ACCEPTANCE

As described in previous sections, the need to properly assess consumer perception and acceptance of food products is a crucial task that can be a differentiator of product success or product failure. To repeat, prosperous companies tend to excel in obtaining and understanding their consumers (Meilgaard et al., 2016). This section will describe a few methodologies/practices commonly used in the field of sensory science to assess consumer perception and product acceptability.

Maximum Difference Scaling

Maximum Difference Scaling (MaxDiff), also known as Best-Worst Scaling, is a method to determine the relative importance of attributes in a list. The method was conceptualized by Jordan Louviere in 1987 and introduced by Finn and Louviere (1992) where they utilized best-worst scaling to evaluate public opinion on social issues and concerns. The term maximum difference was conjured up by Louviere as stated that a participant would select the "top" or "best" choice and the "bottom" or "worst choice" when presented with a subset of attributes and that those two choices would reflect the maximum difference in value to the participant (Louviere et al., 2015).

Outside of MaxDiff, one commonly used scale to capture consumer perception of products is the 5-point scale rating from not at all important to extremely important. This type of scale can promote scale use bias as some participants may only concentrate on using a small section of the scale (Orme, 2020). The use of MaxDiff eliminates individual scaling bias presented by category scales (Louviere et al., 2015; Cohen, 2003; Orme, 2020) and it is easy to use (Cohen, 2003; Orme, 2020). Also, the MaxDiff model assumes that every possible pair in each subset is examined, thus it can be a more efficient alternative to collecting data using paired comparison (Cohen, 2003). Since participants are asked to indicate their "best" choice and "worst" choice in a subset list that typically contains 3-5 attributes, multiple inferences can be drawn from just those two choices (Orme, 2020). For example, consider a scenario where four attributes are presented (Fig. 1). If a participant indicates that 'services and support' is the most important feature and 'multiple channel availability' is the least important feature when they are purchasing or recommending a server, we can conclude the following:

1. 'Services and support' is the most important.
2. 'Multiple channel availability is the least important.
3. 'Services and support' is more important than 'ease of configuration and software installation' and 'ongoing cost'.
4. 'Ease of configuration and software installation' and 'ongoing costs' are more important than 'multiple channel availability.

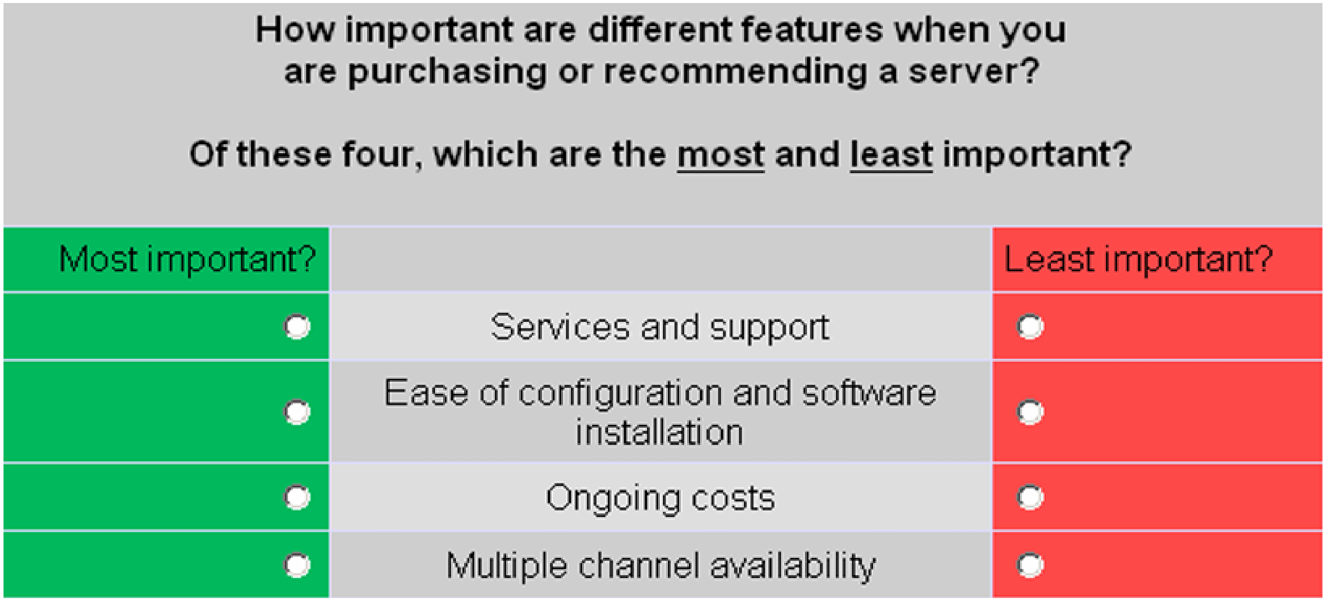

Figure 1. An example of a MaxDiff exercise task containing 4 features (Taken from Cohen, 2003).

However, we cannot conclude the relationship between ‘ease of configuration and software installation’ and ‘ongoing costs’ from this one task. To summarize, one MaxDiff activity can infer that ‘services and support’ > ‘ease of configuration and software installation’ and ‘ongoing costs’ > ‘multiple channel availability’. In order to acquire the same information using the paired comparison method, participants would have to respond to five paired comparison tasks as opposed to one MaxDiff task.

MaxDiff data is often analyzed using statistical models such as aggregate logit, latent class, or hierarchical Bayes estimation (HB) which leads to relationships presented in relative positive and negative values (can also be converted to 0-100). Items with larger scores are more important/desirable than items with lower scores, however, it is important to note that negative values do not mean that the items are not important or undesirable since MaxDiff scores are relative (Orme, 2020). Although researchers can infer the importance of MaxDiff items to each other, it is impossible to conclude if any of the items in the list are actually important or would properly translate to an increase in product purchases without additional data. Two methods have been suggested to address the arbitrary scale origin of MaxDiff data: dual-response and direct method. The use of either indirect dual-response or direct method along with MaxDiff has been referred to as anchored MaxDiff and allows for important items and not important items to be differentiated (Orme, 2020). Indirect dual response includes a question asking respondents to indicate if the attributes listed are “very important”, “not important”, or “some are very important, some are not” following every MaxDiff task. The direct method, on the other hand, presents the complete list of attributes at the end of the MaxDiff exercise and asks respondents to check all the attributes that they consider important. Lattery (2010) suggests that the direct method is superior to the indirect method because it requires fewer tasks and demonstrates using simulated data that the direct method is better at differentiating important items and unimportant items. However, more research is needed from real participants.

MaxDiff has been applied to many consumer studies on dairy products. Harwood and Drake (2019) utilized MaxDiff, in addition to adaptive choice-based conjoint, to compare the appeal of 32 protein product features and found that the overall MaxDiff results closely matched the importance scores from the ACBC. Sipple et al. (2022) used MaxDiff to determine attributes that were perceived to make a frozen dessert “better-for-you” and found that sweetener type and the frozen dessert base were the most important attributes to “better-for-you” consumers overall. Harwood and Drake (2018) utilized MaxDiff to rank qualities and issues associated with organic milk from organic milk consumer perspectives, while Rizzo et al. (2020) used MaxDiff to determine lactose-free milk attributes that were important to consumers. Schiano et al. (2021) designed three MaxDiff exercises to characterize consumer definitions relating to sustainability, health factors, and natural factors pertaining to dried dairy ingredients. MaxDiff has also been used in various research related to cheese such as a study conducted by Speight et al. (2019) to determine the most important reasons that led consumers to purchase pre-packaged Cheddar cheese shreds, a study by Best et al. (2023) to determine the importance of various characteristics/inclusions for restaurants styled and ready-to-eat cheese dips, a study by Del Toro-Gipson (2021) to determine the importance of attributes related to smoked Cheddar cheese, and a study by Racette and Drake (2022) which utilized MaxDiff to rank the importance of attributes of natural hot-pepper cheeses.

Kano Analysis

Kano analysis is a questionnaire modeling technique that can be used to evaluate consumer needs for a product based on how certain attributes or features affect customer satisfaction (Xu et al., 2009). The Kano method requires questionnaires to be modeled to include functional and dysfunctional statements (Mikulić, 2007). A functional statement represents the presence of a certain attribute/feature while a dysfunctional statement is the contrasting opposite which represents the absence of an attribute/feature. For example, the functional statement for the seat warming feature in a car would be worded as “a car that has a seat warmer” while the dysfunctional statement would be “a car that does not have a seat warmer”. When designing a Kano exercise, researchers typically generate various attributes/features about a particular product and first present the functional statements to respondents followed by the dysfunctional statements. For each statement, respondents are presented with the following choices: “I like it”, “I expect it”, “I don’t care/I can tolerate it”, “I can live with it”, or “I dislike it” (Kim et al., 2013, Xu et al., 2009). Those options capture the level of satisfaction of each functional and dysfunctional statement.

Satisfactory responses are then translated into consumer wants and needs categories grounded into basic needs, performance needs, or delight needs. The three needs categories have been further broken down into Performance/One-dimensional (P), Must-be/Must-have (M), Attractive (A), Indifferent (I), Reverse (R), and Questionable (Q). Considering the seat warmer example, if a respondent selected "I like it" on "a car that has a seat warmer" (functional statement) and "I dislike it" on "a car that does not have a seat warmer" (dysfunctional statement), a seat warmer feature would be categorized as a performance feature (Fig. 2). Performance, also often called one-dimensional, is considered an attribute that increases consumer satisfaction when present and decreases satisfaction when present (Sharif Ullah and Tamaki, 2010) meaning that consumers like having that feature and would dislike the product if that particular feature is absent. Must-be or must-have attribute is defined as an attribute if its absence produces absolute dissatisfaction, and its presence does not increase satisfaction (Sharif Ullah and Tamaki, 2010) meaning that consumers expect this attribute to be there and will be extremely dissatisfied with the product in its absence. An attractive attribute leads to greater satisfaction when it is present, but it is not expected by consumers. An attribute is categorized as indifferent if its presence or absence does not impact satisfaction meaning that consumers do not place great importance on this attribute. An attribute is considered reverse when its presence results in dissatisfaction and vice versa meaning that consumers do not want to see this attribute. Lastly, an attribute is considered questionable when conflicting responses between functional and dysfunction statements are obtained. For example, if a respondent selects "I like it" for both "a car that has a seat warmer" (functional) and "a car that does have a seat warmer" (dysfunction), a satisfactory level cannot be identified because those responses are contradictory. Following the categorization of attributes, a frequency table can be constructed to determine which attribute leads to high satisfaction (performance and must-have) and which attribute should be avoided (reverse).

Dysfunctional (feature absent)

Functional (feature present)

	Like it	Expect it	Don't Care	Live With	Dislike
Like it	Q	A	A	A	P
Expect it	R	I	I	I	M
Don't Care	R	I	I	I	M
Live With	R	I	I	I	M
Dislike	R	R	R	R	Q

Figure 2. A table used to classify consumer responses on a functional statement and a dysfunction statement into one of the following needs: Performance/One-dimensional (P), Must-be/Must-Have (M), Attractive (A), Indifference (I), Reverse (R), and Questionable (Q). (Taken from Zacarias, 2015).

Kano modeling has been integrated into product development strategies (Matzler and Hinterhuber, 1998; Sharif Ullah and Tamaki, 2010). It has also been applied to determine the satisfactory level of attributes related to food products such as fluid milk (Harwood and Drake 2018), fresh market tomatoes (Oltman et al., 2014), steamed brownies (Wimarnaya et al., 2021), and chocolate milk (Kim et al., 2013).

Consumer Acceptance Testing

Acceptance testing, also known as affective tests, is a form of testing that comprises various methodologies including quantitative and qualitative measurements to achieve the goal of obtaining insights on consumer acceptability and preference of products or concepts. In contrast to the objective nature of descriptive analysis, acceptance testing captures the subjective opinion from participants, often consumers of the product, to help guide product development and influence business decisions. Sample size, the number of participants, is an important consideration when conducting acceptance testing because it directly affects the power, discriminating ability, of the test method; a more powerful test is less likely to miss a true difference (Lawless and Heymann, 2010). It is recommended that the sample size should be between 75-150 (Lawless and Heymann, 2010), but 100 or more is recommended (Hough et al., 2006; Drake, 2007; Mammasse and Schlich, 2014). Moreover, the test generally, but not always, relies on user groups classified based on the rate of consumption or product usage frequency (Meilgaard et al., 2016).

The most widely accepted and commonly used measurement tools to quantify product acceptability are the 9-point hedonic scale and the Just-About-Right scale (JAR). The 9-point hedonic scale is a rating scale used to assess the degree of product liking introduced by Peryam and Pilgrim in 1957 (Lawless and Heymann, 2010). The scale consists of 9 categorical options going from “dislike extremely”, “dislike very much”, “dislike moderately”, “dislike slightly”, “neither like nor dislike”, “like slightly”, “like moderately”, “like very much”, and “like extremely”. The options are then converted into numerical values with dislike extremely = 1 and like extremely = 9. The wordings for each scale option were based on approximately equal-interval property determined by Thurstonian methods, thus allowing for the application of parametric statistics in the data analysis (Lawless and Heymann, 2010). The 9-point liking scale has been critically applied to measure the overall liking of the product and the liking of specific attributes such as appearance, flavor, texture, aftertaste, and so on.

While the liking scores alone can help guide product development in the right direction, it is often paired with other scales to obtain a more complete picture of product preferences. A common pairing to the 9-point hedonic scale is the JAR scale. The JAR scale is a 5-point categorical scale that is used to describe the perceived level of specific attributes in a product (1 = too little, 3 = just about right, and 5 = too much). The addition of the JAR scales allows for product acceptability (from the attribute likings) to be combined with intensity to determine the optimal product adjustments (Rothman and Parker, 2009). Imagine a scenario where the mean sourness liking score (obtained from the 9-point hedonic scale with 150 consumers) for a sour cream is 2.5 suggesting that the sourness is between "dislike moderately" (3) to "dislike very much" (2). A sensory scientist would be wary of this score, but the mean sourness liking score alone points out the problem but not the solution. To elaborate, just looking at the sourness liking score would not tell the research if the product is too sour or not sour enough. The addition of the sourness JAR (not nearly sour enough, somewhat not sour enough, just about right, somewhat too sour, and much too sour) would provide the developer with proper directional guidance. Furthermore, the application of the JAR scales along with the 9-point hedonic scale allows for the application of penalty analysis. Penalty analysis, or mean drop analysis, is a method for determining if the JAR ratings for a specific attribute are associated with a drop in liking, commonly applied to overall liking (Schraidt, 2009). Consumers are categorized, based on their JAR rating, into the "too much" group, the "just about right" group, and the "too little" group. To determine the "mean drop", the hedonic mean for each group is calculated and subtracted from the "just about right" group (Lawless and Heymann, 2010). The "mean drop" should be used in tandem with the citation proportion of each group. For example, a "too sour" group (n=2 out of 100) with an overall liking mean drop of 3 is negligible despite the large drop in the overall liking because only 2% of the consumers indicated that the product is too sour.

Aside from the JAR scale, hedonic ratings have been paired with check-all-that apply to associate product characteristics related to like/dislike (Moss et al., 2022; Falkeisen et al., 2022; Jaeger et al., 2023). Furthermore, acceptance tests often include open-ended comments immediately following the overall liking question to allow participants to describe attributes that influence their like/dislike rating and product ranking to further support the hedonic results (Lawless and Heymann, 2010).

OBJECTIVES

With the rising popularity of plant-based cheese and strong competition in this category, food companies must have a thorough understanding of how to deliver plant-based cheeses that are desirable to consumers. Developing a successful product strategy requires the understanding of what attracts consumers, barriers to entry, and potential improvements as well as having the ability to objectively compare a product to competitors. With many studies showing flavor and texture as the key barrier to plant-based foods, it is more crucial than ever for producers to be able to identify and quantify the sensory attributes of plant-based cheeses. The objective of this study is to investigate consumer perception and acceptance of commercially available plant-based cheeses. It is also imperative that producers have the tools to help them understand their products from a sensorial perspective; therefore, another objective of this thesis is to develop a sensory language that can be used to characterize and quantify attributes associated with plant-based cheeses.

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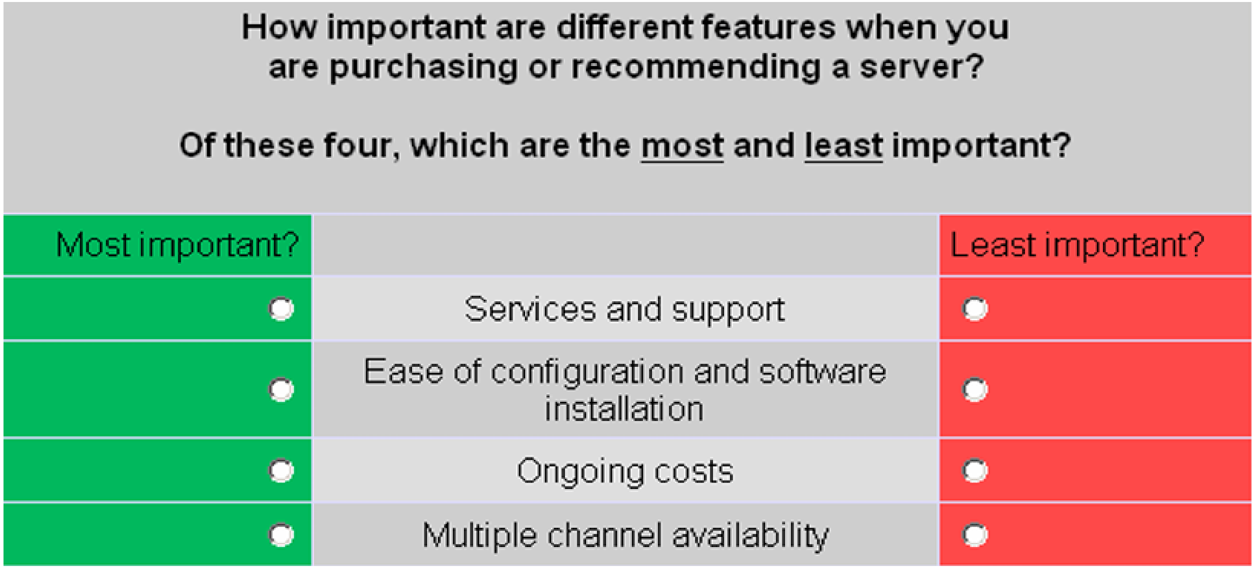
How important are different features when you are purchasing or recommending a server?

Of these four, which are the most and least important?

Most important?		Least important?
○	Services and support	○
○	Ease of configuration and software installation	○
○	Ongoing costs	○
○	Multiple channel availability	○

Figure 1.1. An example of a MaxDiff exercise task containing 4 features (Taken from Cohen, 2003).

Functional (feature present) \ Dysfunctional (feature absent)	Like it	Expect it	Don't Care	Live With	Dislike
Like it	Q	A	A	A	P
Expect it	R	I	I	I	M
Don't Care	R	I	I	I	M
Live With	R	I	I	I	M
Dislike	R	R	R	R	Q

Figure 1.2. A table used to classify consumer responses on a functional statement and a dysfunction statement into one of the following needs: Performance/One-dimensional (P), Must-be/Must-Have (M), Attractive (A), Indifference (I), Reverse (R), and Questionable (Q). (Taken from Zacarias, 2015).

CHAPTER 2: DEVELOPMENT OF A LEXICON FOR PLANT-BASED CHEESES.

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INTERPRETIVE SUMMARY

Plant-based cheese has gained popularity as a dairy alternative in recent years. This study identified a sensory language to objectively document sensory properties of plant-based cheeses. The developed lexicon provides a tool for strategic product development and communication.

ABSTRACT

The plant-based food market has experienced a steady increase over the past decade. Plant-based cheese is part of this market, and there is a need to understand sensory properties of these products and to document how they are distinct from their traditional dairy counterparts. The objective of this study was to identify a sensory language to provide a standardized tool to identify and quantify the flavor and texture attributes of plant-based cheese (PBC). Subsequently, projective mapping (PM) was applied to further characterize differences among PBC and traditional dairy cheeses. Twenty-eight commercial PBC were used to construct initial flavor and texture lexicons, and a hot texture lexicon. A trained panel refined the lexicons and identified attributes and definitions for each attribute. The lexicons were validated by sensory evaluation of twenty-one commercial PBC (shredded and sliced) using the lexicons. Twenty-three attributes were identified for PBC flavor, and seventeen and sixteen attributes were identified for cold and hot texture, respectively. The PBC were differentiated using the lexicons ($p<0.05$). By PM, PBC were distinct from each other and remained distinct from dairy cheeses ($p<0.05$). The developed lexicon provides a tool for strategic product development and communication.

INTRODUCTION

The plant-based foods sector has experienced a boom in popularity within the past decade with retail sales reaching eight billion dollars in 2022 within the U.S. alone (Plant Based Foods Association, 2023). The plant-based dairy alternative sector is the leading sector with plant-based milk accounting for 15% of all fluid milk beverages sold in the U.S. (Plant Based Foods Association, 2023). The success of plant-based milk catalyzed the emergence of other plant-based dairy alternatives including popular categories such as ice cream, creamer, yogurt, and cheese. While fluid dairy products have experienced fluctuation in interest, the dairy cheese market continued to capture success with a 17.1% growth increase in 2020 (Mills, 2023; Riebe, 2023). The total sale of dairy cheese in the U.S. was twenty-eight billion dollars in 2021 (Roberts, 2022). In 2022, the total sale of plant-based cheese in the U.S. was $233M which contributed to only ~0.8% of all cheese sold (Ignaszewski and Pierce, 2023). The continued growth in the dairy cheese sector and the minimal penetration by the plant-based companies into the cheese category suggests profitable opportunities for plant-based producers to offer a product of their own. Research suggests that consumers are largely interested in plant-based foods because of their positive sustainability and health halo (Schiano et al, 2020; Sucapane et al., 2021; Falkeisen et al., 2022). Plant-based dairy products generally have been shown to have low acceptability due to sensory barriers. Falkeisen et al. (2022) specifically investigated acceptability of commercially available plant-based Cheddars with consumers. The study concluded that plant-based Cheddars were not well-liked by consumers due to attributes such as mouthcoating, rubbery, off-flavors, and pungency and these authors indicated that consumers did not think plant-based cheeses in the study tasted similar to traditional dairy cheese which could be a barrier of entry for omnivores and flexitarians (Falkeisen et al., 2022; McClements and Grossmann, 2022).

Descriptive sensory analysis was first developed in the 1940s to address the need for an objective scientific method to accurately analyze and measure the sensory properties of foods (Lawless and Heymann, 2010). There are many descriptive analysis methods today, one commonality between all descriptive analysis methods is the use of a lexicon. A lexicon is a set of words used in conjunction with a descriptive analysis method to objectively describe and quantify sensory attributes of a product (Drake and Civille, 2003; Lawless and Civille, 2013). Identification of a lexicon is the first step in descriptive analysis product evaluation. The panel either adopts an existing lexicon or develops one of their own. The development of a lexicon starts with a sensory review of a particular product category to develop terms that are descriptive and representative of that product category. Subsequent steps include identification of definitions for attributes and where applicable, identification of references or examples for attributes followed by refinement of the lexicon to remove redundant terms (Dus et al., 2018). Once developed, the lexicon can be used with a trained panel to objectively characterize and quantify product sensory attributes and when combined with consumer acceptance, to determine drivers of likes/dislikes.

Another objective methodology often adopted for product differentiation is projective mapping. Projective mapping was introduced by Risvik et al. (1994) as an alternative approach to descriptive analysis for the usage of overall product differentiation (Albert et al., 2011). Panelists place products on a piece of paper or digital screen based on their similarities and differences. The advantage of projective mapping is that it can provide a meaningful spatial separation and grouping of products without fully evaluating the profile of products and the method has been shown to generate reasonably good data when used with untrained panelists (King et al., 1998; Nestrud and Lawless, 2010; Lawless and Heymann, 2010; Risvik et al., 1997). Projective mapping has been applied with trained panelists to differentiate wood smoke aromas to circumvent the variability of aroma scaling (Del Toro Gipson et al., 2020). Projective mapping could also be applied to generate a biplot of sensory similarities/differences for products that do not share consistent sensory attributes, making a traditional principal component analysis challenging.

A large portion of the growth for plant-based products is flexitarian and omnivore consumers who believe in the benefits of reducing meat consumption due to ethical and environmental concerns (Bryant, 2019). For such a group of consumers, it may be important that plant-based foods mimic the sensory properties of traditional products to reduce the barrier of entry (Michel et al., 2021; McClements and Grossmann, 2022). Therefore, it is important to monitor the degree of similarity and differences between plant-based products and their traditional counterparts. To our knowledge, no study has proposed a sensory language to characterize and quantify attributes of plant-based cheeses. With the increase in interest but low consumer acceptability, there is a need for plant-based cheese product developers to thoroughly understand the characteristics of their products to assist with development of plant-based cheeses that will better satisfy consumers. The first objective of this study was to develop a sensory lexicon for cold flavor, cold texture, and melted texture evaluation for plant-based cheese. The second objective of this study was to determine the overall perceived similarity/difference among plant-based mozzarella and Cheddar cheeses compared to their dairy counterparts utilizing projective mapping.

MATERIALS AND METHODS

Experimental overview

The study was conducted in compliance with North Carolina State University Institutional Review Board regulations for Human Subjects. Lexicons were developed in three stages: initial language generation, lexicon refinement, and practical application/validation. Initial language generation included a plant-based (PB) cheese category survey and a literature review to generate relevant terms followed by language refinement with an experienced descriptive analysis panel and finally validation by evaluation of PB cheeses using the identified lexicons. Three lexicons were developed: cold PB cheese flavor, cold PB cheese texture lexicon and hot PB cheese texture. Lexicon refinement utilized a trained descriptive analysis panel to evaluate multiple plant-based cheeses (hot and cold) and to refine generated terms. Lastly, the application stage coupled a trained panel with the identified lexicon to evaluate attributes and intensities for representative duplicate lots of plant-based Cheddars (shredded and sliced) and shredded plant-based mozzarella products. Following descriptive analysis using the lexicons, plant-based Cheddar shreds, plant-based Cheddar slices, and plant-based mozzarella shreds were subjected to projective mapping along with their traditional dairy counterparts to evaluate the overall similarity/difference between these categories.

Language generation

Twenty-eight commercial plant-based cheeses (14 Cheddars, 8 mozzarella, 3 parmesan, 1 feta, 1 Gouda, and 1 not specified) were purchased at local grocery stores (Raleigh, NC). Products were stored at 4C in the dark until analysis. Two descriptive analysis experts with over 5000 h of experience with descriptive analysis screened all 28 products to construct the initial lexicon that included a cold flavor lexicon, a cold texture lexicon, and a hot texture lexicon. A hot flavor lexicon was not generated since preliminary work at this stage and in the subsequent refinement section did not reveal any unique flavor attributes when PB cheeses were evaluated hot versus cold. Existing lexicons (including dairy products, natural and processed cheeses, and dairy and plant proteins) were used to assist with the initial development of the language (Brown et al., 2003; Drake et al., 2001; Drake et al., 2007; Drake et al., 2010; Liu et al., 2023; Meals et al., 2020; Russell et al., 2006; Shepard et al., 2013).

Refinement of the lexicons and product evaluation

The identified lexicons (**Tables 1-3**) were refined using a trained panel of 7 panelists (5 females and 2 males, ages of 22 to 52 y), each with at least 50 h of prior experience with descriptive analysis using a 0-15 point scale consistent with the Spectrum descriptive analysis method (Meilgaard et al., 1999). Lexicon refinement was conducted across 40, 45-min sessions. During the sessions, panelists were provided with the commercial plant-based cheeses used in the initial lexicon development along with the identified potential attributes. Separate sessions were devoted to cold and hot evaluation, respectively.

Panelists discussed the characteristics of the samples and identified and or refined terms and identified references for the sensory languages (**Tables 4-6**). Dairy milk and mild cheese related characteristics absent from PB cheeses such as cooked milk, whey, and milkfat flavors were eliminated as no samples possessed those attributes. Sulfur flavor is a hallmark of aged Cheddar cheese **(**Drake et al., 2001), but was not documented in the PB cheeses. The sour aromatic attribute reference was altered from (dairy) yogurt to vinegar due to a lack of dairy sour aromatic in PB cheeses. Sour aromatic flavor is not a common attribute of Cheddar cheeses (Drake et al., 2001, 2005b), but has been documented in other dairy-based cheeses (Chambers et al., 2010; Jo et al., 2018). Many PB cheeses have pea protein as an ingredient and green pea was an anticipated flavor as it is present in pea protein (Liu et al., 2023). However, upon review of PB cheeses along with rehydrated pea protein and frozen green peas, this attribute was not included. Panelists noted beany and cardboard flavors. Cardboard flavor is a ubiquitous flavor in protein-based ingredients (Russell et al., 2006; Wright et al., 2009; Smith et al., 2016; Liu et al., 2023) and beany flavor has been documented in soy and pea proteins and protein products (Lawrence et al., 2016; Liu et al., 2023). Once the lexicons were deemed complete by the panel (no new attributes, and definitions clarified), a formal evaluation of PB cheeses was conducted.

PB Cheddar (n=8 shredded, 6 sliced) and PB mozzarella (n=7) were selected for evaluation using the refined lexicons (**Table 7**). One PB sliced Cheddar was evaluated cold but was not evaluated hot due to sourcing issues. Shredded and sliced formats were the only commercial formats for these PB cheeses. Products were purchased in duplicate 3 weeks apart to obtain representative samples. Panelists received ~25g of the shredded cheeses in 120 mL soufflé cups. Sliced Cheddars were stacked and cut into 2.5 x 2.5 x 2.5 cm cubes using a wire cutter (approximately 6-8 slices depending on the thickness) and dispensed into 120 mL soufflé cups. Prior to each evaluation session, samples were allowed to equilibrate at 10C for approximately 1.5h (Drake et al., 2005). Flavor and texture were evaluated in separate sessions. Hot products were evaluated in separate sessions as well.

For hot evaluation, the methods of Meals et al. (2020) were used with modifications. Approximately 15g of cheese shreds were weighed into metal desiccation dishes (7.62 cm diameter, VWR International). Sliced samples were cut into 2.5 x 2.5 cm (approx. 17 g) using a wire cutter and placed on metal desiccation dishes. Samples were baked in a home use oven at 176.7 C for 4 minutes. Products were served immediately to panelists, and panelists were provided with plastic forks.

A warm-up sample was provided with each evaluation session with each modality. A consensus profile (established in refinement sessions) was provided with this sample and the purpose was to focus the panelist (O'Mahony et al., 1988; Plemmons and Resurreccion, 1997). No more than five cheeses were evaluated in a session and no more than 2 sessions were conducted in a day. Samples were evaluated monadically by each panelist in a randomized balanced order and data was collected using Compusense Cloud (Guelph, Canada). A 4 min rest was enforced between samples and panelists were provided with bottled spring water and unsalted crackers for palate cleansing. Each panelist evaluated each lot of each product in each modality (hot, cold) in triplicate.

Projective Mapping

Following lexicon validation, the same trained panel conducted projective mapping (PM) with PB and dairy cheeses. Our objective was to evaluate the overall similarity (or lack of) between PB and dairy cheeses. Since very few sensory attributes overlap between the 2 categories, it was not feasible to compare these 2 categories by descriptive analysis. Eight shredded Cheddars (6 PB and 2 dairy), 7 sliced Cheddars (5 PB and 2 dairy), and 9 PB shredded mozzarella (7 PB and 2 dairy) were evaluated by projective mapping as-is (cold) and melted for a total of 6 projective mapping activities (cold Cheddar shreds PM, hot Cheddar shreds PM, cold Cheddar slices PM, hot Cheddar slices PM, cold mozzarella PM, and hot mozzarella PM). The dairy cheeses were national brands and were screened prior to use to confirm that they displayed typical mild Cheddar or Mozzarella flavors and textures. Samples were prepared as described in the previous section. Projective mapping was conducted as described by Del Toro Gipson et al. (2020). Ten 30-minute sessions were dedicated to training and calibrating to familiarize panelists with the method. The exercises were built using the projective mapping option with the mapping dimension of 650 x 650 in Compusense version 22.19 (Compusense, Guelph, Ontario, Canada). All data was collected in Compusense. For each activity, all samples within that activity were served simultaneously. Panelists were allowed to request additional samples as needed. Each panelist completed each PM activity in quadruplicate.

Statistical Analysis

Descriptive analysis data were analyzed using analysis of variance with Fisher's least significant difference at 95% confidence level ($p < 0.05$). Subsequently, principal component analysis (PCA) was applied to the descriptive data means using the correlation matrix to visualize the variability of the products and the discriminating ability of the lexicons. Principal component analysis was applied to the mean attribute intensity scores for Cheddar shreds, Cheddar slices and Mozzarella shreds individually and together for each modality (cold flavor, cold texture, hot texture). A greater percentage of variability was explained when flavor and textural attributes were analyzed separately; therefore, the flavor and texture results for each PB cheese will be discussed individually. X and Y coordinates data from PM were analyzed using Multiple Factor Analysis (MFA) to visualize similarities and differences among cheeses. All analyses were done using XLSTAT (version 2023.1.1, Addinsoft, Boston, USA).

RESULTS AND DISCUSSION

Plant-based Cheese Flavor

PB Cheddars (shredded and sliced) and mozzarellas were differentiated using the developed lexicons (**Tables 8-16**). Unlike natural (dairy) cheeses which are made from milk with the addition of starter culture, coagulant and salt, the ingredients used to produce PB cheeses vary widely (**Table 7**). This wide use of ingredients was reflected in the variability of the mean flavor attributes. Of the 22 flavor attributes documented in the PB Cheddar shreds, five aromatics were documented in all PB cheeses while nine aromatics were present in some of the cheeses (**Table 8**). Three aromatics were only detected in one PB cheese shred. Bitter taste was documented in one PB cheese shred. The selected PB Cheddar shreds were differentiated ($p<0.05$) by the identified flavor attributes except for nutty flavor which was not detected in any of the shredded PB Cheddars. Flavor attribute intensities of PB Cheddar shreds were generally mild (<5.0 on the Spectrum™ intensity scale), which is consistent with the flavor attribute intensity range of natural Cheddar cheeses (Drake et al., 2001; Drake et al., 2005).

The first two dimensions of the PCA for cold flavor attributes of shredded PB Cheddars explained 55.14% of the variability combined (**Fig. 1**). Dimension one explained 31.66% of the variability and was comprised of aroma intensity, fat/oil non-dairy, brothy, sour taste, umami taste, astringent mouthfeel, and aftertaste intensity. Dimension two explained 23.48% of the variability and was associated with sour aromatic, diacetyl, fruity, potato, and free fatty acid. PBSHC1 was distinct from other shredded PB Cheddars. PBSHC1 was generally characterized by a lack of or low intensity of flavors except for coconut flavor and salty taste. Water and coconut oil were the first two ingredients of this PB cheese. PBSHC2 was differentiated from other PB cheeses by the presence of beany and cereal aromatics and bitter taste. These flavors were unique to PBSHC2. Beany is a common characteristic found in plant-based products, especially those derived from soy (Short et al., 2021). PBSHC2 utilizes multiple legumes including navy beans, organic garbanzo beans, and faba bean protein and may explain the presence of these flavors. PBSHC3, PBSHC4, PBSHC5, and PBSHC7 were similarly clustered together on the PCA due to their moderate intensities of many attributes relative to the other samples. Differentiating characteristics of PBSHC3 were higher intensities of sweet and fruit aromatics. The only differentiating attribute for PBSHC5 was a significantly higher sour aromatic intensity ($p<0.05$). PBSHC4 and PBSHC7 had no differentiating attribute that was significantly different from the rest of the samples. PBSHC6 was significantly higher in aroma intensity, diacetyl and potato flavors, astringent mouthfeel, and aftertaste intensity ($p<0.05$).

Diacetyl flavor was documented in 14 of the 21 PB cheeses evaluated in this study. Diacetyl flavor is sourced to the chemical compound diacetyl and other similar compounds (Rincon Delgadillo et al., 2012). This flavor is present and prevalent in cultured dairy products and mild dairy cheeses (Singh et al., 2002). It is produced naturally by starter culture fermentation, but similar flavors can be added to foods (Rincon Delgadillo et al., 2012), and it is not surprising that this flavor would be documented in PB cheeses. PBSHC8 displayed the highest intensity of fat/oil flavor and was the only PB cheese with cardboard flavor ($p<0.05$). Cardboard flavor is a ubiquitous flavor attribute of protein powders (Russell et al., 2005; Liu et al., 2023) which are used as ingredients in PB cheeses. Cardboard flavor is sourced to lipid oxidation products, and fats and oils can also be sources of cardboard flavor (Lindsay, 2017).

Sliced PB Cheddars were also distinguished by the identified lexicon (**Table 9**). Fruity flavor and bitter taste were not detected in sliced PB Cheddars (unlike shredded PB Cheddar), but nutty flavor was documented in two of sliced PB Cheddars. The first two dimensions of the PCA explained 69.79% of the variability (**Fig. 2**). Dimension one (49.87%) was comprised of aroma intensity, cooked non-dairy, sour aromatic, diacetyl, fat/oil non-dairy, nutty, cereal, cardboard, sour taste, salty taste, umami taste, astringent mouthfeel, and aftertaste intensity. Dimension two (19.92%) was comprised of brothy, free fatty acid, and sweet taste.

PBSLC1 was characterized by the highest intensity of sweet aromatic and nutty flavors ($p<0.05$). PBSLC1 was the only PB Cheddar labeled as “mature” on the package. A mature or aged Cheddar cheese is generally associated with a more intense flavor profile that includes an array of sensory attributes including sulfur, catty, caramelized and nutty among others (Drake et al., 2001; 2005b), which may explain the nutty flavor in this sample. PBSLC2 was differentiated by generally lower intensity across all attributes, and sweet aromatic flavor and astringent mouthfeel were lower in PBSLC2 than in other cheeses ($p<0.05$). PBSLC2 was the only cheese that lacked coconut and potato flavors. PBSLC3 was differentiated by a significantly higher intensity of free fatty acid flavor ($p<0.05$). Free fatty acid flavor is defined by short-chain free fatty acids, most notably butyric acid, and is an attribute present in natural dairy cheeses sourced to hydrolysis of milkfat triglycerides (Singh et al., 2003). Short chain fatty acids display cheesy aromas, and it is not surprising that this attribute was present in PB cheeses since these organic acids can be used as flavoring agents. PBSLC6 was characterized by the highest intensities of sour aromatic, brothy, and cardboard flavors and sweet and umami tastes ($p<0.05$). The presence of yeast extract as an ingredient in this PB cheese may explain the high brothy flavor and umami taste. Six shredded PB Cheddar and sliced PB Cheddars were the same commercial brands (PBSHC1 and PBSLC1; PBSHC3 and PBSLC6; PBSHC4 and PBSLC2; PBSHC5 and PBSLC3; PBSHC7 and PBSLC4; PBSHC8 and PBSLC5). When these shredded and sliced PB Cheddars were subjected to PCA together (results not shown), five out of six shredded PB Cheddars were similar in sensory profiles to their sliced counterparts. This is unsurprising as the ingredients for the shredded PB Cheddars were similar to ingredients for the sliced PB Cheddars counterparts within the same brand with the only difference being the lack of the anticaking agent in the sliced version.

Three aromatics were documented in all PB mozzarellas (**Table 10**). Seven attributes were documented in some cheeses, and three attributes were only documented in one PB mozzarella. Fruity flavor was not detected in any of the PB mozzarellas. Bitter taste was documented at low intensity in one PB mozzarella. The intensities of PB mozzarella were mild, similar to that of PB Cheddar shreds and slices. The PCA explained 71.23% of the variability in the first and second dimensions (**Fig. 3**). Dimension one (40.28%) was comprised of aroma intensity, cooked non-dairy, fat/oil non-dairy, coconut, cereal, brothy, cardboard, sweet and salty tastes, and astringent mouthfeel. Dimension two explained 30.48% of the variability and was associated with sour aromatic, potato, sour taste, umami taste, and aftertaste intensity. Significantly differentiating attributes for PBM1 were cereal and potato flavors, sour taste, aftertaste intensity and a low bitter taste ($p<0.05$). PBM2 and PBM7 were characterized by coconut flavor and sweet taste. Coconut flavor was detected in all but one sliced PB Cheddar, and in a few of the shredded Cheddars and mozzarella. Interestingly, PBM6, PBSHC7, and PBSLC4 utilized highly refined coconut oil and had detectable coconut flavor which is contradictory to a previous finding that refined coconut oil had no perceptible aromas and flavors (Villarino et al., 2007). PBM2 was differentiated by a high intensity of sweet aromatic flavor and faint free fatty acid flavor. PBM3 was the only sample with nutty flavor and the highest umami taste ($p<0.05$). PBM4 was differentiated by beany flavor, and it was the only sample with that attribute. PBM5 was differentiated by a higher aroma intensity and fat/oil and cardboard flavors ($p<0.05$). The differentiating characteristics of PBM6 were high intensities of diacetyl and brothy flavors ($p<0.05$). In general, flavor attributes and intensities were not distinct between PB Cheddars and plant-based Mozzarellas.

Plant-based Cheese Cold Texture

PB cheeses were differentiated by cold and hot texture attributes (Tables 11, 12). Out of seventeen appearance and texture attributes, eleven attributes were detected across all PB shredded Cheddars. Five attributes, including hand cohesiveness, degree of breakdown, cohesiveness, smoothness of mass, and oily mouth coating was detected in some PB shredded Cheddars. Wet/oily was detected in only a single PB shredded Cheddar (PBSHC2). Dimension one of the PCA for cold texture attributes for PB Cheddar shreds explained 43.09% of the variability while dimension two explained 24.05% (Fig. 4). Dimension one was comprised of visual homogeneity, hand cohesiveness, tooth pull/tackiness, degree of breakdown, cohesiveness, adhesiveness, smoothness of mass, and smoothness of mouth coating. Factor two was comprised of the attributes color, visual particulates, and smoothness of pieces. PBSHC2 and PBSHC 3 were distinct in appearance/texture from the other plant-based shreds. PBSHC2 scored significantly higher in color, visual particulates, hand cohesiveness, and mouth coating pieces ($p<0.05$) (Table 11). PBSHC2 and PBSCH3 both shared a high tooth pull/tackiness intensity. PBSHC3 received the highest score in many attributes with degree of breakdown, cohesiveness, smoothness of mass, smoothness of pieces, and smoothness of mouth coating being significantly different from the shreds ($p<0.05$). This shred also received the lowest color intensity making it the lightest colored sample ($p<0.05$). PBSHC1 was scored significantly lower in oily/moist to lips and adhesiveness ($p<0.05$), and it was the only sample that lacked the oily mouth coating. PBSHC4 was differentiated by its higher score of wet/oily appearance, oily/moist to lips, and firmness ($p<0.05$), indicating that it was the firmest sample when tasted cold. The differentiating attribute for PBSHC5 was the high adhesiveness to lips score which was significantly higher than the other shreds ($p<0.05$). PBSHC6 was differentiated by its significantly lower score in smoothness of mouth coating ($P<0.05$).

Thirteen out of seventeen attributes were detected among all sliced PB Cheddars, and two attributes were detected in the majority but not all of the samples (**Table 12**). The last two attributes were only detected in one sample: PBSLC 6 for wet/oily and PBSLC3 for visual particulates. Visual particulates were detected in all, except one, samples of the shredded PB cheeses (Cheddar and mozzarella). Sliced PB Cheddars also had notably high visible homogeneity with the mean score ranging from 12.9 to 15.0. The first two dimensions of the PCA accounted for 74.30% of the variability (**Fig. 5**). Dimension one explained 49.05% of the variability and was correlated with the attributes color, visual particulates, hand cohesiveness, adhesive to lips, tooth pull/tackiness, degree of breakdown, cohesiveness, smoothness of mass, smoothness of pieces, smoothness of mouth coating, and oily mouth coating. Dimension two explained 25.25% of the variability and was correlated with visual homogeneity, firmness, and adhesiveness. PBSLC1 was characterized by relatively high visual homogeneity and mouth coating pieces, and scored significantly lower in color, oily/moist to lips, tooth pull/tackiness, degree of breakdown, cohesiveness, and adhesiveness ($p<0.05$). PBSLC6 was characterized by the attributes tooth pull/tackiness, degree of breakdown, cohesiveness, adhesiveness, oily mouth coating, and wet/oily and scored higher intensities of these attributes than the rest of the samples ($p<0.05$). PBSLC2 scored significantly higher in oily/moist to lips ($p<0.05$), and also received a high visual homogeneity intensity score, similar to PBSLC1. PBSLC3 was characterized by a darker color ($p<0.05$), and it was the only sample with visible particulates. PBSLC4 was characterized by high smoothness of pieces, smoothness of mouth coating, firmness, and hand cohesiveness. PBSLC5 was located in the center of the PCA due a lack of differentiating characteristics aside from having a significantly lowered visible homogeneity intensity score than the rest of the sliced samples ($p<0.05$).

Nine visual or texture attributes were detected among all shredded PB mozzarella, and seven attributes were detected with some (**Table 16**). Similar to the sliced and shredded PB Cheddars, wet/oily appearance was only detected in one sample. The first two dimensions of the

PCA accounted for 74.45% of the variability (**Fig. 6**). The first dimension explained 53.74% of the variability comprising of hand cohesiveness, firmness, tooth pull/tackiness, degree of breakdown, cohesiveness, adhesiveness, smoothness of mass, smoothness of pieces, smoothness of mouth coating, mouth coating pieces, and oily mouth coating. The variability in dimension one was largely driven by the differences between PMB7 compared to the rest of the samples. Dimension two explained 20.70% of the variability and was comprised of color, visual particulates, adhesive to lips, and oily moist to lips. The differentiating attributes of PBM7 were significantly higher detection of hand cohesiveness, tooth pull/tackiness, degree of breakdown, cohesiveness, adhesiveness, smoothness of mass, smoothness of pieces, smoothness of mouth coating, and oily mouth coating ($p<0.05$). PMB7 was also the only sample recorded as lacking visual homogeneity. PBM3 was characterized by a significantly darker color and a high intensity of oily/moist to lips ($p<0.05$). It was also the only sample that was characterized as wet/oily in appearance. The differentiating attribute for PBM5 was a significantly higher visual particulates intensity ($p<0.05$), and low adhesive to lips and low oily/moist to lips. PBM6 was significantly high in visual homogeneity ($p<0.05$).

Overall, variability in the ingredients and processing method resulted in the PB cheeses that were distinct in appearance and texture. The developed lexicon was able to differentiate PB shredded cheeses that utilized plant-based milk as the main ingredient (PBSHC2, PBSHC3, and PBM7) from the rest of the PB cheeses that utilized water as the main ingredient (**Fig. 4**). The plant-based milk utilized in PBSHC2, PBSHC3, and PBM7 contained water and a plant source and did stabilizers or thickeners unlike traditional plant-based milks (McClements et al., 2019). The district texture may also be due to the variety of starches, proteins and oils utilized in the different plant-based cheeses (Grossmann and McClements, 2021) (**Table 7**). PB Cheddars (sliced and shredded), unsurprisingly, all scored higher in color intensity than PB mozzarella as all PB Cheddars had some degree of orange color. The visible wet/oil attribute was detected in three cheeses (PBSHC4, PBSLC6, and PBM3). Two of these cheeses (PBSHC4 and PBM3) were the same brand and contained similar ingredients. The visible wet/oil attribute may be due to the utilization of expeller pressed canola and/or safflower oil as those two oils are high in unsaturated fatty acids and do not solidify at room temperature (Grossmann and McClements, 2021). PBSHC4 and PBM3 also did not utilize an anticaking agent unlike some other brands investigated in this study. Visual particulates attribute was minimally detected in one sliced Cheddar sample (PBSLC3). This attribute was documented at variable intensities across all shredded samples except one (PBM6). Meals et al. (2021) reported visual particulates/powder were due to anticake agents in cheese shreds and that higher application of anticaking agent resulted in higher visible powder. A low cohesiveness in shredded PB cheeses suggests that shredded PB cheeses were more likely to crumble within the package which could explain the higher visual particulates than sliced samples.

Plant-based Cheese Hot Texture

Eight hot texture attributes were detected in all PB Cheddar shreds and the other eight were detected in some of the shredded PB Cheddars (**Table 14**). Dimensions one and two of the PCA for hot evaluation of shredded PB Cheddars explained 60.52% of the variability (**Fig. 7**). Dimension one explained 44.68% of the variability and was correlated with surface moisture, meltedness, stretchability, oiliness to lips, elasticity, cohesiveness, exudes moisture, oiliness, and dissolution. Dimension two explained 16.99% of the variability and was loaded with firmness, adhesive to lips, and tooth pull/tackiness. Hot PBSHC4 was the most distinct of the cheeses and had nine textural attributes that were scored significantly higher than other shreds including surface moisture, meltedness, stretchability, oiliness to lips, firmness, cohesiveness, exudes moisture, oiliness, and smoothness of mass ($p<0.05$). PBSHC4 also scored lower for dissolution and mouth coating ($p<0.05$). PBSHC2 scored significantly higher for the attribute tooth pull/tackiness and mouth coating ($p<0.05$). PBSHC5 scored significantly higher for the attribute dissolution and residual adhesive to lips ($p<0.05$). PBSHC6 had higher adhesiveness than other samples ($p<0.05$). The only differentiator for PBSHC7 was the significantly lower score of residual adhesives to lips ($p<0.05$). PBSHC8 scored the highest in adhesive to lips, making that the differentiating attribute for PBSHC8 ($p<0.05$).

Ten attributes were documented among all sliced PB Cheddars, and six attributes were detected in some (**Table 15**). The first two dimensions of the PCA displayed 75.62% of the variability for hot evaluation of sliced PB Cheddars (**Fig. 8**). Dimension one explained 50.95% of the variability and was comprised of surface moisture, meltedness, stretchability, oiliness to lips, tooth pull/tackiness, elasticity, adhesiveness, exudes moisture, oiliness, and mouth coating. Dimension two comprised 24.69% of the variability and was loaded with the attribute firmness, cohesiveness, smoothness of mass, and dissolution. Sliced PB cheeses are well separated on the PCA due to unique differentiating attributes for each of the PBSLC. PBSLC1 was characterized by significantly higher adhesiveness ($p<0.05$). PBSLC2 was characterized by firmness, cohesiveness, and residual adhesive to lips ($p<0.05$). PBSLC3 had the most differentiating attributes which were surface moisture, meltedness, oiliness to lips, exudes moisture, oiliness, dissolution, and mouth coating ($p<0.05$). PBSLC4 was characterized by the attribute tooth pull/tackiness. Lastly PBSLC5 was characterized by stretchability and elasticity. PBSLC4 and PBSLC5 were grouped together based on their relatively high elasticity which was only detected in three samples (PBSLC4, PBSLC5, and PBSLC 1).

Nine hot visual and texture attributes were detected across all shredded PB mozzarella and 7 were detected among some (**Table 16**). The first two dimensions of the PCA for shredded PB mozzarella explained 76.13% of the variability with dimension one contributing 56.12% and dimension two contributing 20.01% (**Fig. 9**). Principal component one was correlated with the majority of the attributes including surface moisture, meltedness, stretchability, oiliness to lips, firmness, elasticity, cohesiveness, oiliness, smoothness of mass, dissolution, and residual adhesive to lips while principal component two was correlated with adhesiveness. The variability in the first dimension was largely driven by PBM3. PBM3 had eight differentiating attributes from other PBM that included surface moisture, meltedness, stretchability, oiliness to lips, firmness, elasticity, cohesiveness, and smoothness of mass ($p<0.05$). PBM1 was characterized by adhesiveness, dissolution, and residual adhesive to lips ($p<0.05$). Adhesive to lips was the differentiating attribute for PBM5 ($p<0.05$). PBM7 was characterized by mouth coating ($p<0.05$).

PB cheeses were differentiated when evaluated hot using the developed lexicon. PBSHC4, PBM3, and PBSLC2 were from the same brand. Meltedness, a desirable quality of Cheddar and mozzarella cheeses, varied widely with PB mozzarella shreds (0.7-8.2 on a 0 to 15 point scale (**Table 16**). PBSHC4 and PBM3 were distinct within their respective categories when evaluated hot (**Figures 7, 9**). These two samples were noted as having a wet/oily appearance when cold, so it is unsurprising that they displayed differentiating characteristics when evaluated hot: surface moisture (from oil), oiliness to lips, and oiliness (in the mouth). These differentiating properties could be due to the combination of coconut oil, canola, and safflower oil in the ingredient decks of these cheeses (**Table 7**). Coconut oil is a popular ingredient among plant-based cheeses because it allows PB cheeses to maintain a solid phase structure in ambient temperatures due to the high saturated fat content while converting to liquid which allows PB cheese to melt when heat is applied (Chaleepa et al., 2010; Grossmann and McClements, 2021). The three types of oil used in PBSHC4 and PBM3 may be necessary to mimic melt properties of dairy cheeses.

Projective Mapping

MFA for PM of shredded Cheddars tasted cold explained 69.02% of the variability with dimension one explaining 55.07% and dimension two explaining 13.95% (**Fig.10**). Plant-based shredded Cheddars were perceived to be relatively similar to each other with the exception of PBSHC4 that were distinctly separated from other plant-based shredded Cheddars. The two dairy shredded Cheddars were perceived to be very similar to each other and remained distinct from the rest of the plant-based shredded Cheddars. A similar PM was observed with sliced dairy and plant-based Cheddars (**Fig. 11**). Plant-based mozzarella were also distinct from each other (**Fig. 12**). PBM7 was the closest sample to the dairy mozzarellas.

MFA for PM of shredded Cheddars tasted hot explained 71.98% of the variability (**Fig. 13**). PBSHC1, PBSHC8 and PBSHC7 formed a distinct cluster that are different from the other three PB shredded cheddars. However, the PB cheeses were largely separated on dimension two which only account for 17.38% of the variability compared to the separation between the PB cheeses to the dairy cheese which is largely loaded on dimension one which accounts for 54.61% of the variability. MFA for PM of sliced Cheddars tasted hot explained 75.31% of the variability (**Fig.14**). PBSLC4, PBSLC5, and PBSLC2 were perceived to be very similar to each other. The main contributor to the variability in factor 2 was PBSLC3 which was distinct from the other PB sliced Cheddars. Again, the largest variability was from the overall perceived differences between the PB cheeses and dairy cheeses which were loaded on dimension 1 (58.98%).

MFA for PM of shredded mozzarella taste hot explained 64.87% of the variability (**Fig.15**). Similar to previous projective maps, a large variability (49.47%) was loaded on dimension one which reflected the large overall perceived differences between PB, and dairy compared to PB mozzarella cheeses to each other. The perceived differences between the PB mozzarella cheeses were represented by dimension two (15.41%) with PB cheeses scattered across the second dimension. Overall, PM exercises demonstrated the overall perceived similarity/difference between plant-based cheeses and the dairy cheeses when tasted cold and hot. All plant-based cheeses investigated in the study were perceived to be very different from the dairy cheeses based on the distance on the MFA biplots. Moreover, plant-based cheeses were generally perceived to be different from each other. Dairy-based mild Cheddar and mozzarella cheeses display a range of flavor and texture attributes so variability among PB cheeses within a category (e.g. Cheddar style or mozzarella style) would be expected. The PB cheese category is relatively young, and new products continue to emerge in this market. Lexicons can be refined and new terms added as new attributes are encountered within a category (Lawless and Civille, 2018). Future studies should subject the lexicons identified in this study to different PB cheese varieties such as parmesan and/or feta to determine if additional terms are needed. Moreover, the products in this study demonstrated that ingredients in PB cheeses varied greatly even within a similar type of cheese, thus new terms may need to be added or existing attributes modified accordingly as new ingredients or processing methods are incorporated in the product category.

CONCLUSION

Lexicons (cold flavor, cold texture, and melted texture) were developed and validated for the evaluation of plant-based cheeses. Sliced and shredded PB Cheddars and mozzarellas were differentiated using the identified lexicons. Using projective mapping, PB cheddars, shredded and sliced, and shredded PB mozzarella remained distinct from their dairy counterparts suggesting that more development work is needed to achieve a closer similarity to dairy cheeses.

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Table 2.1. Initial plant-based cheese cold flavor lexicon.

Terms
Aroma Character Description
Aroma intensity
Milk fat
Cooked milk
Cooked non-dairy
Sour aromatic
Sweet aromatic
Diacetyl
Non-dairy fat/oil
Green pea
Coconut
Fruity
Nutty
Beany
Cereal/grain
Brothy
Potato
Free fatty acid
Cardboard
Sweet taste
Sour taste
Bitter taste
Salty taste
Umami taste
Astringent mouthfeel
Aftertaste intensity

Adapted from Russell et al., 2006; Drake et al., 2001; Drake et al., 2007; Shepard et al., 2013; Liu et al., 2023; Meilgaard et al., 1999; Drake et al., 2003.

Table 2.2. Initial plant-based cheese cold texture lexicon.

Terms
Color
Visual particulates
Hand cohesiveness
Firmness
Degree of breakdown
Tooth pull/Tackiness
Cohesiveness
Adhesiveness
Smoothness of mass
Smoothness of mouthcoating

Adapted from Brown et al., 2003 and Meals et al., 2020.

Table 2.3. Initial plant-based cheese hot texture lexicon.

Terms
Color
Visible surface moisture
Meltedness
Stretchability
Oiliness to lips
Hardness
Tackiness
Cohesiveness
Adhesiveness
Oiliness
Smoothness of mass
Mouthcoating

adapted from Meals et al., 2020.

Table 2.4. Refined plant-based cheese cold flavor lexicon

Term	Definition	Example
Orthonasal aroma		
Aroma character	Description of the primary attributes perceived orthonasally	
Aroma intensity	Overall impact of the orthonasal headspace	
In-mouth flavor		
Cooked non-dairy	Aromatics associated with cooked starch	Cooked starches, such as cooked flour and water paste, heated corn starch paste, cooked white rice
Sour aromatic	Aromatics associated with organic acids, primarily acetic acid	White vinegar
Sweet aromatic	Sweet aromatic associated with cake mix	vanilla cake mix
Diacetyl	Aromatic associated with diacetyl[2]	Diacetyl, 20ppm
Non-dairy fat/oil	Aromatics associated with fresh oils and fats not of dairy origin	Vegetable oils
Coconut	Aromatics of raw coconut	Bakers coconut flakes
Fruity	Aromatics associated with various fruits [2]	Ethyl hexanoate 20 ppm in ethanol, canned pineapple tidbits
Nutty	The nut like aromatic associated with different nuts [3]	Lightly toasted unsalted nuts
Beany	Aromatics of associated with beans	canned great northern beans
Cereal/grain	Aromatics associated with cereal, oatmeal, grain [1]	Cheerios, 50 g in 200 mL distilled water
Brothy	Aromatics associated with vegetable broth[3]	Vegetable broth or stock
Potato	Flavor and aftertaste of boiled potatoes[4]	Methional, unpeeled white potato cubes boiled until soft
Free fatty acid	Aromatics associated short chain fatty acids, primarily butyric and hexanoic acids	Butyric acid, 200 ppm in sniff jar, dairy based Feta cheese
Cardboard	Aromatics associated with wet cardboard[7]	Brown paper bag or cardboard soaked in boil water
Sweet taste	Basic taste sensation elicited by sugars[6]	Sucrose 5% in distilled water
Sour taste	Basic taste sensation elicited by acids[6]	Citric acid 0.08% in distilled water
Bitter taste	Basic taste sensation elicited by compounds such as caffeine and quinine[6]	Caffeine 0.08% in distilled water, tonic water

Salty taste	Basic taste sensation elicited by salts[6]	NaCl 1% in distilled water
Umami taste	Basic taste sensation elicited by certain peptides and nucleotides[6]	MSG 0.5% in distilled water
Astringent mouthfeel	Sensation of drying, drawing and/or puckering of mouth surfaces[4]	Alum in distilled water, black tea
Aftertaste intensity	Overall impact remaining after expectoration	n/a

[a]Violife cheddar shredded (UPC: 810934030215).
[b]Kraft mild cheddar finely shredded (UPC: 021000055012).
[1]Adapted from Russell et al., 2006.
[2]Adapted from Drake et al., 2001.
[3]Adapted from Drake et al., 2007.
[4]Adapted from Shepard et al., 2013.
[5]Adapted from Liu et al., 2023.
[6]Adapted from Meilgaard et al., 1999.
[7]Adapted from Drake et al., 2003.

Table 2.5. Refined plant-based cheese cold appearance and texture lexicon

Term	Definition	Technique	Reference or Example
Appearance			
Color	The value of the color from light to dark[2]	View the sample from above using overhead fluorescent lights	A= 7.9 B = 11.6
Wet/oily	Degree to which the sample appears moist or oily on the surface	View the sample from above using overhead fluorescent lights	B = 7.7 C= ND
Visual particulates	Degree to which small particulates such as anti-caking agents or shattered shreds are visible	View the sample from above using overhead fluorescent lights	A = 4.0 B = 1.0
Visual homogeneity	Degree to which the shreds or slices appear uniform	View the sample from above using overhead fluorescent lights	A = 2.0 C = 13.7
Hand evaluation			
Hand cohesiveness	Degree to which the sample holds together[2]	Press sample in the palm of hand 5 times	A = ND C = 6.2
Surface texture			
Adhesive to lips	Degree to which the sample sticks to the lips	Press dry lips onto sample 3 times	B = 2.8 C = 8.7
Oily/moist to lips	Amount of oil, fat or moisture perceived on the lips[2]	Press dry lips onto sample 3 times	A = 0.7 B = 11.3
Mouth evaluation first bite			
Firmness	Amount of force required to bite completely through the sample[1]	Using the molars, bite completely through the sample	A = 4.5 B = 6.2 C = 3.0
Mouth evaluation mastication			
Tooth Pull / tackiness	Amount of force required to pull the teeth apart	Chew 3 to 4 times	A = 0.8 C = 2.7
Degree of breakdown	The amount of breakdown in the sample as a result of mastication (melts or dissolves)[1]	Chew the sample 7 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = ND C = 7.5
Cohesiveness	The degree to which the chewed mass holds together[1]	Chew the sample 7 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = ND C = 6
Adhesiveness	Degree to which the chewed mass sticks to any of the mouth surfaces[1]	Chew the sample 7 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = 1.5 C = 6.0
Smoothness of mass	The degree to which the chewed mass surface is smooth (free of any particles) prior to swallow[1]	Chew the sample 7 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = ND C = 6.5

Smoothness of pieces	The degree to which any remaining pieces of sample are smooth prior to swallow	Chew the sample 7 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = 3.1 B = 1.6 C = 7.2
Residual			
Smoothness of mouth coating	The degree of smoothness felt in the mouth[1]	Expectorate the sample and evaluate remaining residue in the mouth	A = 2.4 B = 1.6 C = 7.9
Mouth coating pieces	Amount of particulates of any size remaining	Expectorate the sample and evaluate remaining residue in the mouth	B = 5.9 C = 2.2
Oily mouth coating	Degree to which any residual mouth coating is oily	Expectorate the sample and evaluate remaining residue in the mouth	B = 2.5 C = 0.9

[a]Violife Cheddar shredded (UPC: 810934030215).
[b]Daiya Cheddar shredded (UPC: 871459003214)
[c]Kraft mild Cheddar finely shredded (UPC: 021000055012).
[1]Adapted from Brown et al., 2003.
[2]Adapted from Meals et al., 2020.

Table 2.6. Refined plant-based cheese hot appearance and texture lexicon

Term	Definition	Technique	Reference or Example
Appearance			
Surface moisture	Degree to which the sample appears moist or oily on the surface[1]	View the sample from above using overhead fluorescent lights	A= 7.9 B= 9.5 C = 10.5
Meltedness	Homogeneity of the sample[1]	View the sample from above using overhead fluorescent lights	B = 7.7 C = ND
Stretchability	The number of inches that the cheese can be stretched vertically	Measure, in inches, the length the sample can be lifted vertically with a fork	A = 0.5 B = 6.7
Surface texture			
Adhesive to lips	Degree to which the sample sticks to the lips	Tap sample against dry lips 3 times	A = 5.5 C = ND
Oiliness to lips	Amount of oil or fat perceived on the lips[1]	Tap sample against dry lips 3 times	A = ND B = 11 C = 4.8
Mouth evaluation first bite			
Firmness	Amount of force required to bite completely through the sample	Using the molars, bite completely through the sample	A = 2 B = 4
Mouth evaluation mastication			
Tooth pull/tackiness	Amount of force required to pull the teeth apart[1]	Chew 3 to 4 times	A = 1.1 C = 1.7
Elasticity	Degree to which the sample recovers original shape	Chew the sample 4 to 5 times at a steady rate of 1 chew per second and evaluate	A = ND B = 5.8 C =2.4
Cohesiveness	The degree to which the chewed mass holds together[1]	Chew the sample 5 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = 2.1 C = 12.1
Adhesiveness	Degree to which the chewed mass sticks to any of the mouth surfaces[1]	Chew the sample 5 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = 4.7 B = 2.5 C = ND
Exudes moisture	Degree to which any moisture is released	Chew the sample 5 times at a steady rate of 1 chew per second and evaluate the chewed mass and mouth surfaces	B = 2.1 C = 1.2
Oiliness	Degree to which oil or fat is perceived[1]	Chew the sample 5 times at a steady rate of 1 chew per second and evaluate the chewed mass and mouth surfaces	A = 0.6 B = 8.2 C = 2.8
Smoothness of mass	The degree to which the chewed mass surface is smooth (free of any particles) prior to swallow[1]	Chew the sample 5 times at a steady rate of 1 chew per second and evaluate the chewed mass	A = 9.9 B = 12.6 C = 9.1

Dissolution	The degree to which the sample breaks up and dissolves on the mouth (not mechanical breakdown)	Chew the sample 5 times at a steady rate of 1 chew per second and evaluate just prior to expectoration	A = 6.0 B = 1.6 C = ND
		Residual	
Mouth coating	Amount of residue remaining in the mouth[1]	Expectorate the sample and evaluate remaining residue in the mouth	A = 4.1 C = 2.1
Residual adhesive to lips	Degree to which the sample sticks to the lips	Expectorate and evaluate residue remaining on the lips	A = 1.6 C = ND

[a]Violife Cheddar shredded (UPC: 810934030215).
[b]Daiya Cheddar shredded (UPC: 871459003214)
[c]Kraft mild Cheddar finely shredded (UPC: 021000055012).
[1]Adapted from Meals et al., 2020.

Table 2.7. Cheeses used for profiling using the refined lexicons and projective mapping.

Sample	Type	Ingredients
PBSHC1	PB Shredded Cheddar	Filtered Water, Coconut Oil, Food Starch-Modified (Potato & Corn), Corn Starch, Salt (Sea Salt), Cheddar Flavor (Vegan Sources), Olive Extract, Paprika Extract & Beta Carotene (Color), Vitamin B12, Powdered Cellulose (Added to Prevent Caking)
PBSHC2	PB Shredded Cheddar	Cultured Vegan Milk (Oat Milk (Filtered Water, Organic Oats), Navy Beans, Organic Garbanzo Beans, Cultures), Filtered Water, Organic Coconut Oil, Faba Bean Protein, Potato Starch, Organic Tapioca Starch, Contains Less Than 2% of Sea Salt, Calcium Sulfate, Natural Flavors, Organic Yeast Extract, Organic Annatto, Organic Cultured Dextrose, Konjac, Organic Locust Bean Gum
PBSHC3	PB Shredded Cheddar	Nutmilk (Water, Cashews), Coconut Oil, Modified Food Starch, Potato Starch, Nutritional Yeast, Sea Salt, Annatto, Natural Flavour, Cultures
PBSHC4	PB Shredded Cheddar	Filtered Water, Tapioca Starch, Coconut Oil, Expeller Pressed: Canola and/or Safflower Oil, Vegan Natural Flavors, Chickpea Protein, Salt, Potato Protein, Tricalcium Phosphate, Lactic Acid (Vegan), Konjac Gum, Yeast Extract, Xanthan Gum, Annatto Color, Turmeric Color, Inactive Yeast, Potassium Chloride
PBSHC5	PB Shredded Cheddar	Water, Modified Food Starch, Coconut Oil, Natural Flavor, Pea Starch, Salt, Paprika Oleoresin (Color), Turmeric & Annatto Extracts (Color)
PBSHC6	PB Shredded Cheddar	Filtered Water, Organic Coconut Oil, Potato and Corn Starch, Expeller-pressed Canola Oil, Natural Flavors (Contains Autolyzed Yeasts), Less than 2% of Potato Protein, Calcium Phosphate, Sea Salt, Organic Vegan Cane Sugar, Organic Vegetable Glycerin, Citric Acid, Sodium Citrate, Lactic Acid, Sodium Bicarbonate, Annatto for Color, Beta Carotene for Color, Paprika Extract for Color
PBSHC7	PB Shredded Cheddar	Filtered Water, Highly Refined Coconut Oil, Modified Potato Starch, Modified Tapioca Starch, Potato Starch, Sea Salt, Olive Extract, Natural Flavor, Paprika Extract (Color), Beta Carotene (Color)
PBSHC8	PB Shredded Cheddar	Filtered Water, Coconut Oil, Food Starch (Tapioca and Potato), Sunflower Oil, Natural Flavors (Vegan Sources), Chickpea Protein, Calcium Citrate, Sea Salt, Konjac, Xanthan Gum, Paprika And Beta Carotene (Color), Powdered Cellulose Added To Prevent Caking
PBSLC1	PB Sliced Cheddar	Filtered Water, Coconut Oil, Food Starch-Modified (Potato & Corn), Potato Starch, Salt (Sea Salt), Mature Cheddar Flavor (Vegan Sources), Olive Extract, Beta Carotene (Color), Vitamin B12
PBSLC2	PB Sliced Cheddar	Filtered Water, Potato Starch, Coconut Oil, Expeller Pressed: Canola and/or Safflower Oil, Tricalcium Phosphate, Vegan Natural Flavors, Salt, Pea Protein, Xanthan Gum, Lactic Acid (Vegan), Konjac Flour, Fruit and/or Vegetable Juice Color, Annatto Color, Yeast Extract, Vegan Enzyme, Vitamin B12
PBSLC3	PB Sliced Cheddar	Water, Modified Food Starch, Coconut Oil, Natural Flavor, Salt, Paprika Oleoresin (Color), Turmeric & Annatto Extracts (Color)
PBSLC4	PB Sliced Cheddar	Filtered Water, High Refined Coconut Oil, Modified Potato Starch, Modified Tapioca Starch, Sea Salt, Olive Extract, Natural Flavor, Paprika Extract (Color), Beta Carotene (Color)
PBSLC5	PB Sliced Cheddar	Filtered Water, Coconut Oil, Potato Starch, Food Starch – Modified (Tapioca and Potato), Natural Flavors (Vegan Sources), Chickpea Protein, Sea Salt, Potato Protein, Paprika and Beta Carotene (Color)

PBSLC6	PB Sliced Cheddar	Nutmilk (Water, Cashews), Coconut Oil, Modified Food Starch, Potato Starch, Sea Salt, Nutritional Yeast Extract, Annatto, Natural Flavour, Cultures
PBM1	PB Shredded Mozzarella	Filtered Water, Organic Coconut Oil, Potato and Corn Starch, Expeller-Pressed Canola Oil, Sea Salt, Less than 2% of Natural Flavors, Potato Protein, Calcium Phosphate, Organic Vegan Cane Sugar, Organic Vegetable Glycerin, Cellulose, Sodium Citrate, Citric Acid, Lactic Acid, Sodium Bicarbonate, Beta Carotene for Color
PBM2	PB Shredded Mozzarella	Filtered Water, Coconut Oil, Food Starch-Modified (Potato & Corn), Corn Starch, Salt (Sea Salt), Mozzarella Flavor (Vegan Sources), Olive Extract, Beta Carotene (Color), Vitamin B12, Powdered Cellulose (Added to Prevent Caking)
PBM3	PB Shredded Mozzarella	Filtered Water, Tapioca Starch, Coconut Oil, Expeller Pressed: Canola and/or Safflower Oil, Vegan Natural Flavors, Chickpea Protein, Salt, Potato Protein, Tricalcium Phosphate, Lactic Acid (Vegan), Konjac Gum, Xanthan Gum, Yeast Extract, Fruit and/or Vegetable Juice Color
PBM4	PB Shredded Mozzarella	Water, Modified Food Starch, Coconut Oil, Pea Starch, Natural Flavor, Salt, Fava Bean Protein, Turmetric & Annatto Extracts (Color)
PBM5	PB Shredded Mozzarella	Filtered Water, Coconut Oil, Food Starch (Potato and Tapioca), Sunflower Oil, Natural Flavors (Vegan Sources), Chickpea Protein, Calcium Citrate, Sea Salt, Konjac Xanthan Gum, Annatto and Turmeric Extracts (Color), Powdered Cellulose Added to Prevent Caking
PBM6	PB Shredded Mozzarella	Filtered Water, High Refined Coconut Oil, Modified Potato Starch, Modified Tapioca Starch, Potato Starch, Sea Salt, Olive Extract, Natural Flavor
PBM7	PB Shredded Mozzarella	Nutmilk (Water, Cashews), Coconut Oil, Modified Food Starch, Potato Starch, Sea Salt, Annatto, Natural Flavour, Nutritional Yeast, Cultures
DSHC1	Dairy Shredded Cheddar	Cheddar Cheese (Pasteurized Milk, Cheese Culture, Salt, Enzymes, Annatto [Color]), Modified Cornstarch Added to Prevent Caking, Natamycin (A Natural Mold Inhibitor)
DSHC2	Dairy Shredded Cheddar	Cheddar Cheese [Pasteurized Milk, Cheese Culture, Salt, Enzymes, Annatto (Vegetable Color)]. Potato Starch (To Prevent Caking), Powdered Cellulose (To Prevent Caking), Natamycin (A Natural Mold Inhibitor)
DSLC1	Dairy Sliced Cheddar	Pasteurized Milk, Cheese Culture, Salt, Enzymes, Annatto (Vegetable Color)
DSLC2	Dairy Sliced Cheddar	Pasteurized Milk, Cheese Culture, Salt, Enzymes, Annatto Color
DM1	Dairy Shredded Mozzarella	Low-Moisture Part-Skim Mozzarella Cheese (Pasteurized Part-Skim Milk, Cheese Culture, Salt, Enzymes), Modified Cornstarch Added to Prevent Caking, Natamycin (a Natural Mold Inhibitor)
DM2	Dairy Shredded Mozzarella	Low-Moisture Mozzarella Cheese (Pasteurized Milk, Cheese Culture, Salt, Enzymes), Modified Cornstarch Added to Prevent Caking, Natamycin (a Natural Mold Inhibitor)

Table 2.8. Cold flavor attributes mean of shredded plant-based Cheddars.

Category	Aroma Intensity	Cooked Non-dairy	Sour Aromatic	Sweet Aromatic	Diacetyl	Fat/oil Non-dairy	Coconut	Fruity	Nutty	Beany	Cereal	Brothy	Potato	Free Fatty Acid	Card board	Sweet Taste	Sour Taste	Bitter Taste	Salty Taste	Umami Taste	Astringent Mouthfeel	Aftertaste Intensity
PBSHC1	2.2e	2.2f	0.8f	1.0d	1.8b	1.2f	1.1a	ND	ND	ND	ND	ND	ND	0.7c	ND	1.6c	1.0f	ND	3.9ab	1.5g	1.9cd	1.6f
PBSHC2	3.1c	1.6g	2.0b	0.5e	ND	2.1c	ND	0.6c	ND	2.1a	1.7a	1.8c	ND	0.8abc	ND	2.0b	3.1a	1.3	3.8bc	2.5e	2.6b	2.5b
PBSHC3	2.9d	2.3e	1.5d	1.8a	ND	1.9d	ND	1.2a	ND	ND	ND	2.7a	ND	1.0ab	ND	2.3a	1.4e	ND	3.8bcd	2.8c	1.4e	1.6f
PBSHC4	3.3b	3.0b	1.7c	ND	1.0d	1.7e	ND	ND	ND	ND	ND	1.7d	ND	1.0ab	ND	1.5cd	2.2c	ND	3.6e	3.1b	2.5b	1.7ef
PBSHC5	3.0d	2.7d	2.5a	1.2c	1.3c	2.1c	0.5c	0.8b	ND	ND	ND	2.1b	0.7b	1.0ab	ND	1.4d	2.7b	ND	3.6e	2.3f	1.9d	2.0d
PBSHC6	3.4a	2.9c	1.2e	1.9a	2.7a	2.3b	ND	ND	ND	ND	ND	2.1b	2.7a	0.5d	ND	1.9b	2.8b	ND	3.7de	2.6d	3.0a	2.9a
PBSHC7	3.1c	3.2a	1.1e	1.2c	0.9d	2.0c	0.7b	ND	ND	ND	ND	1.2f	0.8b	0.8bc	ND	1.6c	2.0d	ND	3.7cde	2.8c	2.0c	1.8e
PBSHC8	3.3b	3.2a	1.5d	1.5b	ND	3.0a	1.0a	ND	ND	ND	ND	1.4e	0.9b	1.0ab	4.8a	2.4a	3.2a	ND	4.0a	3.5a	2.6b	2.2c

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).

The score of 0.0 were replaced by ND (not detected).

Different letters within a column represent significant differences in the mean scores ($p < 0.05$).

Table 2.9. Cold flavor attributes mean of sliced plant-based Cheddars.

Category	Aroma Intensity	Cooked Non-dairy	Sour Aromatic	Sweet Aromatic	Diacetyl	Fat/oil Non-dairy	Coconut	Fruity	Nutty	Beany	Cereal	Brothy	Potato	Free Fatty Acid	Card board	Sweet Taste	Sour Taste	Bitter Taste	Salty Taste	Umami Taste	Astringent Mouthfeel	Aftertaste Intensity
PBSLC1	2.8e	2.1f	ND	2.1a	1.4a	1.7e	1.1b	ND	1.3a	ND	ND	2.3b	1.6b	ND	ND	1.8c	2.1e	ND	3.4c	3.0c	1.8c	1.9d
PBSLC2	3.3c	2.7d	1.0c	1.2e	0.8b	1.7e	ND	ND	0.8b	0.9a	ND	1.6d	ND	0.8b	ND	2.1b	2.0e	ND	3.7b	2.9d	1.4e	1.8d
PBSLC3	3.0d	2.2e	2.0b	1.5c	1.2a	2.5c	0.9c	ND	ND	ND	ND	1.8cd	0.8e	1.1a	ND	1.5d	2.8b	ND	3.7b	2.7e	2.5a	2.3c
PBSLC4	3.0d	3.1c	0.6d	1.3d	ND	2.0d	0.6d	ND	ND	ND	ND	2.4b	1.0d	ND	1.5b	2.0b	2.3d	ND	3.8b	3.2b	1.7d	1.8d
PBSLC5	3.4b	3.5a	1.9b	1.6c	ND	3.5a	1.3a	ND	ND	ND	1.3a	1.9c	1.9a	0.9b	1.6b	2.0b	3.4a	ND	3.9a	3.4a	2.4a	2.9a
PBSLC6	3.6a	3.3b	2.2a	1.9b	0.7b	2.9b	1.3a	ND	ND	ND	1.1b	2.8a	1.3c	ND	1.9a	2.4a	2.4c	ND	3.9a	3.4a	2.2b	2.7b

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).

The score of 0.0 were replaced by ND (not detected).

Different letters within a column represent significant differences in the mean scores ($p < 0.05$).

Table 2.10. Cold flavor attributes means of shredded plant-based mozzarella.

Category	Aroma Intensity	Cooked Non-dairy	Sour Aromatic	Sweet Aromatic	Diacetyl	Fat/oil Non-dairy	Coconut	Fruity	Nutty	Beany	Cereal	Brothy	Potato	Free Fatty Acid	Card board	Sweet Taste	Sour Taste	Bitter Taste	Salty Taste	Umami Taste	Astringent Mouthfeel	Aftertaste Intensity
PBM1	3.0b	2.5b	1.5ab	1.1c	1.5b	2.6b	ND	ND	ND	ND	1.3a	1.9b	2.7a	ND	1.1c	1.4cd	2.8a	0.6a	3.7a	2.6c	3.0a	2.3a
PBM2	2.4e	3.0a	0.8b	2.8a	1.4c	1.2f	1.0b	ND	ND	ND	ND	1.5c	ND	0.8a	ND	2.3ab	1.6c	ND	3.2b	1.9e	1.9d	1.8d
PBM3	2.6d	3.0a	2.0a	0.7d	ND	1.7e	ND	ND	1.0a	ND	ND	1.9b	1.1b	ND	ND	1.9bc	2.1b	ND	3.6a	3.0a	2.4b	2.0c
PBM4	2.9c	2.3c	1.9a	1.2c	ND	1.9d	ND	ND	ND	1.2a	ND	1.1d	1.0c	ND	ND	1.6bcd	2.1b	ND	3.2b	2.0e	1.9d	2.1b
PBM5	3.2a	1.9d	ND	1.2c	ND	3.1a	ND	ND	ND	ND	1.0b	ND	ND	ND	2.0a	1.0d	1.4d	ND	3.6a	1.5f	3.1a	1.2f
PBM6	2.9c	2.6b	1.9a	1.9b	1.9a	2.5c	0.6c	ND	ND	ND	ND	2.1a	0.5d	ND	ND	2.1abc	2.1b	ND	3.0c	2.8b	2.2c	1.7e
PBM7	2.4e	2.6b	1.2b	1.1c	ND	2.4c	1.2a	ND	ND	ND	ND	1.4c	ND	ND	1.6b	2.9a	1.4d	ND	2.6d	2.4d	2.1c	1.6e

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).

The score of 0.0 were replaced by ND (not detected).

Different letters within a column represent significant differences in the mean scores (p <0.05).

Table 2.11. Cold appearance and texture attribute means of shredded plant-based Cheddars.

Sample	Color	Wet/oily	Visual Particulates	Visual Homogeneity	Hand Cohesiveness	Adhesive to Lips	Oily/moist to Lips	Firmness	Tooth Pull/tackiness	Degree of Breakdown	Cohesiveness	Adhesiveness	Smoothness of Mass	Smoothness of Pieces	Smoothness of Mouth Coating	Mouth coating pieces	Oily Mouth coating
PBSHC1	7.9f	ND	4.0d	12.2a	ND	0.6g	0.7f	4.5bc	0.8e	ND	ND	1.5e	ND	3.1b	2.5d	3.1d	ND
PBSHC2	13.4a	ND	13.5a	3.8e	5.0a	3.5c	1.6e	3.9d	3.0a	3.5b	3.9b	3.6b	1.7b	0.7d	4.3b	7.0a	0.9b
PBSHC3	6.6h	ND	2.4e	10.6c	4.0b	2.4de	1.4e	2.4f	3.0a	4.4a	5.5a	4.4a	5.7a	5.6a	5.8a	3.2d	2.3a
PBSHC4	11.6c	7.7a	1.0f	12.2a	ND	2.8cd	11.3a	6.2a	1.0e	ND	ND	2.5c	ND	1.6c	1.6e	5.9b	2.5a
PBSHC5	12.8b	ND	0.9f	11.1b	2.1c	8.1a	3.5c	3.2e	2.1b	1.5c	0.8c	3.3b	1.1c	1.7c	2.1d	2.8d	1.0b
PBSHC6	11.2d	ND	11.5b	11.4b	1.0d	4.4b	5.3b	2.1f	1.8cd	0.6d	ND	4.5a	0.2d	1.0d	0.7f	4.3c	0.6b
PBSHC7	7.1g	ND	0.5g	12.2a	ND	1.2fg	2.1d	4.5c	1.5d	ND	ND	2.1d	ND	2.9b	3.0c	4.5c	0.8b
PBSHC8	9.0e	ND	8.2c	9.3d	ND	1.7ef	1.7de	4.8b	2.0bc	1.5c	0.8c	2.2cd	1.6b	2.0c	3.1c	3.9c	1.0b

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).
The score of 0.0 were replaced by ND (not detected).
Different letters within a column represent significant differences in the mean scores ($p < 0.05$).

Table 2.12. Cold appearance and texture attributes means of sliced plant-based Cheddars.

Sample	Color	Wet/oily	Visual Particulates	Visual Homogeneity	Hand Cohesiveness	Adhesive to Lips	Oily/moist to Lips	Firmness	Tooth Pull/tackiness	Degree of Breakdown	Cohesiveness	Adhesiveness	Smoothness of Mass	Smoothness of Pieces	Smoothness of Mouth Coating	Mouth Coating Pieces	Oily Mouth Coating
PBSLC1	5.8f	ND	ND	15.0a	0.5d	0.5b	1.3f	4.0b	1.1c	0.5f	0.5f	1.5d	4.0d	7.0d	5.5d	3.1a	1.5c
PBSLC2	11.0b	ND	ND	15.0a	3.2c	ND	7.4a	4.0b	2.1b	4.2d	4.3d	2.8c	5.8c	5.5e	5.9d	3.2a	1.6c
PBSLC3	13.0a	ND	0.6	14.3b	ND	ND	3.3c	3.6c	2.1b	1.7e	1.5e	3.7b	2.5e	1.8f	1.9e	2.1c	0.8d
PBSLC4	6.9d	ND	ND	14.9a	11.9a	1.8a	2.1e	5.3a	2.3ab	6.3b	6.3c	2.4c	8.9a	13.6a	13.4a	2.6b	2.1b
PBSLC5	9.5c	ND	ND	12.9d	6.4b	ND	3.0d	3.4c	2.3ab	5.7c	6.9b	3.3b	7.0b	7.5c	8.0c	2.2bc	1.4c
PBSLC6	6.3e	1.1a	ND	13.9c	6.3b	1.5a	4.8b	2.4d	2.6a	9.0a	8.4a	5.8a	9.3a	9.0b	9.5b	2.5bc	4.0a

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).

The score of 0.0 were replaced by ND (not detected).

Different letters within a column represent significant differences in the mean scores ($p <0.05$).

Table 2.13. Cold appearance and texture attribute means of plant-based mozzarella.

Sample	Color	Wet/oily	Visual Particulates	Visual Homogeneity	Hand Cohesiveness	Adhesive to Lips	Oily/moist to Lips	Firmness	Tooth Pull/tackiness	Degree of Breakdown	Cohesiveness	Adhesiveness	Smoothness of Mass	Smoothness of Pieces	Smoothness of Mouth Coating	Mouth coating pieces	Oily Mouth coating
PBM1	0.6e	ND	3.8c	9.4e	1.3b	3.6a	2.7c	2.7d	1.7c	0.5c	ND	5.5b	0.8b	0.9d	0.6e	3.2cd	0.6c
PBM2	1.0d	ND	2.9d	12.4b	ND	3.7a	1.9d	4.7bc	0.7d	ND	ND	1.7f	ND	6.6b	3.0b	4.6b	0.1d
PBM3	2.9a	8.2a	4.0c	9.3e	ND	4.3a	7.7a	6.1a	0.7d	ND	ND	2.7e	ND	2.6c	2.3c	5.6a	1.7b
PBM4	1.7c	ND	5.7b	11.0c	1.2b	2.0b	1.8d	6.3a	1.8c	1.8b	1.0b	3.1d	0.9b	1.0d	1.0d	3.7c	0.7c
PBM5	1.0d	ND	8.4a	11.0c	ND	1.0c	0.8e	4.9b	0.8d	ND	ND	3.6c	ND	0.6d	1.0d	4.9b	ND
PBM6	2.2b	ND	0.3f	13.2a	ND	4.3a	2.7c	4.5c	2.2b	ND	ND	2.7e	ND	2.3c	3.0b	5.6a	1.7b
PBM7	1.0d	ND	2.0e	ND	4.5a	4.2a	3.1b	2.6d	3.0a	7.5a	7.4a	7.3a	8.6a	8.8a	9.9a	2.8d	2.9a

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).

The score of 0.0 were replaced by ND (not detected).

Different letters within a column represent significant differences in the mean scores ($p < 0.05$).

Table 2.14. Hot appearance and texture attribute means of shredded plant-based Cheddars.

Category	Surface Moisture	Meltedness	Stretchability	Oiliness to Lips	Adhesive to Lips	Firmness	Tooth pull/tackiness	Elasticity	Cohesiveness	Adhesiveness	Exudes Moisture	Oiliness	Smoothness of Mass	Dissolution	Mouth Coating	Residual Adhesive to Lips
PBSHC1	ND	0.6d	0.5d	ND	5.5b	2.0d	1.1d	ND	2.1f	4.7d	0.8cd	0.6f	9.9c	6.0d	4.1d	1.6bc
PBSHC2	0.6e	0.8d	0.8d	1.3c	2.7d	3.3b	3.0a	1.8c	4.2e	6.2b	1.0b	4.4b	6.2f	5.3e	6.6a	1.4c
PBSHC3	ND	0.5d	0.6d	0.9e	3.4c	1.0f	0.6e	ND	6.2c	2.5f	ND	2.8c	8.6d	9.7c	4.2cd	1.1d
PBSHC4	9.5a	7.1a	6.7a	10.9a	ND	3.9a	1.3c	5.8a	12.3a	2.5f	2.1a	8.2a	12.6a	1.6f	2.0g	1.6b
PBSHC5	1.2d	6.0b	0.6d	1.1d	5.2b	1.0f	1.1d	ND	5.2d	4.1e	1.0bc	ND	9.9bc	12.8a	3.3e	2.1a
PBSHC6	5.7b	6.1b	ND	3.4b	1.1e	0.7g	ND	ND	1.8f	6.6a	0.7d	1.9e	7.0e	12.2b	5.0b	1.2d
PBSHC7	2.1c	1.9c	2.2c	1.1d	2.7d	1.6e	1.8b	ND	4.5e	0.7g	1.0bc	2.1d	5.9f	6.2d	2.4f	0.6e
PBSHC8	ND	1.9c	6.2b	ND	6.0a	3.1c	1.2c	4.7b	8.7b	5.7c	ND	0.3g	10.2b	9.7c	4.5c	1.6b

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).
The score of 0.0 were replaced by ND (not detected).
Different letters within a column represent significant differences in the mean scores ($p < 0.05$).

Table 2.15. Hot appearance and texture attribute means of sliced plant-based Cheddars.

Category	Surface Moisture	Meltedness	Stretchability	Oiliness to Lips	Adhesive to Lips	Firmness	Tooth pull/tackiness	Elasticity	Cohesiveness	Adhesiveness	Exudes Moisture	Oiliness	Smoothness of Mass	Dissolution	Mouth Coating	Residual Adhesive to Lips
PBSLC1	5.6b	1.1b	0.7b	0.9c	4.4a	1.9d	1.7b	1.1c	2.7e	6.6a	1.0b	2.0c	9.2a	5.7c	4.8b	2.8b
PBSLC2	1.7d	1.0b	ND	1.9b	3.3b	4.4a	1.0c	ND	9.6a	4.3c	0.8c	2.7b	6.9c	4.5d	4.1c	3.0a
PBSLC3	7.9a	2.0a	ND	8.7a	3.3b	1.3e	0.7d	ND	3.3d	4.8b	2.1a	4.1a	8.4b	9.7a	5.5a	1.0d
PBSLC4	2.1c	1.0b	0.7b	ND	4.3a	4.2b	3.2a	2.0b	8.2b	2.1e	ND	1.1d	8.6b	8.8b	3.2d	ND
PBSLC5	1.3e	1.1b	1.4a	ND	2.6c	2.8c	1.7b	2.3a	5.1c	2.6d	ND	0.4e	9.2a	9.2b	1.9e	1.2c

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).

The score of 0.0 were replaced by ND (not detected).

Different letters within a column represent significant differences in the mean scores ($p < 0.05$).

Table 2.16. Hot appearance and texture attribute means of shredded plant-based mozzarella.

Category	Surface Moisture	Meltedness	Stretchability	Oiliness to Lips	Adhesive to Lips	Firmness	Tooth pull/tackiness	Elasticity	Cohesiveness	Adhesiveness	Exudes Moisture	Oiliness	Smoothness of Mass	Dissolution	Mouth Coating	Residual Adhesive to Lips
PBM1	1.2b	2.7b	ND	4.7b	3.1cd	1.4f	ND	ND	1.6f	7.5a	1.1b	2.3b	6.8c	13.4a	4.4b	4.1a
PBM2	ND	0.8d	ND	0.9d	3.9b	3.7b	1.5a	1.9c	4.4e	ND	0.9c	1.0d	7.2b	6.1d	2.9d	2.9c
PBM3	7.7a	8.2a	10.8a	11.5a	3.0d	4.1a	1.2c	9.3a	13.8a	2.6e	2.2a	8.1a	13.8a	3.1e	2.6e	1.6e
PBM4	1.0bc	1.5c	1.1c	1.9c	3.9b	1.9e	1.1c	0.5d	4.1e	4.4c	2.1a	2.1c	5.2d	6.9c	4.1c	3.0c
PBM5	ND	1.4c	4.0b	1.0d	4.5a	3.4c	ND	3.6b	5.2d	3.9d	ND	2.0c	6.5c	6.7c	2.3f	2.0d
PBM6	ND	0.7d	ND	0.7e	1.9e	2.8d	1.3b	0.7d	7.6b	1.4f	1.0bc	ND	5.2d	6.3d	2.0g	2.2d
PBM7	0.8c	2.7b	0.8c	1.1d	3.4c	1.9e	1.5a	ND	5.6c	5.3b	ND	2.0c	5.1d	8.8b	7.3a	3.8b

Attributes were scored using a 0 to 15-point Spectrum intensity scale where 15 = very high intensity of an attribute and 0 = attribute not detected (Meilgaard et al., 2015).

The score of 0.0 were replaced by ND (not detected).

Different letters within a column represent significant differences in the mean scores ($p < 0.05$)

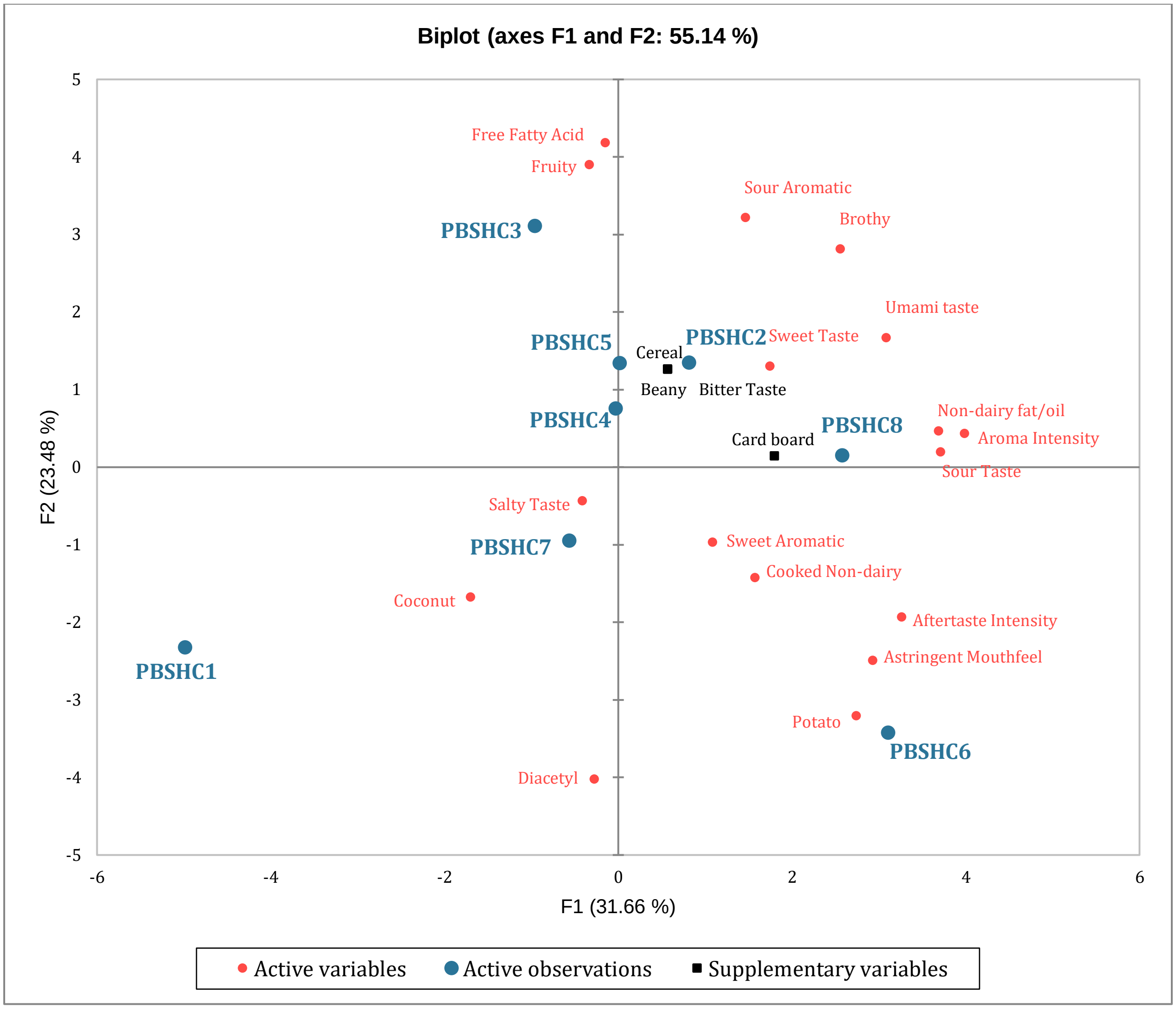

Figure 2.1: PCA biplot of the flavor properties of 8 shredded plant-based Cheddars evaluated cold.

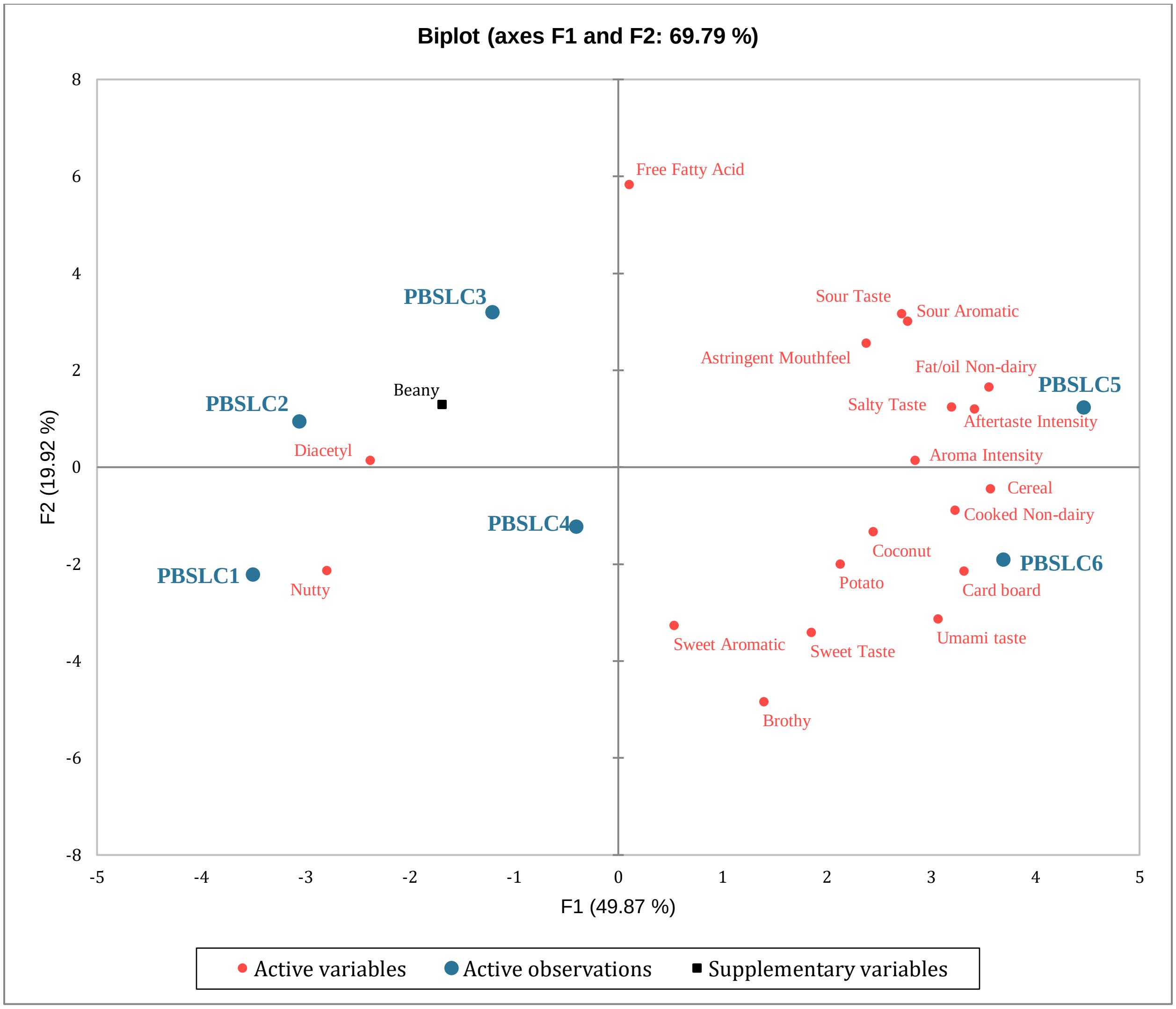

Figure 2.2: PCA biplot of the flavor properties of 6 sliced plant-based Cheddars evaluated cold.

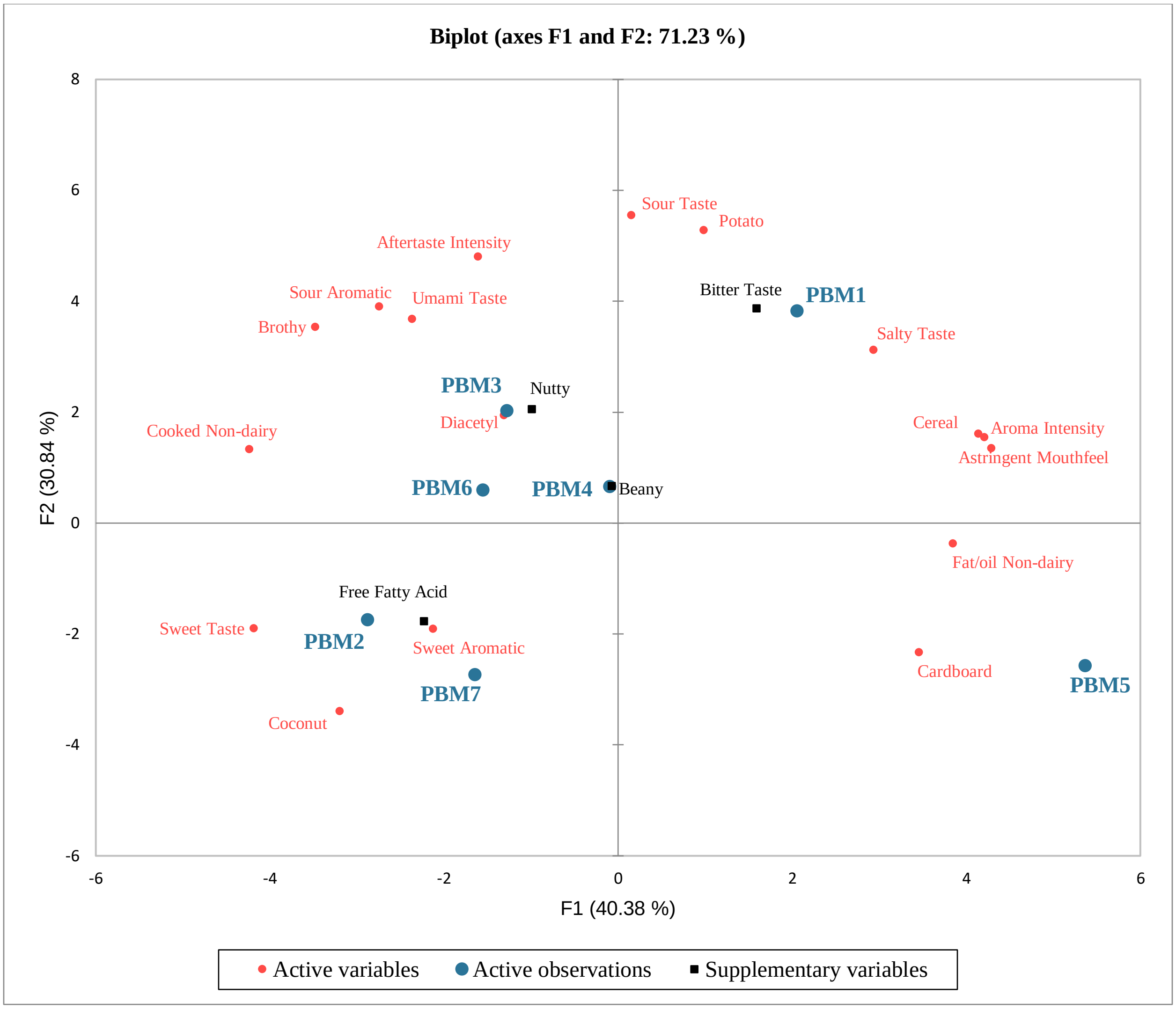

Figure 2.3. PCA biplot of the flavor properties of 7 shredded plant-based mozzarella evaluated cold.

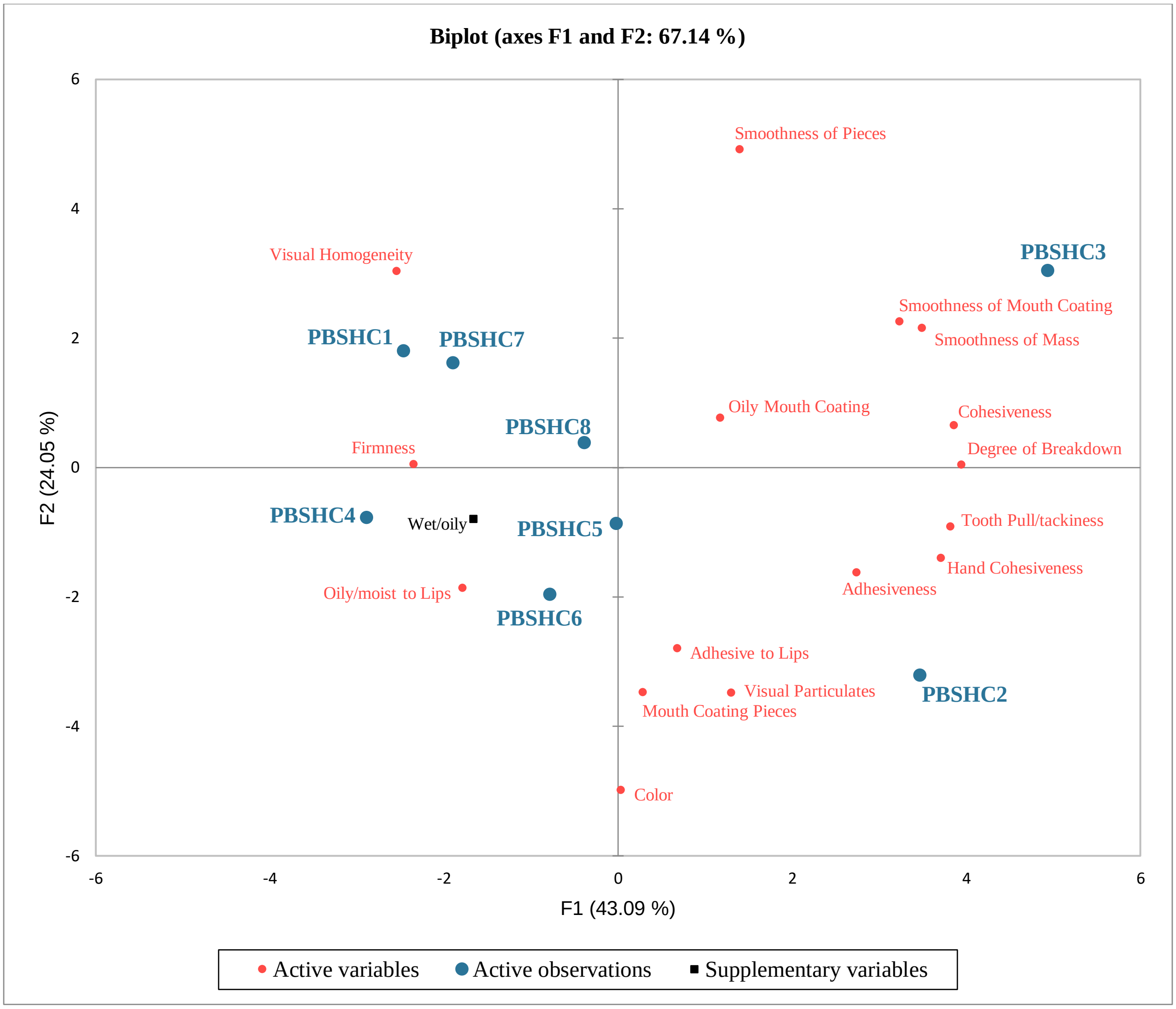

Figure 2.4 PCA biplot of the texture properties of 8 shredded plant-based Cheddars evaluated cold.

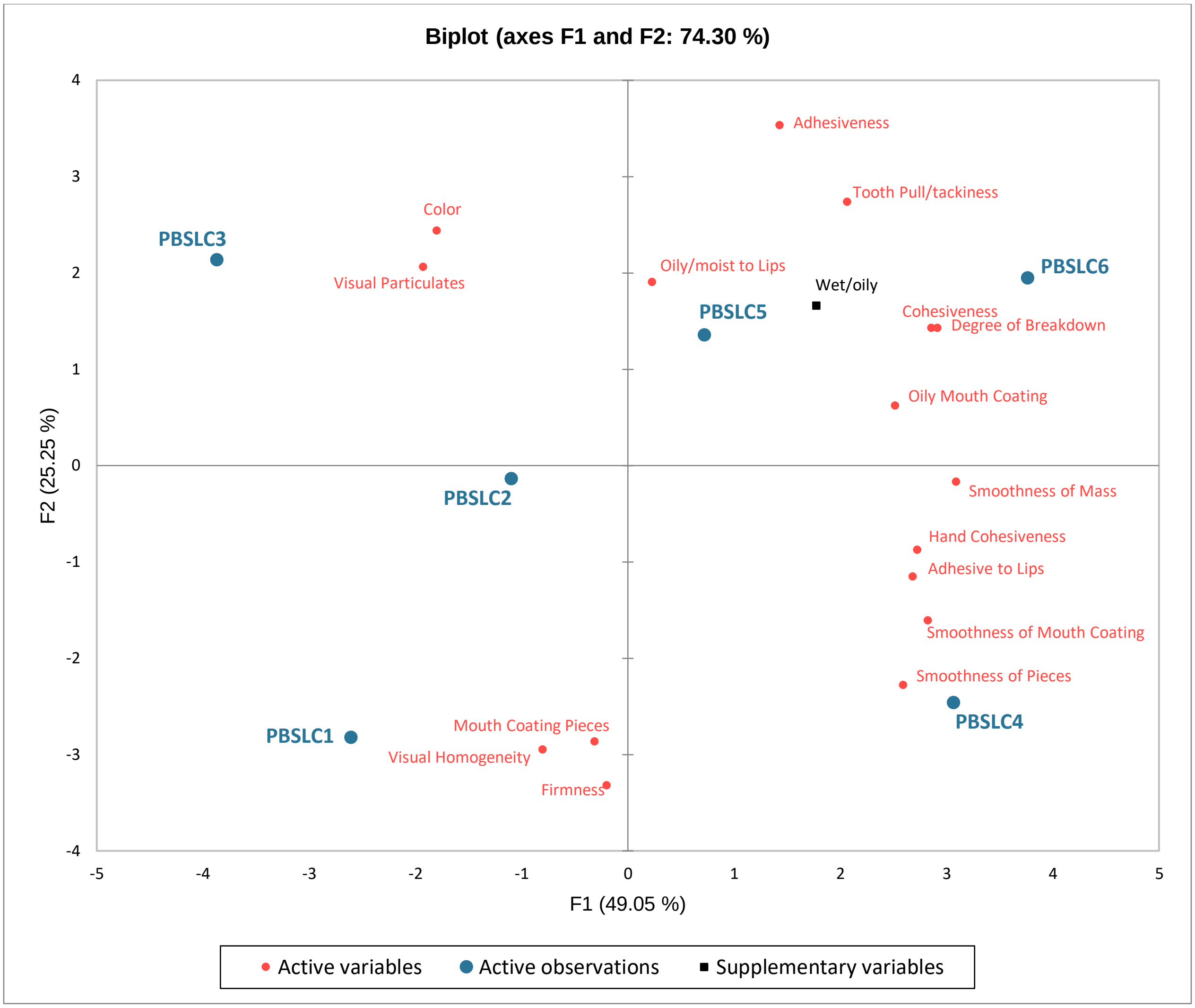

Figure 2.5. PCA biplot of the texture propeties of 6 sliced plant-based Cheddars evaluated cold.

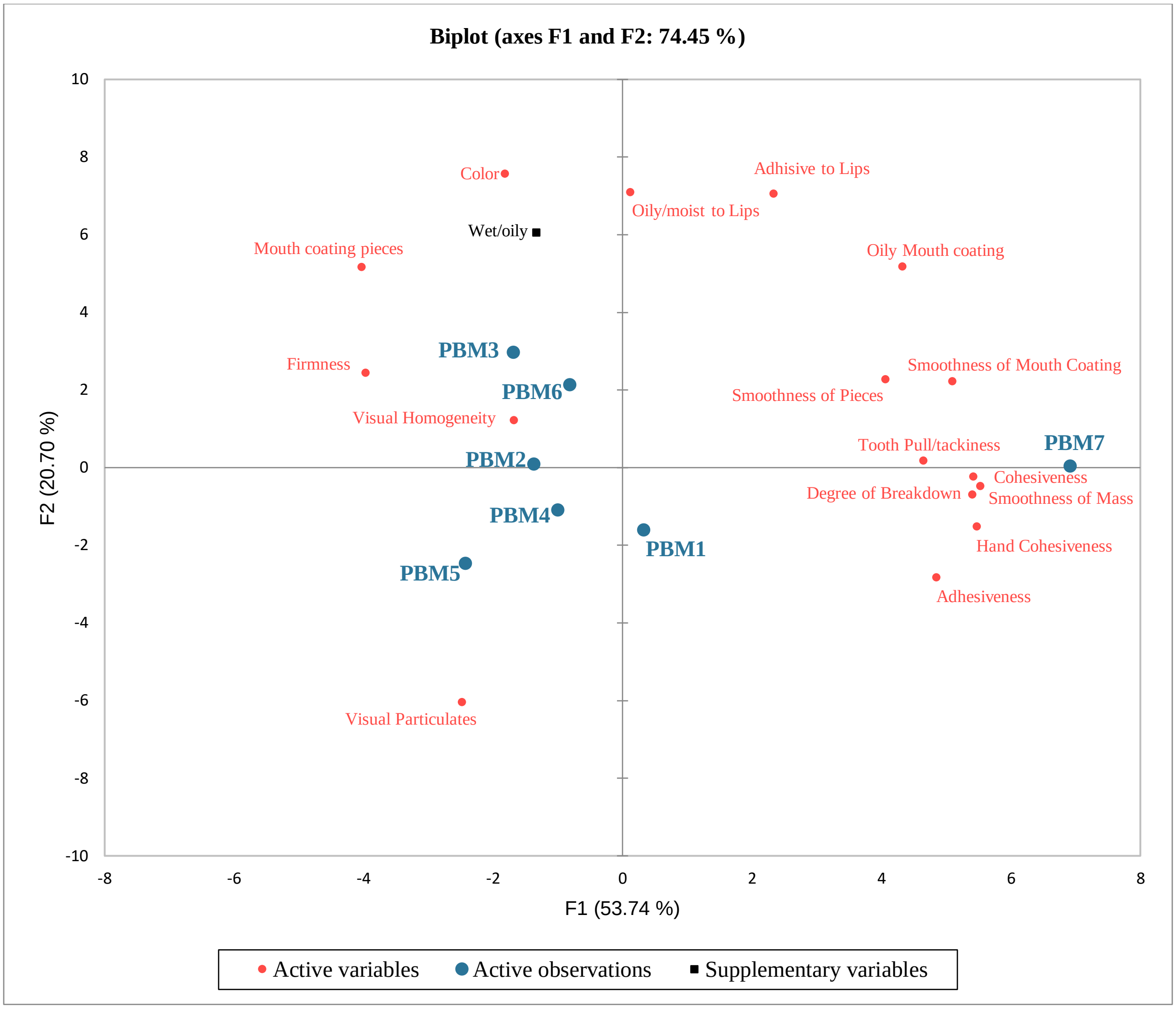

Figure 2.6. PCA biplot of the texture propeties of 6 shredded plant-based mozzarella evaluated cold.

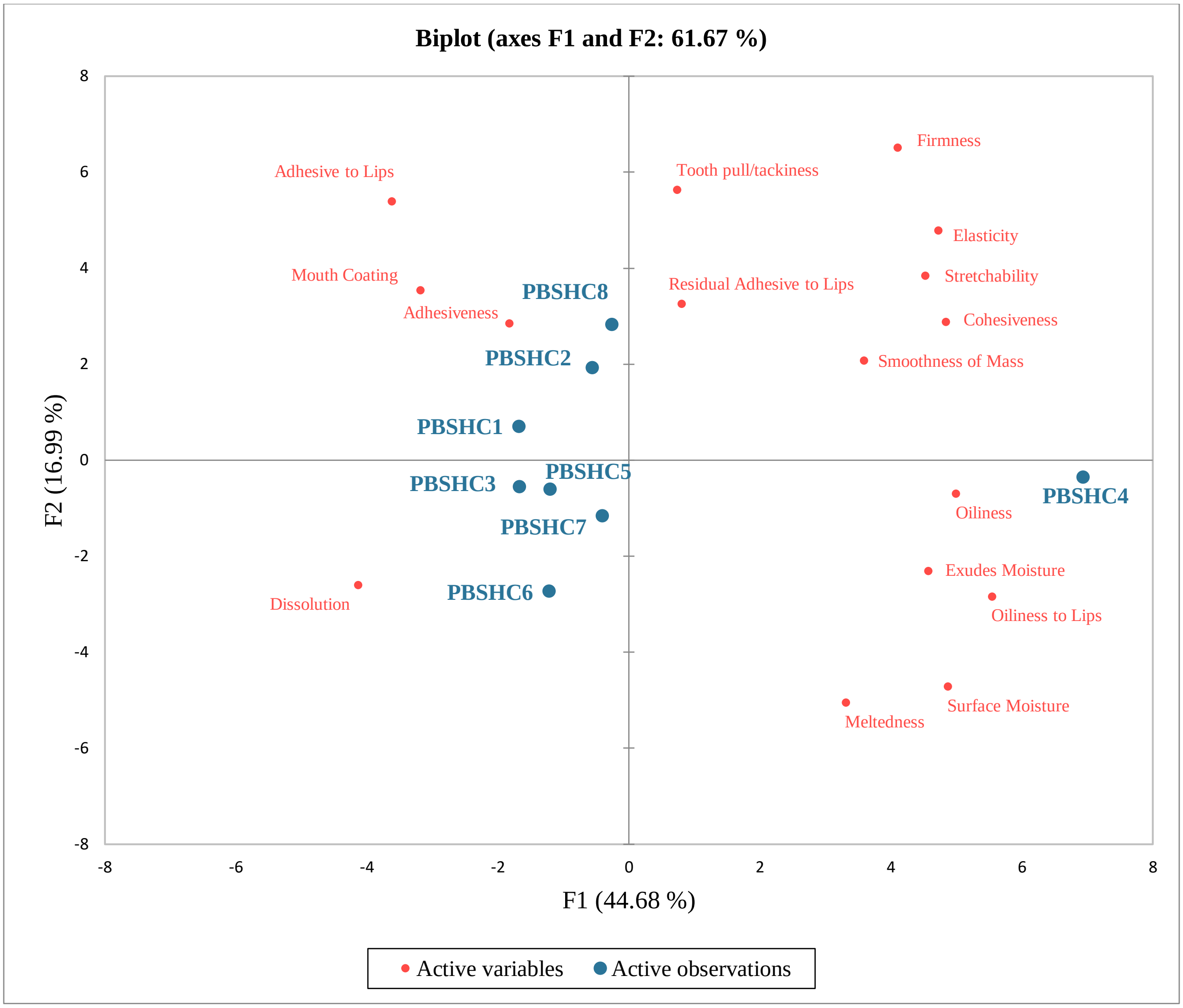

Figure 2.7. PCA biplot of the texture propeties of 8 shredded plant-based Cheddars evaluated hot.

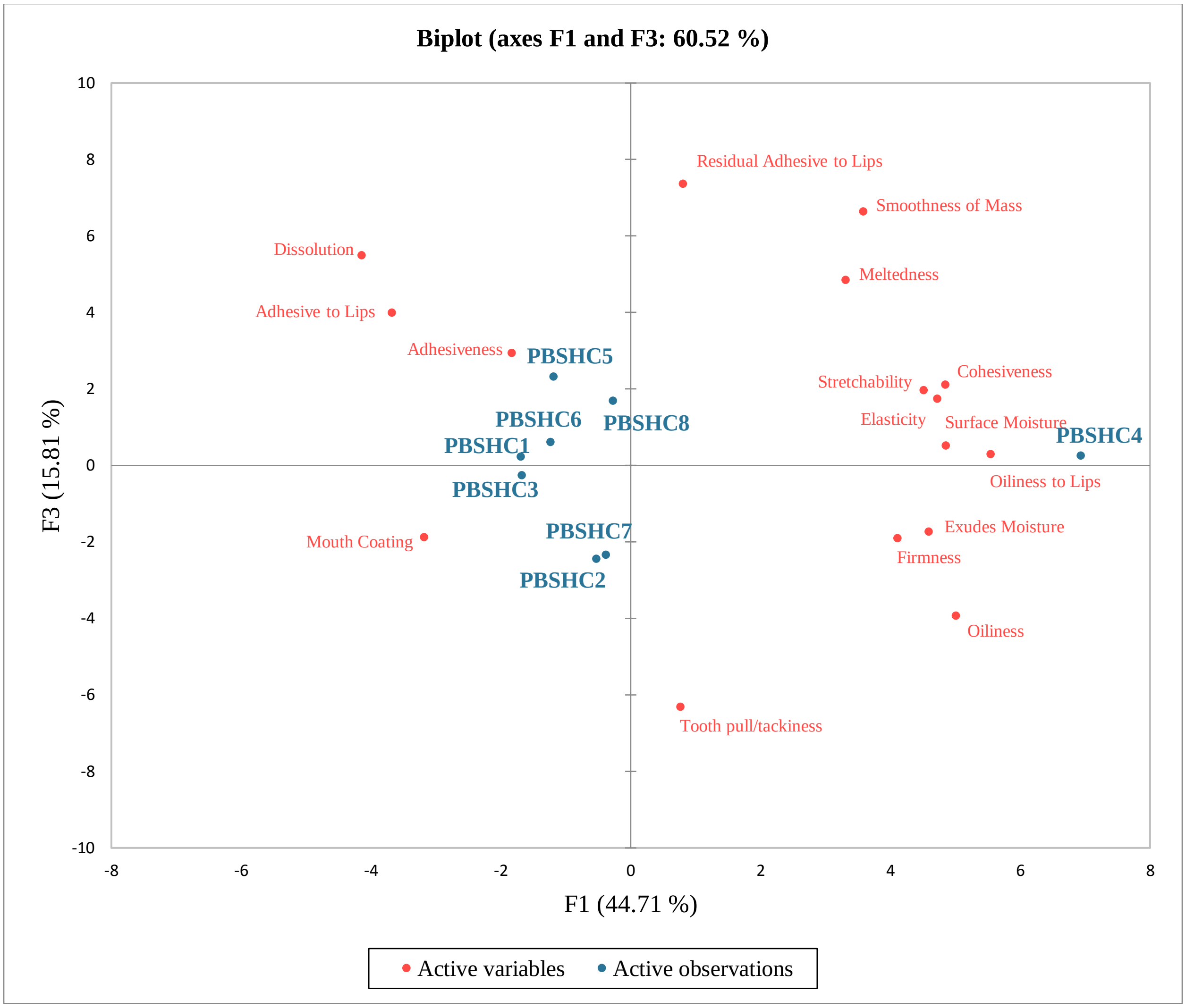

Figure 2.8. PCA biplot of the texture properties of 8 shredded plant-based Cheddars evaluated hot.

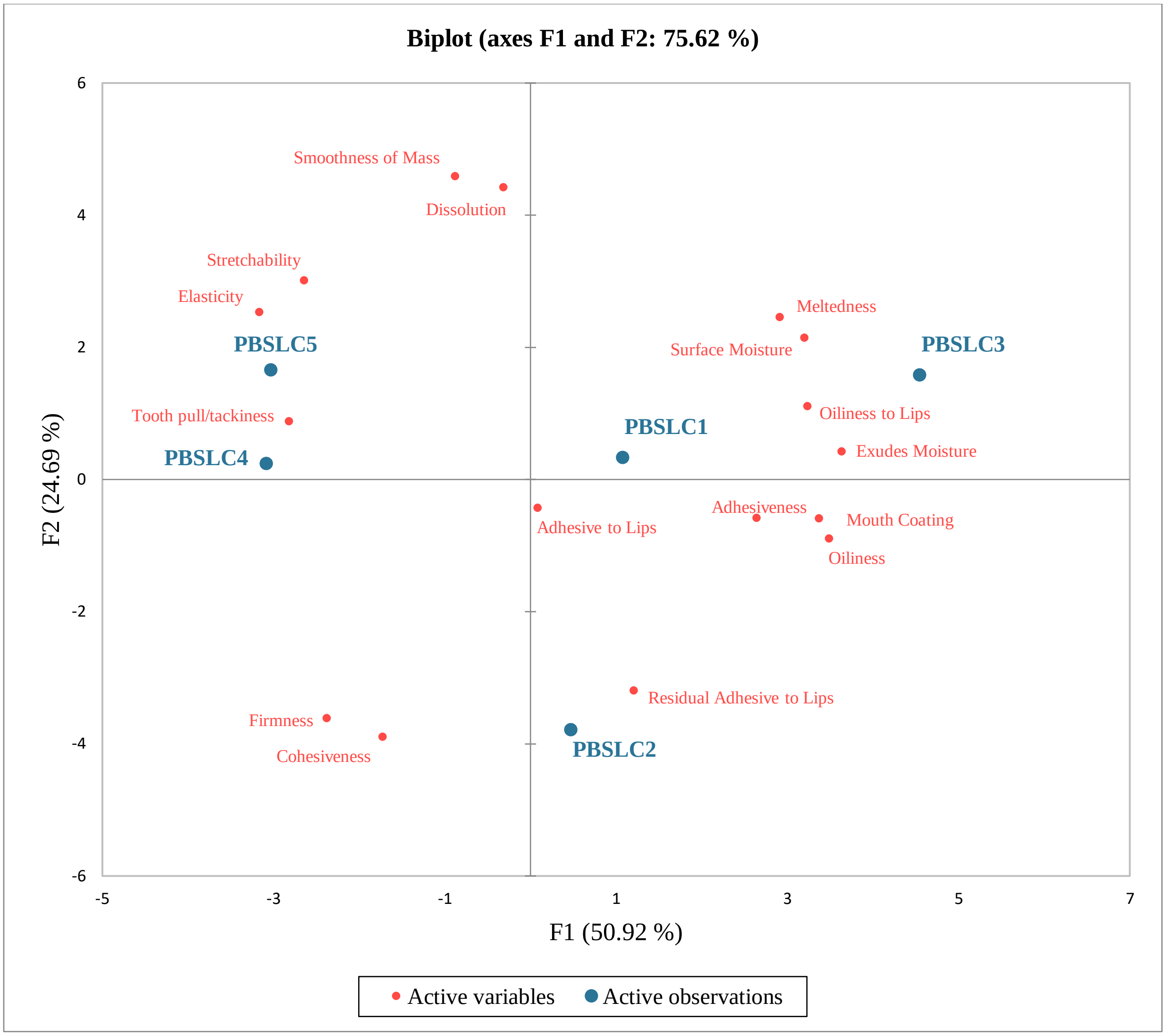

Figure 2.9. PCA biplot of the texture properties of 5 sliced plant-based Cheddars evaluated hot.

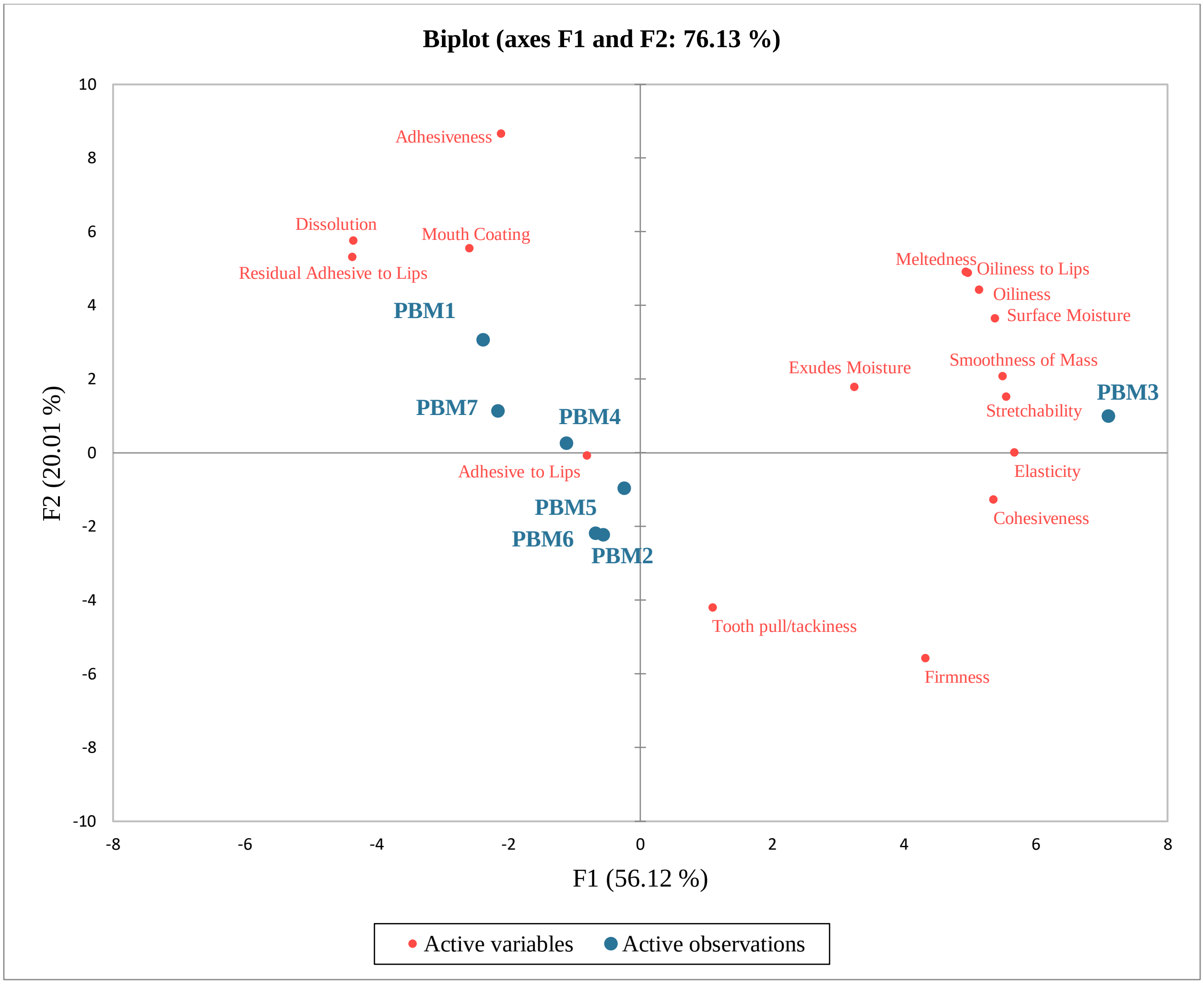

Figure 2.10. PCA biplot of the texture properties of 7 shredded plant-based mozzarella evaluated hot.

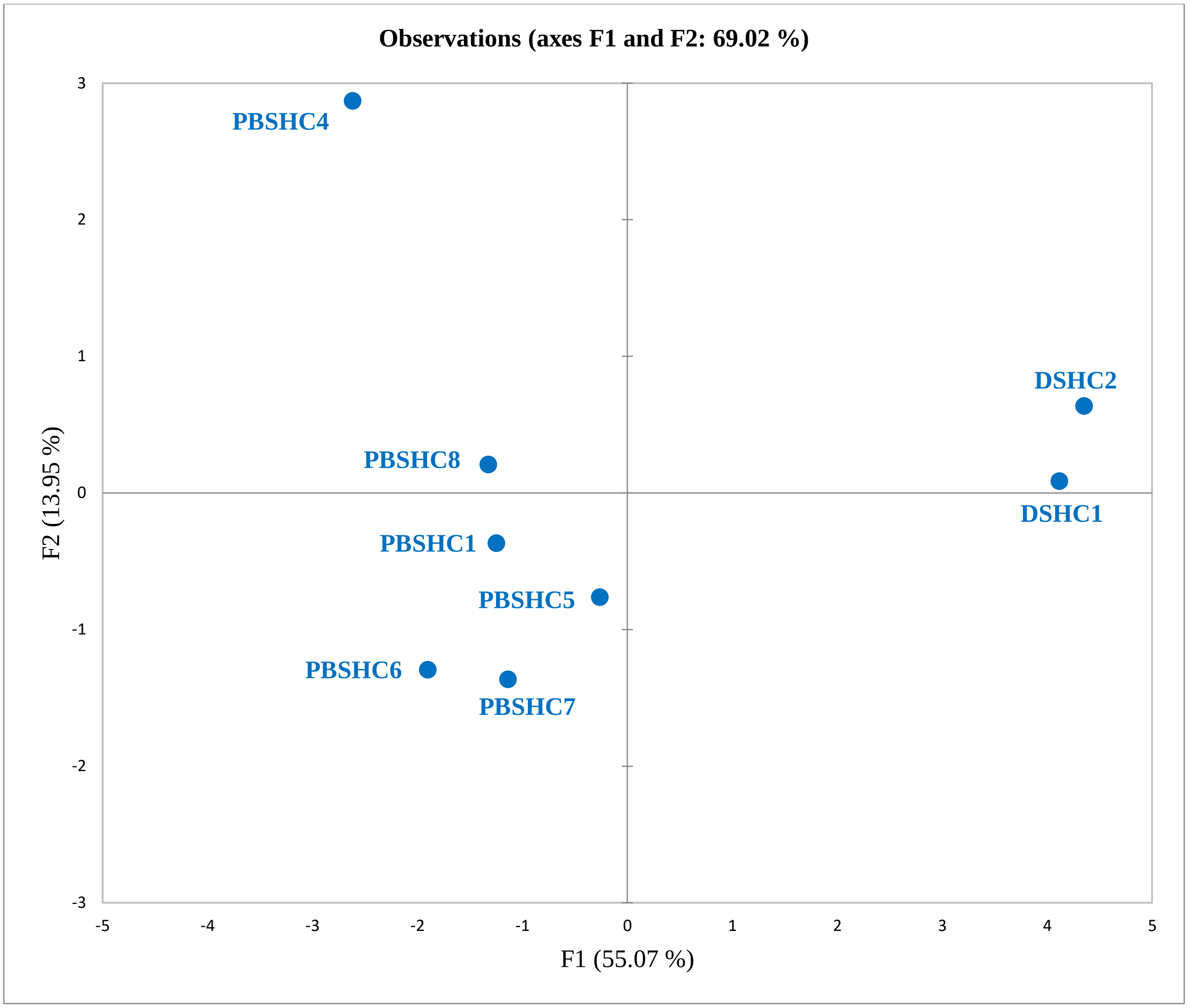

Figure 2.11. MFA biplot of projective mapping activity of 6 shredded plant-based Cheddars and 2 shredded dairy Cheddars evaluated cold.

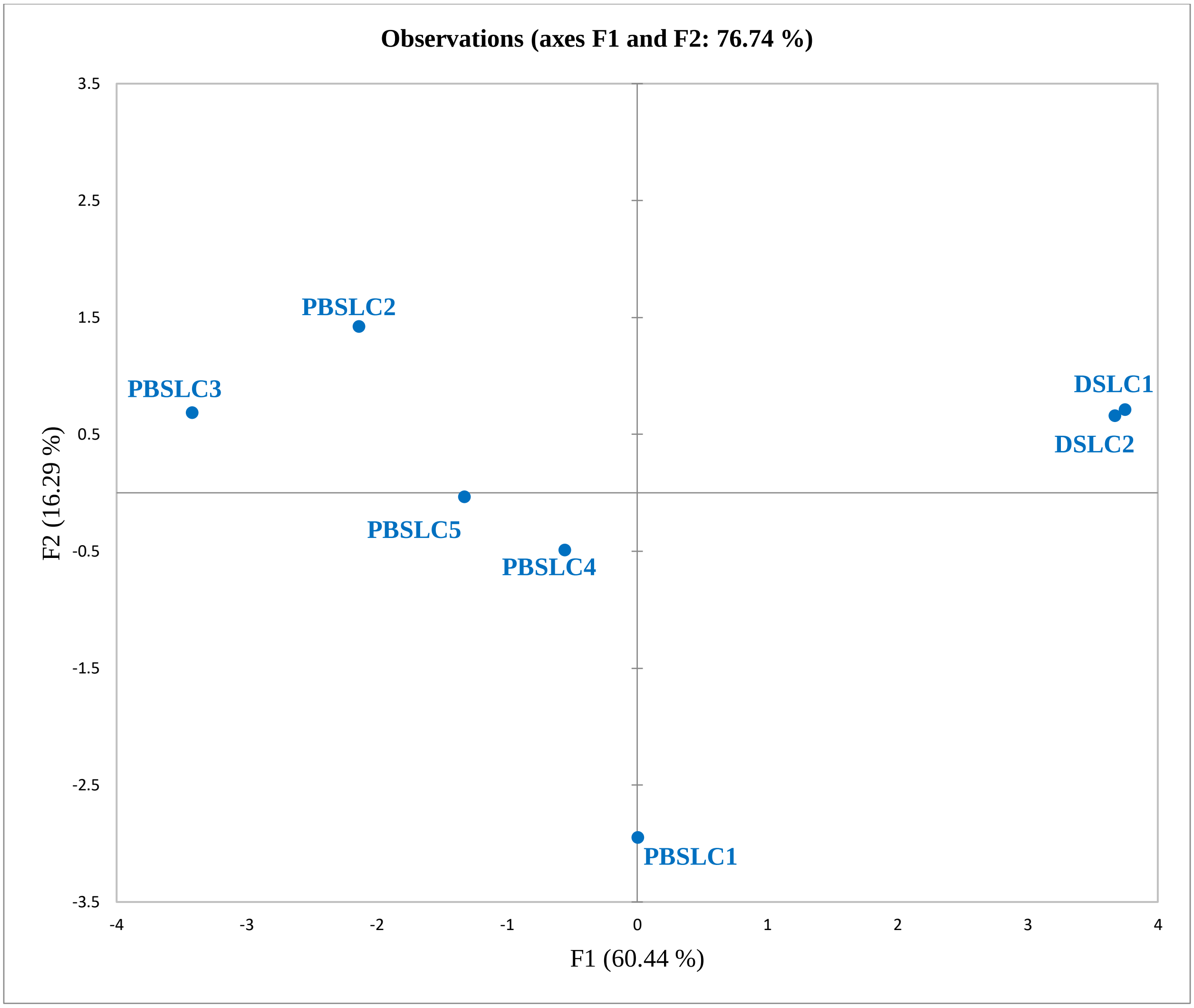

Figure 2.12. MFA biplot of projective mapping activity of 5 sliced plant-based Cheddars and 2 sliced dairy Cheddars evaluated cold.

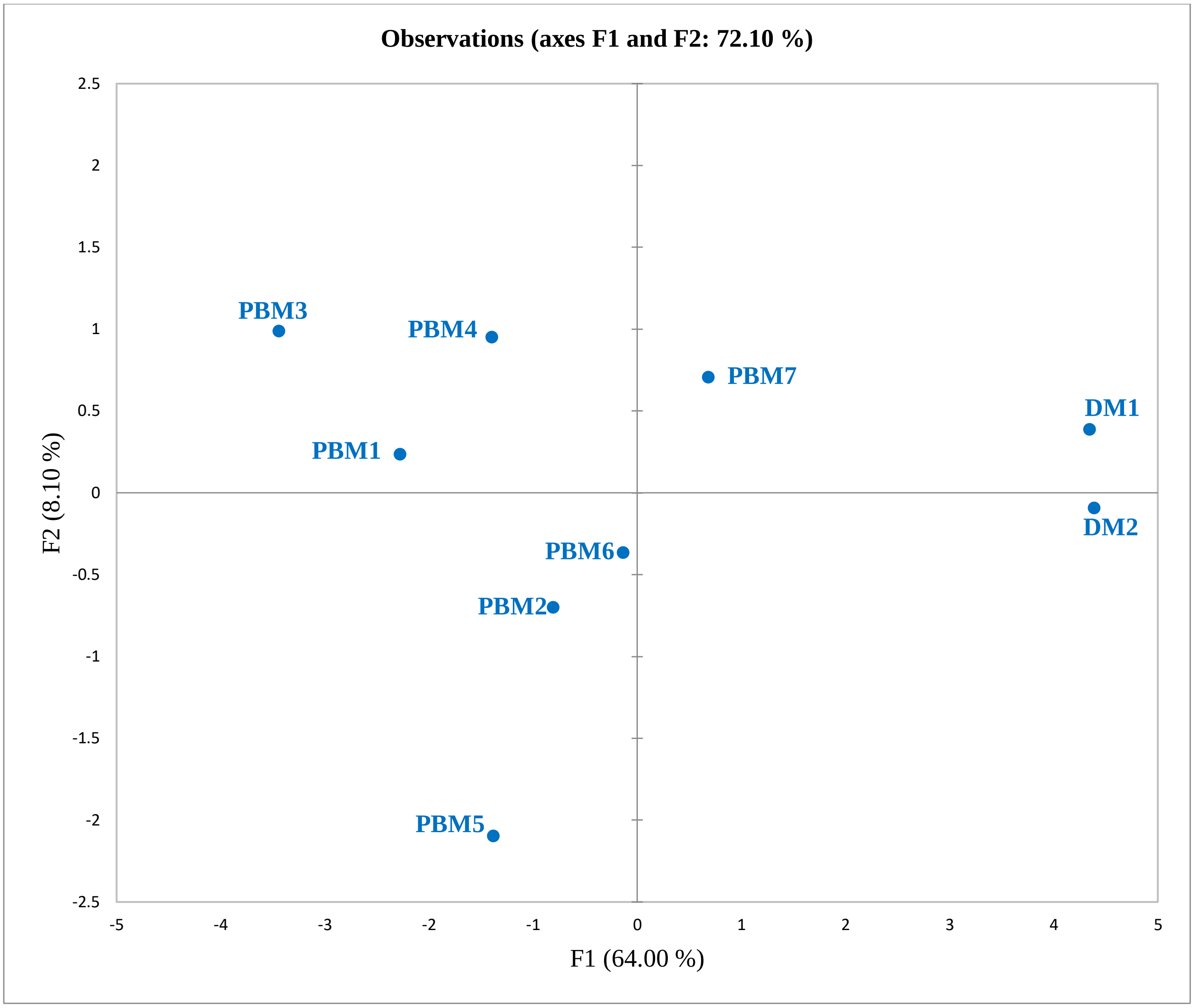

Figure 2.13. MFA biplot of projective mapping activity of 7 sliced plant-based mozzarella and 2 sliced dairy mozzarella evaluated cold.

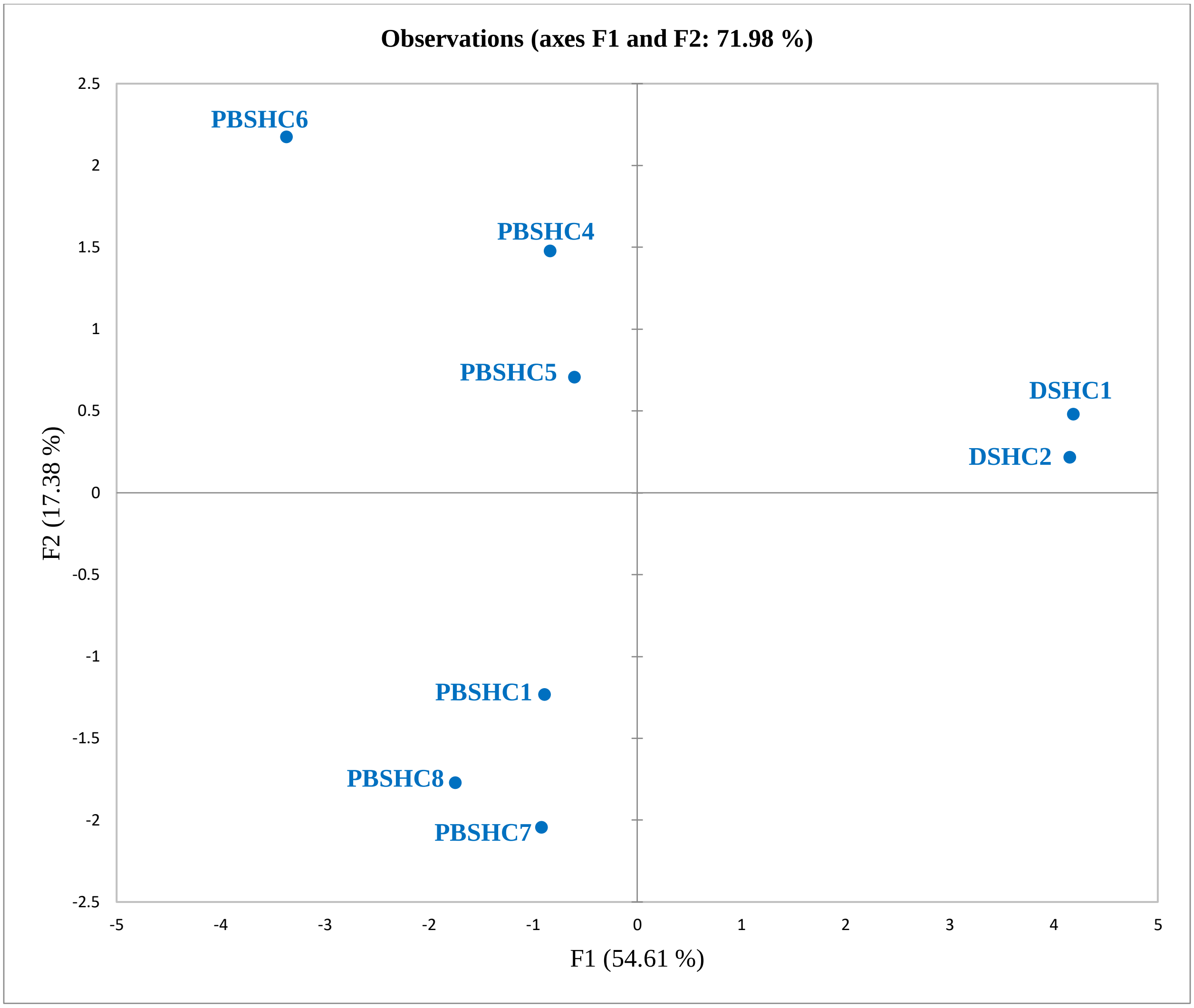

Figure 2.14. MFA biplot of projective mapping activity of 6 shredded plant-based Cheddars and 2 sliced dairy Cheddars evaluated hot.

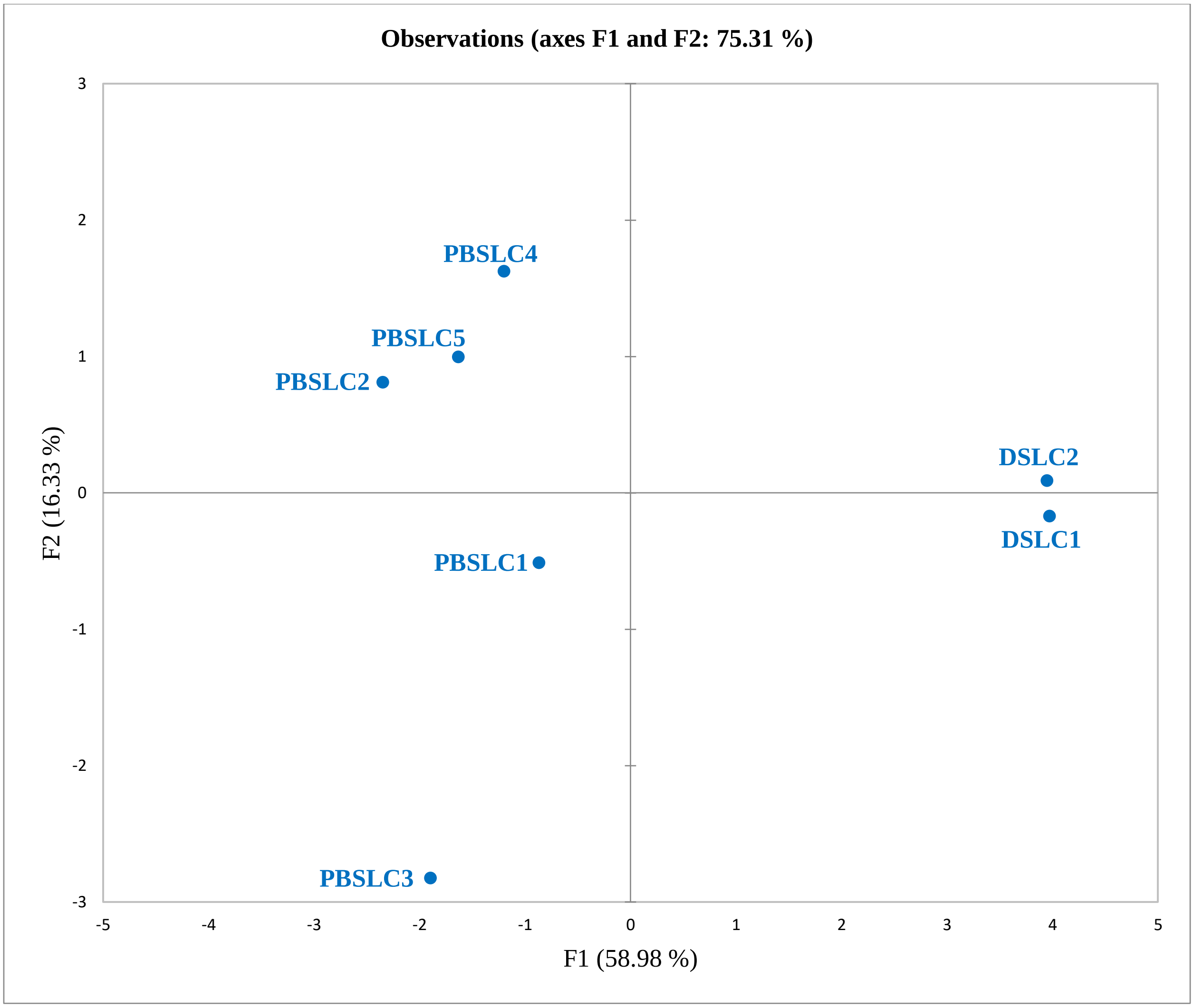

Figure 2.15. MFA biplot of projective mapping activity of 5 sliced plant-based Cheddars and 2 sliced dairy Cheddars evaluated hot.

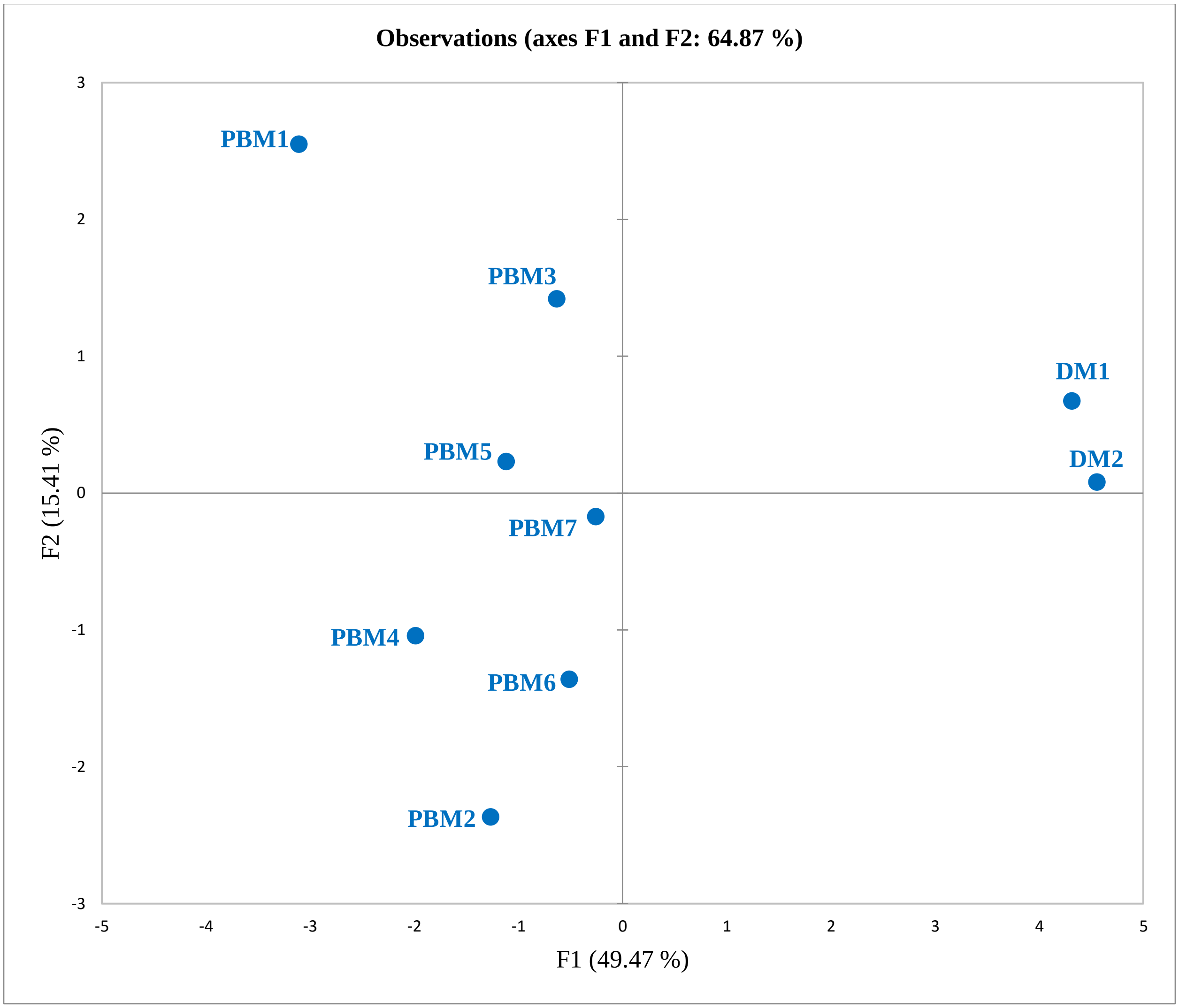

Figure 2.16. MFA biplot of projective mapping activity of 7 sliced plant-based mozzarella and 2 shredded dairy mozzarella evaluated hot.

APPENDIX

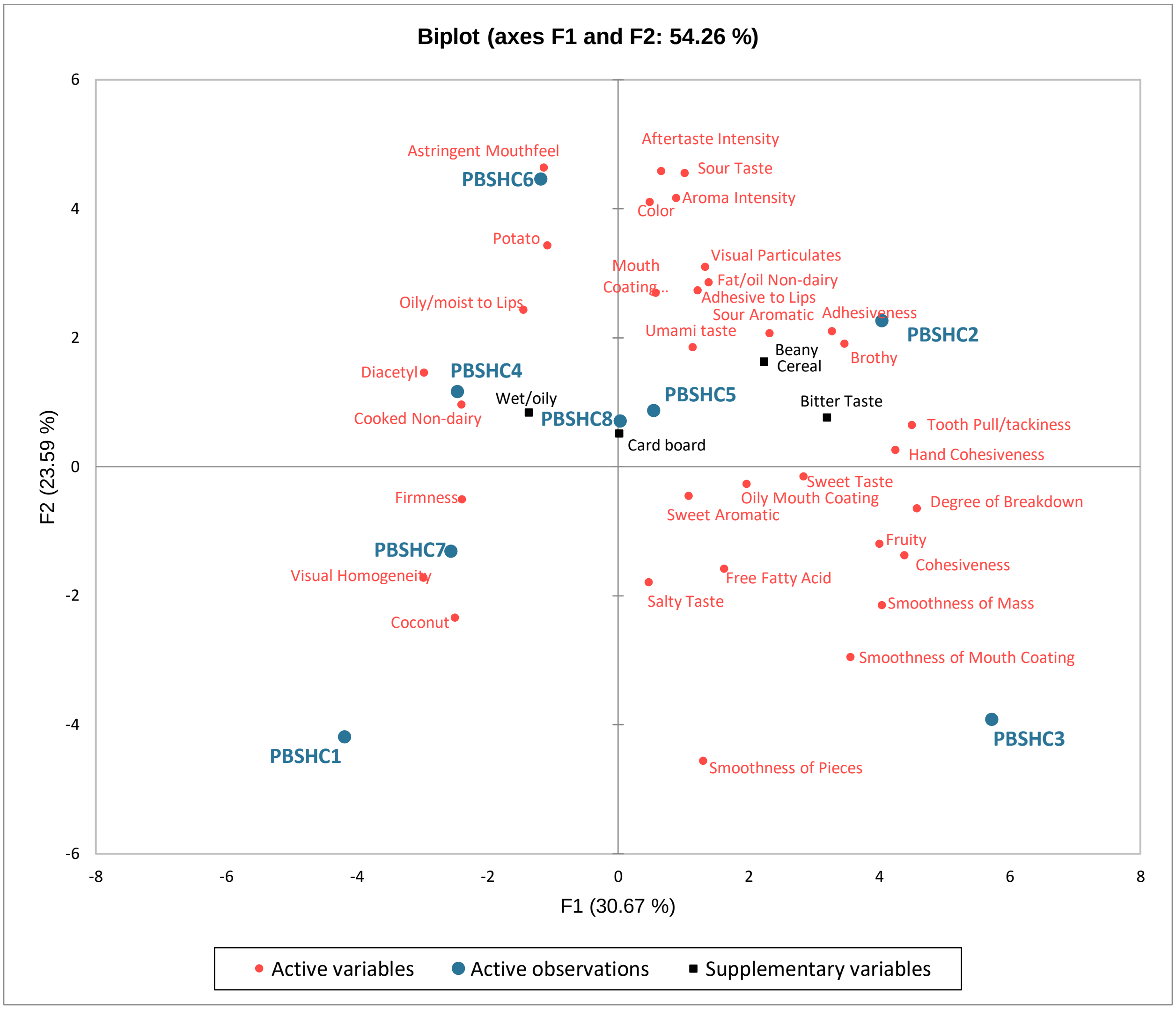

Figure 2.17. PCA biplot of the flavor and texture properties of 8 shredded plant-based Cheddars evaluated cold.

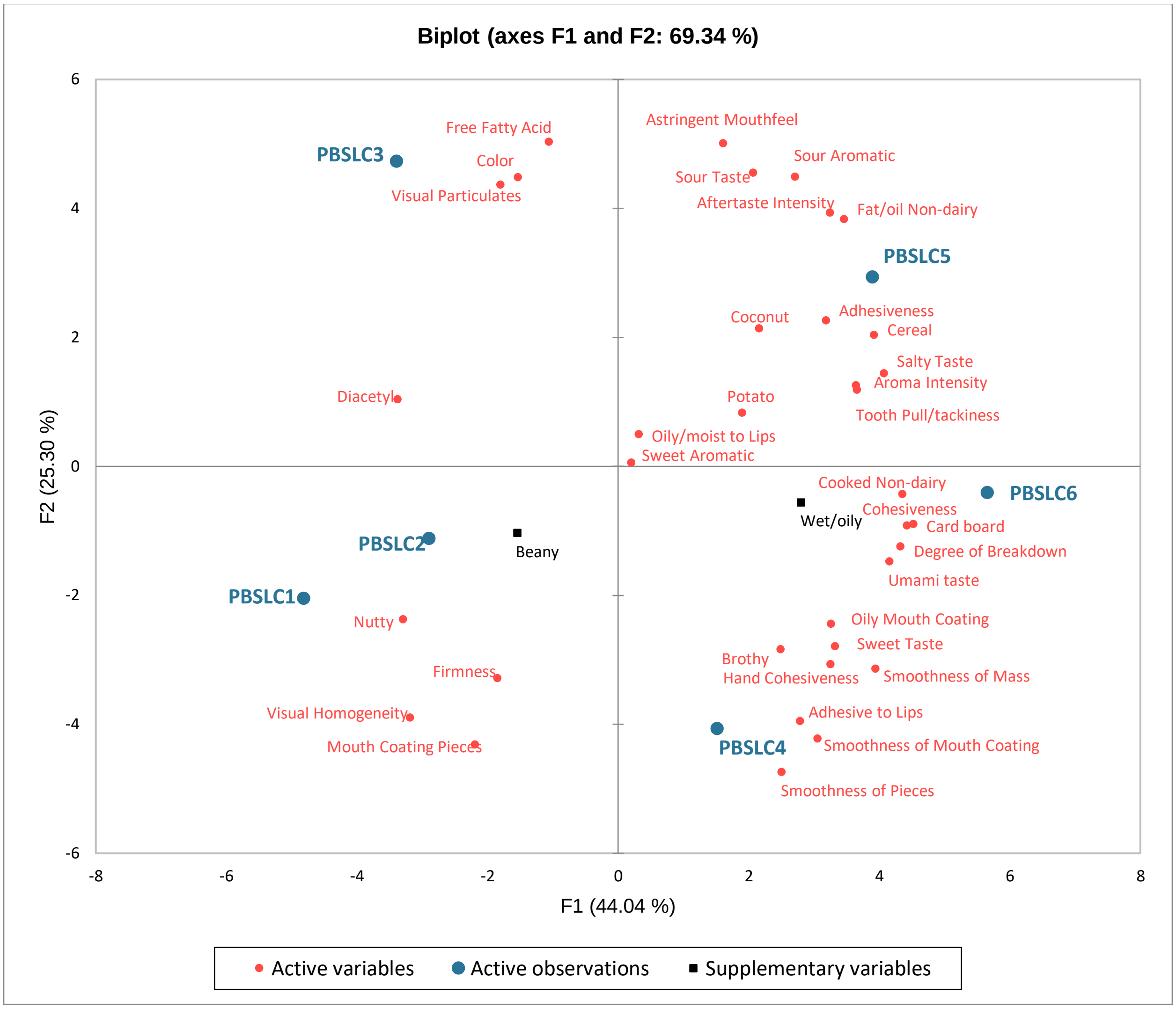

Figure 2.18. PCA biplot of the flavor and texture properties of 6 sliced plant-based Cheddars evaluated cold.

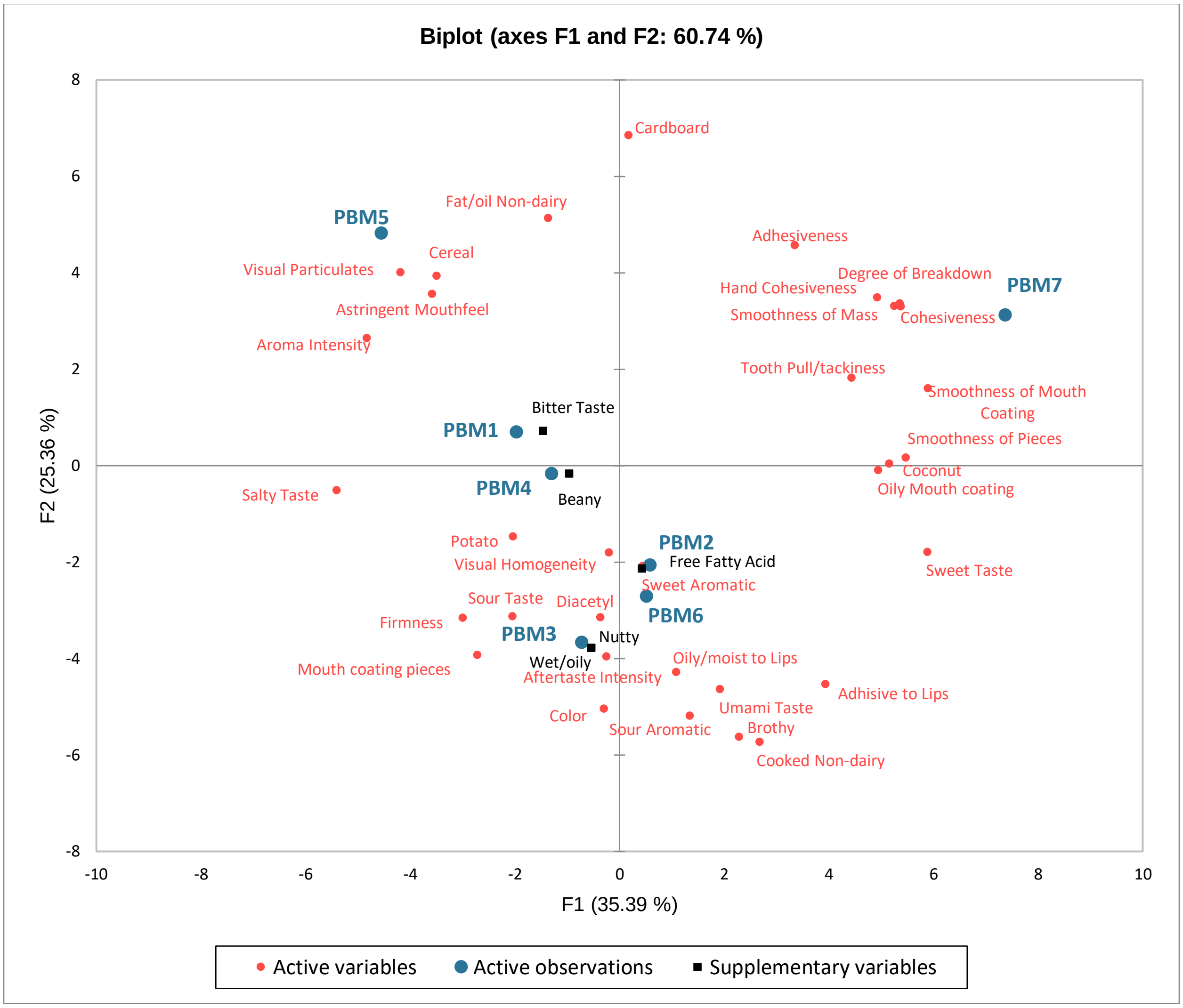

Figure 2.19. PCA biplot of the flavor and texture properties of 7 shredded plant-based mozzarella evaluated cold.

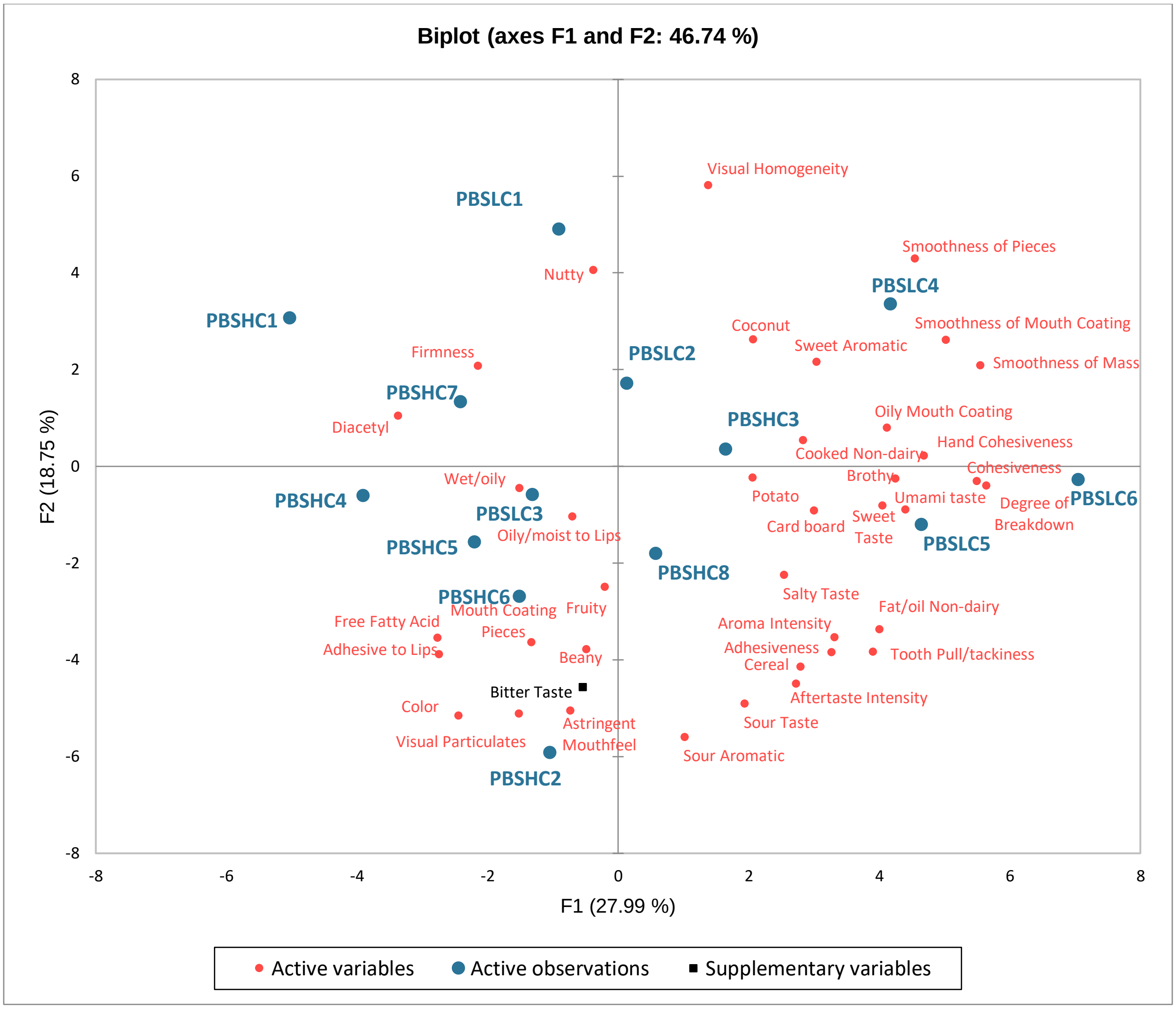

Figure 2.20. PCA biplot of the flavor and texture properties of 8 shredded plant-based Cheddars and 6 sliced plant-based Cheddars evaluated cold.

CHAPTER 3: EXTRINSIC ATTRIBUTES THAT DRIVE PURCHASE INTENT FOR BLOCK MOZZARELLA.

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INTERPRETIVE SUMMARY

Mozzarella is currently the most produced and consumed cheese in the U.S. Mozzarella comes in various fat content, moisture content, shapes, and sizes. This paper aimed to determine the influence of extrinsic attributes, specifically label claims and messages, on the purchase decision of block mozzarella. Subsequently, the importance of features related to block mozzarella was uncovered. Price is the major influence on purchasing decisions, except when consumers are seeking out a higher-quality block mozzarella. Label claims, milk fat, brands, texture, and packaging features all have an impact on consumer perception of a quality block mozzarella. Overall, the ideal block mozzarella for consumers was whole milk, firm texture/shreds well, block/bar shape, with resealable packaging and farmer owned labeling.

ABSTRACT

Consumer demand for cheese continues to increase with mozzarella being one of the primary cheeses in the U.S. The objective of this study was to understand the impact of extrinsic attributes on consumer desires for block mozzarella cheese. An online survey was conducted with mozzarella consumers (n=437). Adaptive Choice-Based Conjoint (ACBC) and Kano modeling were utilized to determine the importance of attributes applicable to block mozzarella. Maximum Difference (MXD) scaling was applied to further quantify the appeal of twenty-three label claims/messages. Subsequently, 2.5-hour immersive qualitative focus groups were conducted (n=28 consumers) including mozzarella usage occasion discussion, naming identification, block mozzarella sorting, label discussion, and group tasting. Survey data were evaluated by univariate and multivariate statistics. The ideal block mozzarella for U.S. consumers was a whole milk, firm texture/shreds well, block/bar shape, with resealable packaging and farmer owned labeling. Milkfat amount and label claims were the most important

attributes ($p<0.05$) across all consumers. Whole milk was more appealing than part skim or fat free ($p<0.05$) while no added hormones and farmer-owned were the most appealing label claims. No hormones, farmer-owned, pasture-raised cows, local and all natural were the most appealing label claims from MXD exercise overall ($p<0.05$). Two consumer clusters that valued different label claims were identified from the MXD exercise. Cluster 1 (n=249) was categorized as the Natural cluster and cluster 2 (n=188) was categorized as the Flavor cluster. Melt was a must-have attribute for mozzarella consumers while easy to shred and slice was a performance attribute. Block mozzarella is generally a price-driven product, except for special occasions where consumers seek out block mozzarella that they perceive to be of higher quality.

INTRODUCTION

Cheese is a global product with much history alongside human civilization (Kindstedt, 2018). Today, many countries contribute to cheese growth in sales and popularity year-over-year. In 2021, the total sale of cheese in the U.S. was approximately twenty-eight billion dollars (Roberts, 2022) with mozzarella cheese claiming the highest total production and the highest consumption per capita (USDA ERS, 2022). The word mozzarella is derived from the Italian word *mozzare*, meaning to cut off or to tear, and the origin of the cheese can be traced back to the southern regions of Italy (Rankin et al., 2006). The introduction of mozzarella in the U.S. market started in the 1920s but did not gain large traction because of the relatively short shelf-life compared to other semi-hard and hard cheeses (Kindstedt, 2019). The status of mozzarella cheese changed with the rise in the popularity of pizza and the advent of the Standards of Identity for Mozzarella in 1965 (Rankin et al., 2006). Today, mozzarella comes in various fat content, moisture content, shapes, and sizes. The Code of Federal Regulations established the standard of identity for mozzarella (CFR 133.155), low-moisture mozzarella (CFR133.156), part-skim mozzarella (CFR133.157), and low-moisture part-skim mozzarella (CFR133.158) based on milk fat (fat percentage by weight of the solids) and moisture content (percentage of water by weight.

The CFR does not place a restriction on the shape that any commercial mozzarella type can embody, nor does it address the use of specific marketing claims. With many players in the market, consumers have an overwhelming selection of mozzarella cheeses to choose from. Consumer-based products, including cheese, should reflect the demands of ever-changing consumer desires. There are many market research techniques to capture consumer desires for food products. Best-worst scaling, also known as Maximum Difference Scaling (MXD), was initially developed as a method to identify the best and worst options from a list of statements (Finn and Louviere, 1992). This technique can provide the level of importance of an attribute or statement relative to the other items on a list resulting in a ranking of all the attributes on the list. Most appealing/least appealing are most common but the technique can be applied to other concepts such as most sustainable/least sustainable, most likely to purchase/least likely to purchase, making it a versatile tool to rank consumer needs and desires. MXD was introduced into food consumer research in a study comparing the performance of an unstructured line scale and MXD for consumer preference of minced pork patties (Jaeger et al., 2008). Since that time, MXD has been applied to identify appealing extrinsic and intrinsic attributes for many products including lactose-free milk (Rizzo et al., 2020) bacon (McLean et al., 2017), and organic milk (Harwood and Drake, 2018).

Another market research technique used to capture consumer valuation of product concepts and attributes is conjoint analysis. Conjoint analysis was first proposed to be a viable method to assess consumer value and judgments for product attributes and concepts in 1971

(Green and Rao, 1971). The key characteristic of conjoint analysis is that respondents evaluate multiple combinations of product attributes and attribute levels (Orme, 2020). As a result, quantitative data are obtained for individual product components and can help guide product development and marketing strategy. There are many conjoint analysis methods including traditional full-profile Conjoint Analysis, Adaptive Conjoint Analysis (ACA), Choice-based Conjoint (CBC), Partial-Profile Choice-Based Conjoint, Menu-based Conjoint, and Adaptive Choice-Based Conjoint (ACBC) (Orme, 2020). Adaptive Choice-Based Conjoint (ACBC) is a more recent type of conjoint analysis that encompasses three parts, a Build-Your-Own (BYO) exercise, a screening section, and finally, tournament choice tasks (Johnson and Orme 2007). This process requires a computer interface because the exercises adapt in real time based on respondent selections. The screening tasks display relevant combinations of attributes based on the responses in the initial BYO exercise (Orme, 2020). Irrelevant attribute levels to a particular respondent are eliminated through the addition of must-have and unacceptable questions in the screening tasks (Bauer et al., 2015). Results from an ACBC exercise include the relative importance of each attribute and the value (utility) of levels within each attribute. ACBC has been applied to identify key consumer attributes and drivers of purchase for many non-food categories and food products including transportation technologies (Nickkar, 2022), sustainability in apparel (Brand and Rausch, 2021), and key purchase drivers for queso dips and sour cream (Best et al., 2023; Jervis et al., 2012).

Kano questions are another approach to understanding product liking or satisfaction. The Kano model presents a functional statement (when an attribute is present) and a dysfunctional statement (when an attribute is not present) for each product attribute. Participants are asked to select one of the following options for each functional and dysfunctional statement: I like it, It must be that way, I am neutral, I can live with it, I dislike it (Xu et al., 2009). The specific wording of the options can vary. Depending on the option the participants select for the functional and dysfunctional statement, an attribute is assigned as either attractive, one-dimensional, must-be, indifferent, reverse, or questionable. This model has been integrated into product development strategies (Matzler and Hinterhuber, 1998; Sharif Ullah and Tamaki 2010) and to characterize consumer satisfaction for food product attributes (Wimarnaya et al., 2021; Harwood and Drake, 2018; Oltman et al., 2014).

Few studies have investigated consumer perception of mozzarella cheese. Pilcher and Kindstedt (1990) surveyed 22 pizza restaurant managers in Vermont on mozzarella cheese quality to obtain insights into quality problems at restaurants and to identify potential improvements for mozzarella manufactured specifically for pizza. Vecchio et al. (2016) investigated the drivers of motivation to consume omega-3-enriched mozzarella cheese. To our knowledge, there has not been a study investigating consumer perception and desires for block mozzarella. With mozzarella being the most consumed cheese in the U.S., there is a need to understand what consumer motivation and expectations are for different types of mozzarella to help manufacturers deliver products that meet consumer needs. The objective of this study was to incorporate market research methods in an online survey to investigate consumer perceptions and desires for block mozzarella. Areas of focus include milk fat content, extrinsic attributes (labeling claim/messaging and packaging functionality), shape, and usage occasions. Subsequently, qualitative focus groups were used to further elaborate quantitative results.

MATERIALS AND METHODS

Experimental Overview

An online survey and focus groups were conducted to achieve experimental objectives (Figure. 1). The online survey and focus groups were conducted in compliance with North Carolina State University Institutional Review Board regulations. Participants were contacted using an online database of >11,000 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 Mozzarella cheese could qualify. Additional participation criteria are documented below.

Online Survey

The survey was programmed using Lighthouse Studio (Sawtooth Software version 9.14.0, Orem, UT). Participants 18 years of age or above who indicated that they had purchased and consumed block mozzarella within the past 3 months (n=249) or were mozzarella consumers and were not opposed to purchasing block mozzarella (n=188) were the target for the online survey. After the demographic/screening stage, consumers who qualified for the survey were presented with a welcome page that defined block mozzarella. Block mozzarella in this study was defined as a low-moisture mozzarella in the shape of a block/bar, ball, square chunk, or log/cylinder. Block mozzarella does not include soft/fresh, pre-shredded, brined, marinated, sliced, or snack/string mozzarella. Subsequently, participants completed purchase frequency questions followed by an Adaptive Choice-Based Conjoint (ACBC), Maximum Difference scaling exercise (MXD), direct binary responses questions, a series of Kano questions, usage occasions, and general viewpoints on block mozzarella. The general viewpoint questions addressed topics such as check-all-that apply motivations for purchase, favorite brands, chip allocation exercises for purchase and expectations when consuming block mozzarella, and openends on block mozzarella use. Two attention check questions were embedded into the survey to ensure that participants were not randomly clicking through the survey. Participants who answered the attention check questions incorrectly were disqualified from the survey.

The ACBC contained 5 attributes: milk fat, texture quality, shape, package feature, and label claim **(Table 1).** Consumers were asked to consider a block mozzarella that they would be more likely to purchase. The exercise consisted of 1 build-your-own (BYO) exercise followed by 8 screening tasks containing 4 concepts per task and 10 tournament questions containing 3 concepts per question (Chapman et al., 2009; Oltman et al., 2014). Each screening task asked consumers to indicate if they "would consider purchase" or "would not consider purchase" the product concept presented. Four must-have questions and five unacceptable questions were shown during the screening tasks to ensure the adaptability of the ACBC exercise (Orme, 2009).

Maximum Difference scaling was used to rank the appeal of 23 label claims or messages for mozzarella packages. All of these claims were collated from current commercial block mozzarellas in the US online and retail market. Consumers were asked to indicate which labels/package attribute was "most appealing" and "least appealing" when selecting a block mozzarella to purchase. Five items were shown per set of questions and 23 sets of questions were shown per respondent. Subsequently, consumers were shown all 23 labels and were asked to indicate whether they would be "more likely to purchase" or "less likely to purchase or I do not care" if they saw each label or attribute on a block mozzarella package. This additional process is called anchored MXD and is used to address the lack of absolute scaling (Lattery, 2010). By incorporating the anchoring process, labels that would increase the likelihood of purchasing can be distinguished from labels that have no impact on purchase decisions.

Questions for Kano analysis included 11 functional statements and 11 dysfunctional statements focused on the appearance and texture quality of block mozzarella. One example of a functional statement is “a mozzarella that has a buttery creamy flavor”. The dysfunction statements directly opposed the function statement. For example, “a mozzarella that does not have a buttery creamy flavor”. Consumers were asked to select one of the following choices for each statement: “I will dislike it”, “I can live with it”, “I do not care”, “I expect it”, or “I will like it”. Depending on their responses to each functional and dysfunctional statement, consumers were placed in one of the following categories: attractive, indifferent, must be/have, performance, questionable, or reverse (Sauerwein et al., 1996; Sharif Ullah and Tamaki, 2010). For example, if a respondent selected “I will like it” for “a mozzarella that has a buttery creamy flavor” (functional statement) and “I will dislike it” for “a mozzarella that does not have a buttery creamy flavor” (dysfunctional statement), the “buttery creamy flavor” attribute would be categorized as a performance feature for that particular respondent.

Focus Groups

Six 2.5-hour immersive qualitative focus groups with moderator-guided discussion and activities were conducted (n=28) following survey completion (within 4 weeks). Invitations were sent to consumers who completed the survey and indicated that they had purchased and consumed block mozzarella within the past 3 months. Focus groups were conducted in person at the North Carolina State University campus. Prior to their focus group session, qualified participants were assigned an online homework activity. The online homework asked participants to submit a photo of mozzarella cheese that they currently had at home in their refrigerator and a photo of the block mozzarella that they purchased most often. Audio and video were recorded for subsequent reference by both the moderator and observer to review the notes and body language of all participants throughout focus groups. All focus groups were completed within a one-week period. The focus groups were divided into stages as follows: usage occasions, expectations, categorization, block mozzarella sorting, label discussion, and tasting discussion. In the mozzarella sorting phase, participants ranked 6 packaged commercial block mozzarellas (purchased locally) from most likely to least likely to purchase. Labeling was then discussed followed by tasting and discussion. Block mozzarella were cut into 2.5 x 2.5 x 2.5 cm cubes using a wire cutter and dispensed into 120 mL soufflé cups. The block mozzarella samples were kept refrigerated at 4C until the tasting activity. Data collected included whiteboard notes on mozzarella categorization, usage occasions, and expectations, notes on mozzarella ranking, and favorite/least favorite label claims/messages. Major themes and recurring statements were used to further emphasize key points from quantitative survey data.

Statistical Analysis

A preliminary analysis of the ACBC data MXD exercise results showed the same order of importance for each attribute and the same top six label claims between block mozzarella users (n=249) and mozzarella consumers who were block acceptors (n=188). As such, these consumers were pooled (n=437) for all analyses. ACBC data and the overall group MXD data were analyzed using Hierarchical Bayesian (HB) Regression in Lighthouse Studio (Sawtooth Software, Version 9.14.0, Orem, UT). Root Likelihood (RLH) cut-off values were generated and used to eliminate potential random respondents (Orme, 2019). The RLH cutoff values of 0.316 and 0.547 were determined using the 95th percentile from 500 randomly generated data in the MXD and ACBC exercises, respectively (Orme, 2019). Data from respondents with RLH values lower than the cutoff value in either exercise were removed (n=4 and n=1, respectively). Statistical lettering for ACBC importance scores, ACBC utility scores, and MXD utility scores were determined using analysis of variance (ANOVA) utilizing Fisher's LSD at 95% confidence ($p<0.05$). Cluster analysis of MXD responses was also performed in Lighthouse Studio using latent class analysis to categorize similar respondents into groups. Frequency tables were constructed following Kano modeling attributes categorization, and biplots were made using correspondence analysis (CA) as suggested by Lillestøl (1991). The remaining analyses were performed with XLSTAT (version 2023.1.1, Addinsoft, Boston, USA). All analyses were performed with 95% confidence ($p<0.05$). Focus group notes were discussed among the moderator and two observers following the completion of all focus groups. Topics mentioned by two-thirds or more of the participants in all focus groups and noted to be relevant by the moderator and observers were deemed as key points.

RESULTS AND DISCUSSION

Participants in the survey (n=437; 249 block mozzarella users; 188 block mozzarella acceptors) were 75.3% female and 24.7% male. Participants were primarily White/Caucasian (69.1%) followed by Hispanic/Latino (8.2%), Black/African American (7.8%), South Asian or Indian (5.7%), East Asian/Middle Eastern (5.6%), and other/prefer not to answer (3.5%). Participant average age was 40±15.5 years old with a median age of 30 years. The majority of participants resided in North Carolina (88.3%). Household income was evenly split among $100,000 or more (33.9%), 31.6% $50,000-$99,999 (31.6%) and below $50,000 (26.1%), with 8.5% preferred not to answer. Overall, the majority of the participants were responsible for household grocery shopping with 58.5% indicating "I do all of the grocery shopping", 26.3% indicating "I do most of the grocery shopping", 12.8% indicated "I share equally the grocery shopping", and 2.5% indicating "I do some of the grocery shopping". All participants purchased and consumed mozzarella in the past 3 months and 57.0% of participants purchased and consumed block mozzarella in the past 3 months (users). A chip allocation exercise asking participants to allocate 100 chips across different mozzarella types based on the frequency of purchase showed that participants purchased block mozzarella 15% of the time on average compared to other forms of mozzarella. Block mozzarella users purchased unflavored/regular block mozzarella most often. In a CATA question, 97.6% of users cited that they had purchased unflavored/regular block mozzarella within the past 3 months. Moreover, 33.3% also cited that they had purchased coated (herbs, spices, etc.) in the past 3 months suggesting that a group of consumers is interested in additional flavoring for block mozzarella. The most commonly purchased size of block mozzarella was 8 oz (60.4%) and 16 oz (26.2%). The average survey completion time was 134.59 minutes with a median of 28.85 minutes, indicating that many participants took a break between survey exercises and then re-entered the survey (which was allowed).

ACBC Exercise

Attribute importance scores for each attribute and zero-centered average utilities for each attribute level were obtained from HB analysis. Items with larger importance scores or utility scores are more important/desirable than items with lower scores. Zero-centered average utilities for attribute levels range from negative to positive values; however, it is important to note that negative values do not mean that the attributes are undesirable but rather a negative attribute is less desirable than an attribute with a higher score (Orme, 2020).

The importance scores for ACBC attributes were in the following order: milk fat (36.3), label claim (20.3), texture quality (15.4), and shape (15.2), and package feature (12.7) (Table 1, Figure 2). Milk fat was the most important attribute to respondents when considering the purchase of block mozzarella ($p<0.05$). Within the milk fat attribute, whole milk level (48.2) received a significantly higher average utility score than part skim (22.9) followed by fat free (-71.1) ($p<0.05$) (Figure 3). Label claim was the second most impactful attribute with farmer owned and no added hormones/rBST free having significantly higher utility scores than the rest of the label claim levels ($p<0.05$). Texture quality and shape attributes were not different from each other ($p>0.05$), and attribute levels for texture quality and shape were not different ($p>0.05$) (Figure 2). The package feature attribute received the lowest importance score ($p<0.05$). For package feature attributes, resealable was the most appealing followed by easy to open/peel (7.0) and none (32.2), respectively. Overall, the ideal block mozzarella for all consumers was whole milk, firm texture/shreds well, block/bar shape, with resealable packaging, and farmer owned labeling (Figure 3).

MXD Exercise

HB regression provides average zero-anchor utility scores for each attribute evaluated in the MXD exercise. The utility scores can be used to compare the desirability of each attribute (Orme, 2020). Furthermore, the anchoring procedure allows for distinctions between label claims that are more likely to influence purchase from label claims that would be less likely to influence purchase. Overall, thirteen labels fell above the anchor indicating consumers are more likely to purchase a block mozzarella with those labels on the package (Table 2, Figure 4). The top five most appealing labels were produced without added hormones, made from milk from our pasture-raised cows, made locally, farmer owned for more than 75 years, and all natural, respectively.

Latent class analysis was conducted on the MXD responses to determine potential segmentations. Two consumer clusters were observed (n=249 and n=188) (Table 2, Figure 5). Cluster 1 (n=249) was identified as the Natural cluster and cluster 2 (n=188) was categorized as the Flavor cluster. There was no evidence of user and acceptor status on cluster membership assignment ($p>0.05$). The Natural cluster was named as such because these consumers placed relatively high importance on label claims such as produced without added hormones, all natural, organic, rBST free, and natural cheese (Table 2). Other label claims such as made with milk from our pasture-raised cows, made locally, good source of calcium and protein, made from pasteurized milk, farmer owned for more than 75 years, premium taste, and traditionally cultured were also likely to invoke purchase interest from this group of consumers.

Cluster 2 (n=188) was categorized as the Flavor cluster. The top five claims in this group were farmer owned for more than 75 years, made locally, made with milk from our pasture-raised cows, established business for more than 75 years, and #1 in Italy (Table 2). This group also valued labels such as premium taste, artisan quality, Italian style, traditionally cultured, and natural cheese. Label claims likely to increase purchase in both groups were farmer owned for more than 75 years, made locally, made with milk from our pasture-raised cows, premium taste, good source of calcium and protein, all natural, natural cheese, and produced without added hormones.

ACBC importance scores were also examined for each consumer cluster derived from the MXD exercise (Table 1, Figure 2). The importance scores of the Natural cluster consumers resembled that of the overall group, while the Flavor cluster placed a higher importance on shape over texture; however, the differences between the average importance of texture quality and shape were small. The ideal block mozzarella for the Natural cluster was made from whole milk, with a firm texture/shreds well, block/bar shape, resealable packaging, and no added hormones/rBST free label claim (Figure 6). The ideal block mozzarella for the Flavor cluster was made from whole milk, melts and stretches, in a round ball, resealable packaging, and farmer owned label claim (Figure 7). Both clusters valued whole milk followed by part skim and fat free. The Natural cluster preferred a block mozzarella with a firmer texture/shreds well over melts and stretches and softer texture/sliceable. However, the Flavor cluster desired a block mozzarella that melts/stretches over firmer texture/shreds well and softer texture/sliceable. Considering the sensorial attributes of block mozzarella, it may be that the Flavor cluster valued melts/stretches over the other two texture levels because of the overall sensorial impact that mozzarella meltability and stretchability may have on the consumption experience, while the Natural Group valued a more functional textural aspect of their block mozzarella; wanting it to shred well.

The Natural cluster preferred the shape of their block mozzarella to be block/bar while the Flavor cluster preferred a round ball followed by block/bar (Figure 6, 7). Both clusters preferred the resealable packaging feature over easy to open/peel or none. This result suggests that respondents valued having an additional feature to their packaging rather than not having anything at all. The label claim levels utility scores were consistent with MXD scores for label claims. The Natural cluster valued no added hormones/rBST free, farmer owned, and organic while the Flavor cluster valued farmer owned (20.9), established business for more than 75 years (9.0), and premium (7.2).

Kano Exercise

Kano questions were also analyzed within the clusters derived from the MXD results. No differences were observed ($p>0.05$) therefore, the Kano results will be discussed from the overall group perspective ($n=437$) (Table 3). Easy to shred and slice was categorized as a must-be attribute 26.9% of the time and performance 41.0% of the time indicating that this attribute is essential and consumer liking increases when it is present. Likewise, melt was categorized as a must-be attribute 38.6% of the time and performance 36.9% of the time suggesting a high value of the meltability aspect of block mozzarella by respondents. These attributes would be expected to be important to consumers for block mozzarella.

The majority of the other attributes in the Kano exercise were largely categorized as indifferent. Despite that, attributes that were largely categorized as indifferent by most consumers were still valued by some respondents. For example, the buttery creamy flavor attribute was categorized as indifferent 34.0% of the time, attractive 27.2% of the time, must be 15.5% of the time, and performance 15.5% of the time, Suerwein et al. (1996) described this possible occurrence stating that the product requirements in the Kano model are often spread out over more than one category. It may be difficult to interpret frequency data alone and may lead to misclassification of the importance of the attribute. The application of correspondence analysis (CA) to generate a biplot allows for full attribute and category associations to be visualized and interpreted more easily. The CA biplot confirmed that easy to shred and slice and melt are strongly correlated with the performance and must be categories (Figure. 8). Stretch is a must-be and attractive attribute. White in appearance, buttery creamy flavor, and soft texture are also closely related to the attractive category with soft texture being the most closely associated. Mild milky flavor is associated with the indifferent category. Salty and browns when cooked are also associated with the indifferent category, but they have potential to be a reverse attribute meaning that their presence may cause great dissatisfaction with certain respondents. Pale yellow in appearance is the attribute that had the strongest association with the reverse category. Lastly, firm texture is strongly associated with the questionable category. Questionable is not a common citation in the Kano model, and the categorization of an attribute as questionable may suggest that either the wording or the attribute is confusing to respondents (Suerwin et al., 1996). In the

ACBC exercise, firm was combined with shreddable while soft was combined with sliceable. The utility score from the overall group suggested firm/shreddable to be the most important textural attribute of block mozzarella compared to the other two. The Kano model provides additional insight suggesting that shreddable is highly valued and leads to satisfaction, while firm texture may not necessarily be of importance to respondents.

Other questions

Price was a factor that was not included in ACBC, MXD, and Kano exercises. Price was the most important attribute followed by flavor and nutrition when respondents were asked about general food purchases in a chip allocation exercise (Figure 9). When applied to block mozzarella specifically, users again placed the highest importance on price, followed by flavor and then texture (Figures 10 and 11). Roughly 80% of users cited store brands as their most typical block mozzarella purchases (results not shown). This aligns with the sentiment on the importance of price for block mozzarella as store brands are typically less expensive than brand names. Furthermore, 41.0% of users cited price as the most important factor for choosing an alternative block mozzarella if the block mozzarella they typically purchased was not available.

The majority of users indicated that the ability to shred their own cheese is a large motivation for block mozzarella purchases (Figure. 12). The motivation for shredding their own cheese aligns with the sentiment about the importance of shredability shown in the Kano exercise and ACBC. In the same CATA, 48.6% of users cited “it is required for the dish/recipe I am making” as the motivation for purchasing block mozzarella (Figure 12). About ninety-two percent of users used block mozzarella in a recipe or a dish and forty-seven percent cited “consume as is” in a CATA question. When used in a recipe or a dish, 57.4% of users shredded the mozzarella.

Focus groups

Consumers expected mozzarella to be mild, creamy, and melt well. Because of the mild flavor of mozzarella, mozzarella was considered a versatile cheese for consumers to put on a variety of dishes without masking the flavor of the dishes. The connection of mozzarella to comfort foods, notably Italian dishes, made it a critical cheese for consumers. In the online survey, consumers cited terms such as happy, enjoyment, indulge, relaxed/calm, pampered, and nostalgic to describe their emotional association with mozzarella consumption (Figure. 13).

The qualitative themes summary can be found in Figure. 14. Consumers largely expressed that block mozzarella should be called block or brick mozzarella. Consumers described the versatility of use, relatively inexpensive price point, and free of additives as the advantages of block mozzarella over other forms. The versatility of use was described by consumers as the ability to cut, shred, or slice the block mozzarella in the shape and quantity that they desired. Once again, consumers noted price as critical for block mozzarella purchases, thus it was not unexpected to see store brands being the most purchased block mozzarella in focus groups, consistent with survey results. However, a large number of users also indicated that they purchased block mozzarella from brand names like Kraft and Sargento. The investigation of brand purchases during the focus groups led to the discussion of block mozzarella purchases based on occasions. Consumers expressed that they generally looked for block mozzarella that is cheaper in price or a block mozzarella that is on sale for their own consumption. However, they were more inclined to gravitate towards block mozzarella that they perceived to be of higher quality when they were hosting guests or cooking for special occasions. This suggests that consumers largely perceived brand name block mozzarella as being of higher quality than the store brands and that brand image is very important for consumers when looking to purchase a "higher quality" block mozzarella. Purchase occasion was not investigated in the quantitative survey, but it was suggested by consumers during focus groups to be another important factor when considering which brand of block mozzarella to purchase.

The sorting activity presented consumers with six block mozzarellas in commercial packaging (Great Value whole milk low moisture, Kraft low-moisture part-skim, Polly-O whole milk, Galbani part skim, Organic Valley mozzarella cheese, and Great Value part-skim) followed by ranking and discussion. From the discussion, consumers knew that there are 'soft' and 'hard' block mozzarella. Low moisture was associated with hardness by some consumers, but the benefit expressed by consumers was that harder blocks were easier to shred and had longer shelf life. Softer blocks were generally assumed to be more expensive than the harder blocks due to its resemblance in texture to fresh mozzarella. Polly-O and Galbani were ranked as most likely to purchase by many consumers. Consumers had positive associations with the word Italian and the company's established date on cheese packages, perceiving those messages to be indicators of higher-quality products. Polly-O likers cited milk fat as the reason for preference because they assumed that whole milk block mozzarella would taste better than part-skim. Whole milk likers generally rated all whole milk products higher than part-skim due to this assumption. Consumers who preferred Galbani were also driven by the term "classic melt & stretch" on top of the Italian style and the company's established date. Likers of Organic Valley cited health as the main reason because they associated the term organic with healthier. Although the mention of prices was omitted, consumers assumed that the Great Value blocks were less expensive than other blocks. Consumers who preferred Great Value unanimously cited least expensive price as their reason for selection. Consumers who ranked the Kraft block mozzarella higher had positive associations with other Kraft-branded products and vice versa. Two of the block mozzarellas presented had convenient package features (easy to open or easy to peel); however, package features were not mentioned by consumers without probing, consistent with low importance by survey conjoint analysis.

Label claims that were liked by consumers aligned with the results from the MXD exercise. Consumers expressed positive associations with the likelihood of purchasing block mozzarella with terms like all natural, farmer owned for more than 75 years, premium taste, and made locally. Unexpectedly, the terms that were of lower importance in the MXD exercise were also not interesting to consumers in focus groups. Two reasons are the lack of familiarity with terms such as certified B corporation or old world, and the sentiment of companies trying too hard to attract consumers such as packaging that includes a picture of the Italian flag or a photo of cows with pasture information (provenance). Lastly, consumers mentioned price as being a bigger consideration than label claims during this activity.

In the tasting activity, consumers tasted the six block mozzarella provided to them in the block sorting activity. Consumers who selected whole milk as a reason for selection in the package exercise were astonished by the fact that they did not prefer whole milk over part skim after tasting because they initially assumed that whole milk would always taste better. Moreover, consumers who did not have high expectations for the Great Value brand were surprised by the overall positive sensorial experience.

One limitation of this study is the concentrated regional participants mainly from the Raleigh, NC area. This study design can be used to investigate the importance of block mozzarella features with consumers from other regions, especially locations with higher demand for this product. Price was found to be a factor of great importance for consumers when purchasing block mozzarella. Future studies may incorporate price into the conjoint exercise to determine the degree of importance of price relative to other features. One of the common themes uncovered in the focus group was the surprising realization regarding whole milk and part-skim post-tasting. Consumers expressed that they did not prefer whole milk over part skim although an assumption that whole milk would taste better was voiced by consumers prior to tasting. The acceptability of part-skim block mozzarella and whole milk block mozzarella can be further explored utilizing official acceptance testing with representative samples, more consumers, and quantifiable data collection strategies.

CONCLUSION

Block mozzarella is a critical cheese to consumers because it is versatile, relatively inexpensive, and free of additives. Consumers expect block mozzarella to be easy to shred, easy to slice, and melt well. Block mozzarella is a value cheese. Price is the main driver when selecting a block mozzarella at the grocery store, but value-added features are considered when hosting guests or cooking for special occasions. Low prices or special promotions will draw attention when consumers shop for everyday use whereas label claims, a good brand reputation, and package design may attract consumers who are looking to splurge for a special occasion. Milk fat was the most important attribute, omitting price, with whole milk preferred. Based on extrinsic attributes, two clusters of consumers were identified: natural focused and flavor focused. Attractive package claims for all mozzarella consumers were farmer owned for more than 75 years, made locally, made with milk from our pasture-raised cows, premium taste, good source of calcium and protein, all natural, natural cheese, and produced without added hormones.

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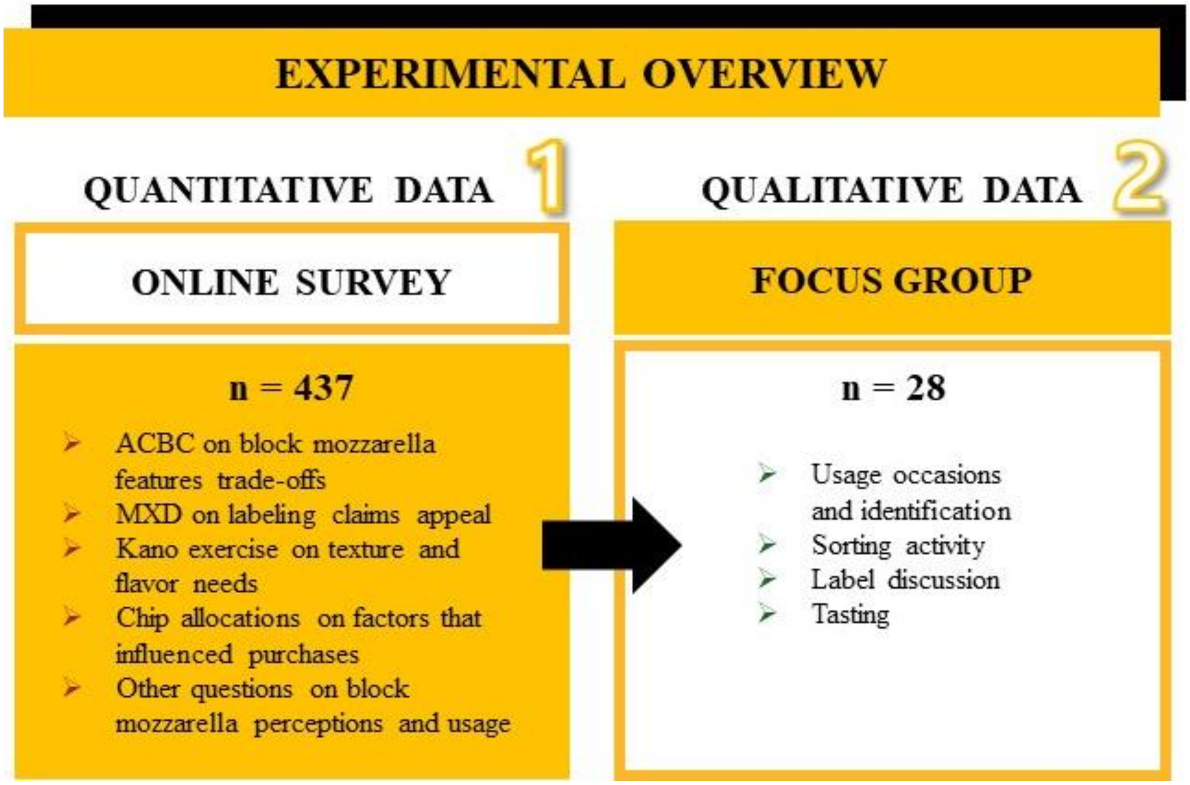

Figure 3.1. Experimental overview.

Table 3.1. ACBC average importance scores for block mozzarella attributes. A higher score indicates a higher importance of an attribute when purchasing a block mozzarella. The importance scores are re-scaled to sum to 100. Different lettering signifies a significant difference ($p<0.05$).

	Overall (n= 437)	Natural Cluster (n=249)	Flavor Cluster (n=188)
Milk Fat	36.3a	36.0	36.7
Label Claim	20.3b	21.7	18.5
Texture Quality	15.4c	15.5	15.3
Shape	15.2c	14.5	16.2
Package Feature	12.7d	12.3	13.3

Table 3.2. Average zero-anchor interval score utility scores for labeling claims and messages on block mozzarella packaing MXD exercise. A higher score indicates higher appeal. Options with a positive value signify that a labeling claim/message would increase the likelihood of block mozzarella purchase whereas options with a negative value (below the 0 anchor point) signify labeling claims and message sthat would not increase the likelihood of purchase. Bolded values signify the top ten options within each column. Different letters indicate significant differences ($p<0.05$).

	Overall (n=437)	Natural Cluster (n=249)	Flavor Cluster (n=188)
Produced without added hormones	**18.8a**	**32.1**	1.1
Made with milk from our pasture-raised cows	**17.7ab**	**19.8**	**15.0**
Made locally	**16.6ab**	**17.1**	**15.9**
Farmer owned for more than 75 years	**14.7bc**	**8.8**	**22.6**
All natural	**14.7bc**	**20.4**	**7.2**
Good source of calcium and protein	**13.1cd**	**15.3**	**10.3**
Natural cheese	**10.0de**	**14.0**	4.8
Organic	**9.7e**	**20.3**	-4.3
Premium taste	**7.9ef**	4.5	**12.3**
Established business for more than 75 years	**6.1fg**	-0.1	**14.1**
Made from pasteurized milk	5.1fgh	**9.1**	-0.1
Artisan quality	3.7gh	-1.8	**11.0**
Traditionally cultured	2.6hi	0.1	6.1
Anchor point	0.0	0.0	0.0
rBST free	-0.5i	**16.5**	-23.2
Italian style	-7.3j	-18.8	**7.9**
#1 in Italy	-7.8j	-23.9	**13.6**
Hand-selected	-8.9j	-12.0	-4.7
Photo of cows with pasture information (provenance)	-9.3j	-13.2	-4.2
Certified B corporation	-21.1k	-11.0	-34.5
Old world	-22.0kl	-29.2	-12.5
Kosher	-23.1kl	-18.7	-29.0
A picture of the Italian flag	-24.7l	-37.2	-8.1
Vegetarian	-28.2m	-19.8	-39.3

Table 3.3. Kano modeling classification of block mozzarella functionality (n=437). Attractive indicates that the attribute is not expected by consumers, but are satified if this attribute is present. Indifferent indicates that consumers do not care about the attribute. Must be indicates that the attribute is essential. Performance indicates that when present, consumer liking increases. Questionable indicates conflicting responses from consumers. Reverse indicates decreased consumer liking when present.

	Attractive	Indifferent	Must Be	Performance	Questionable	Reverse
A Mozzarella that has a mild milky flavor	12.0%	44.6%	20.5%	10.0%	7.2%	5.6%
A Mozzarella that has a buttery creamy flavor	23.3%	31.7%	18.5%	20.5%	4.0%	2.0%
A Mozzarella that has a firm texture	20.9%	42.6%	8.8%	6.0%	13.3%	8.4%
A Mozzarella that has a soft texture	20.5%	40.2%	13.3%	14.1%	9.2%	2.8%
A Mozzarella that is easy to shred and slice	14.5%	13.7%	26.9%	41.0%	3.2%	0.8%
A Mozzarella that melts	7.6%	13.3%	38.6%	36.9%	2.4%	1.2%
A Mozzarella that stretches	15.3%	33.3%	25.7%	20.9%	3.6%	1.2%
A Mozzarella that browns when cooked	9.2%	47.8%	14.9%	10.0%	5.2%	12.9%
A Mozzarella that is salty	12.4%	38.2%	14.9%	6.8%	8.8%	18.9%
A Mozzarella that is white in appearance	16.9%	44.2%	17.7%	15.3%	5.6%	0.4%
A Mozzarella that is pale yellow in appearance	3.6%	57.0%	3.6%	1.2%	8.8%	25.7%

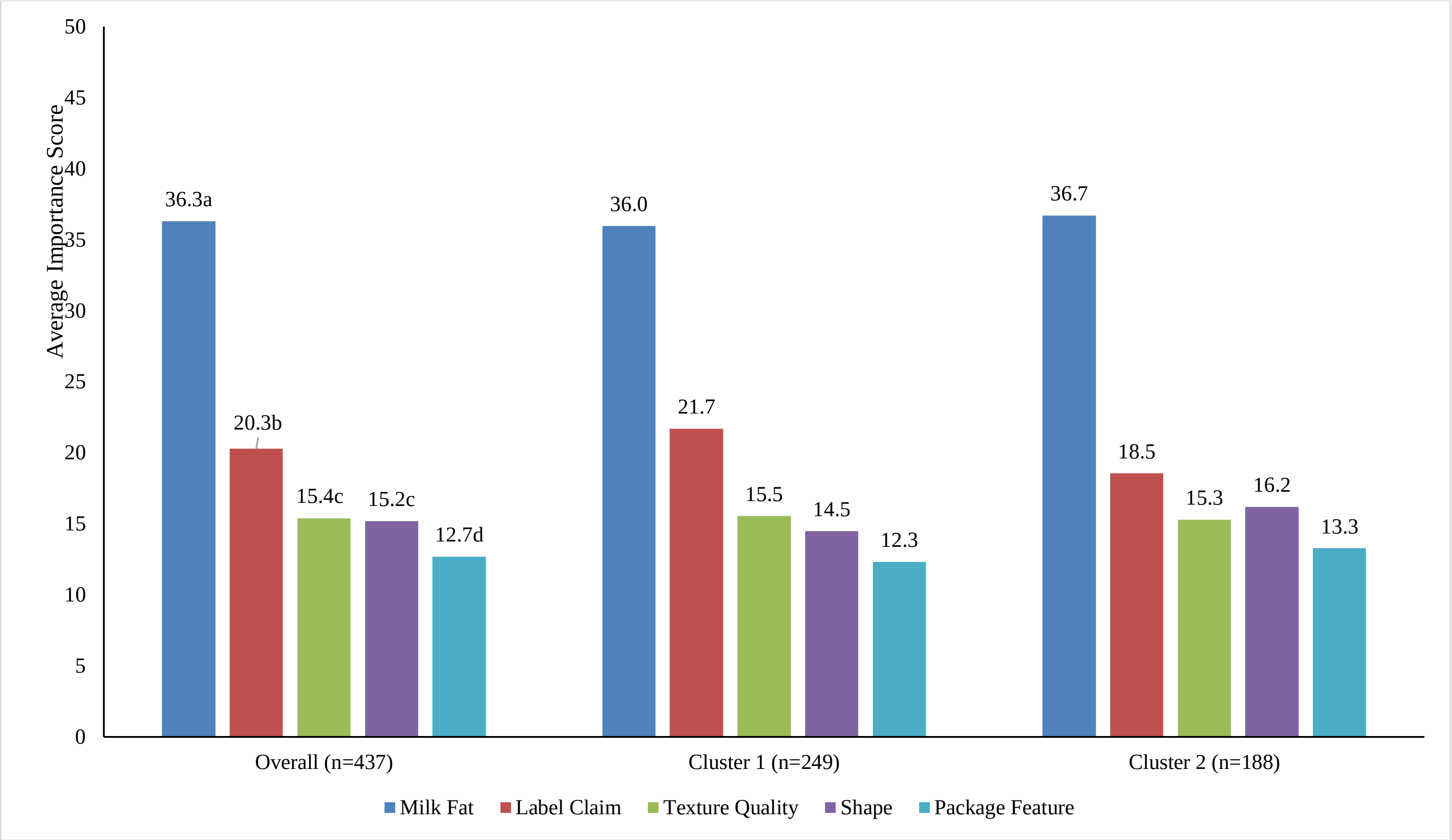

Figure 3.2. Bar charts of ACBC average importance scores for block mozzarella attributes. A higher score indicates a higher importance of an attribute when purchasing a block mozzarella. The importance scores are re-scaled to sum to 100. Different lettering signifies a significant difference ($p<0.05$).

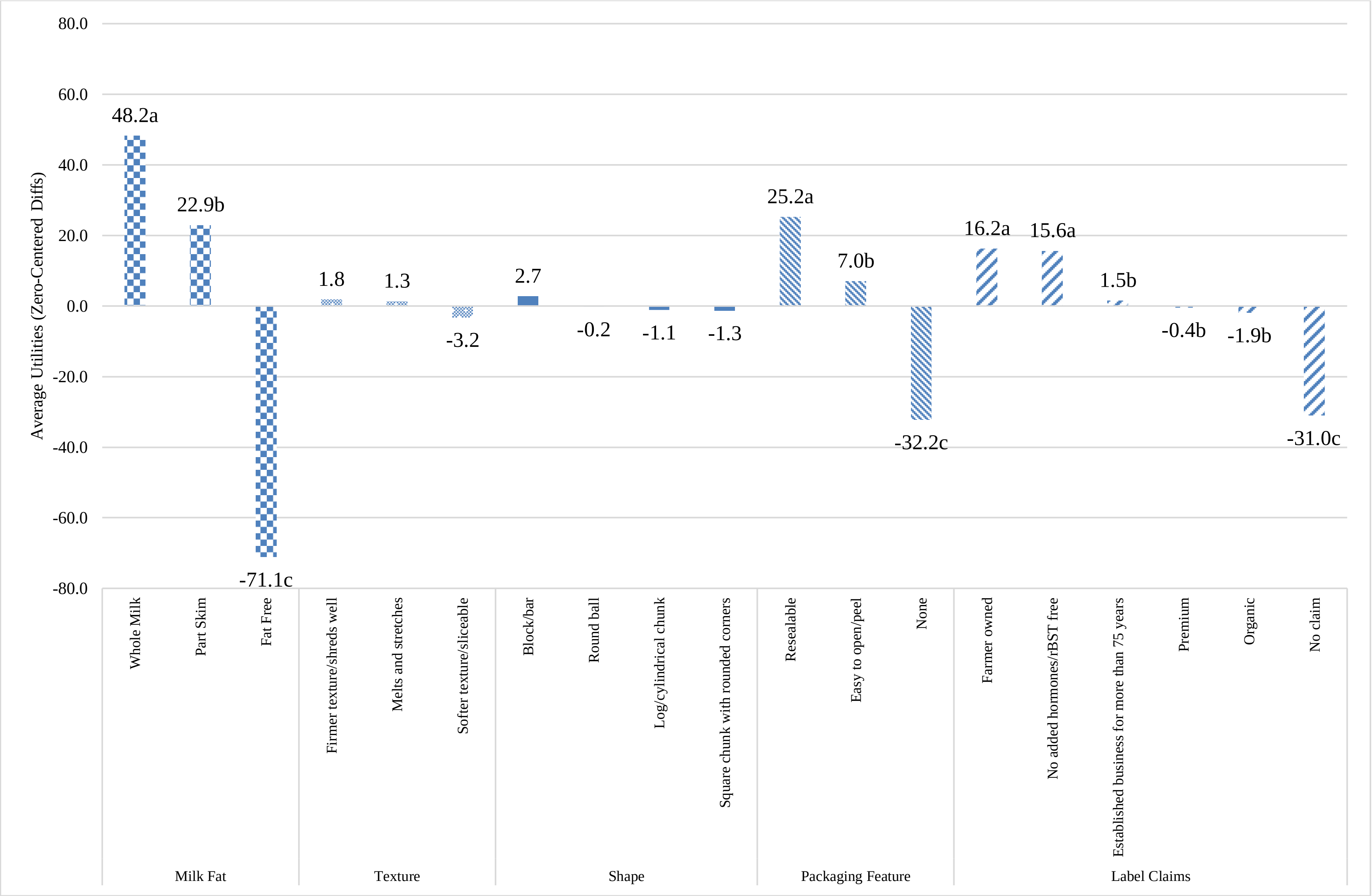

Figure 3.3. ACBC average utility scores for attribute levels for block mozzarella for all participants (n=437). Attribute levels are separated by different fill patterns. Utility scores can only be compared within each attribute. Different letters indicate a significant difference within each attribute ($p<0.05$). Lack of lettering indicates no difference ($p>0.05$).

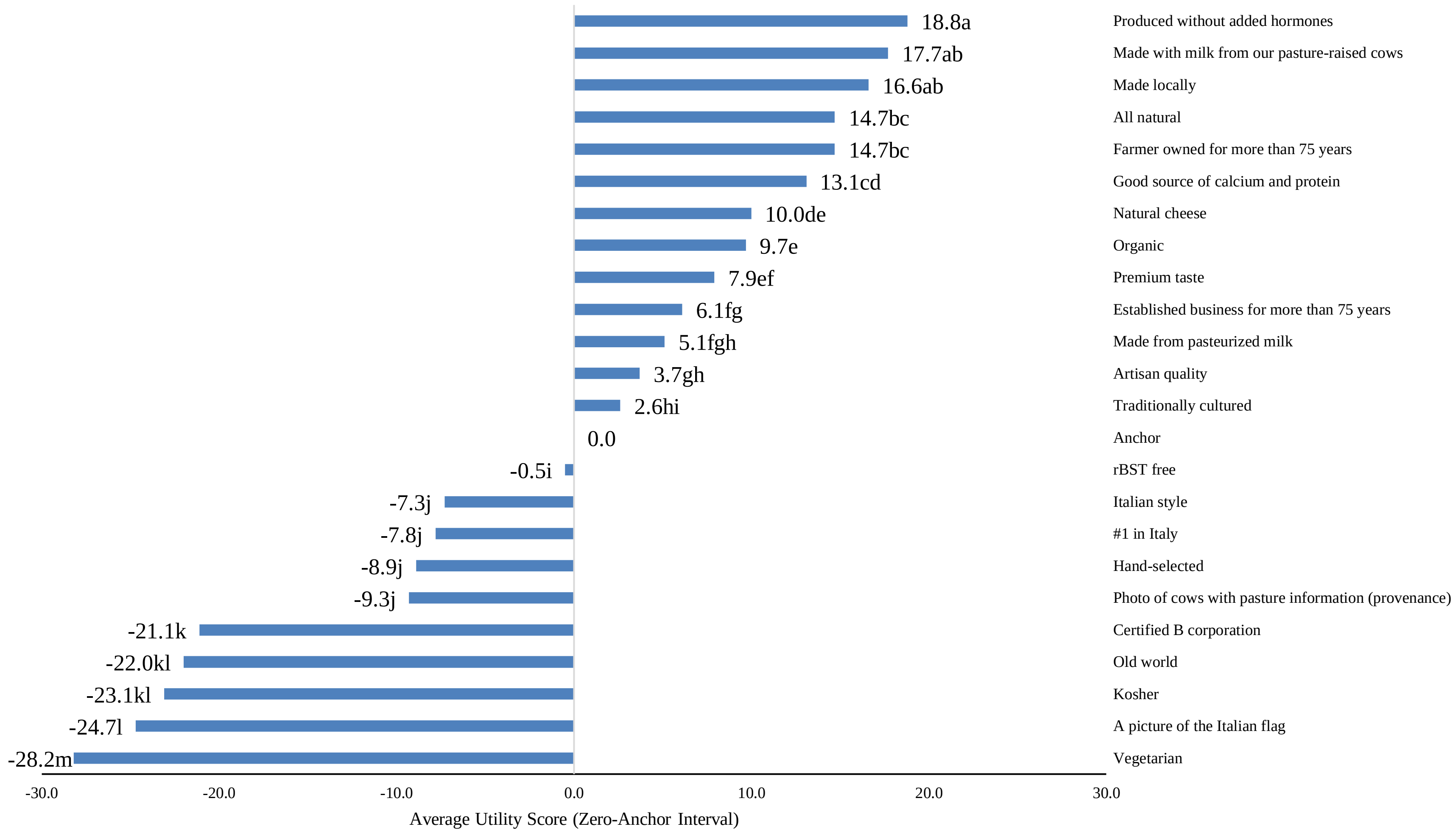

Figure 3.4. Average zero-anchored interval utility scores for block mozzarella labeling claims and messages MXD exercise for all participants (n=437). A higher score indicates higher appeal. Options with a positive value signify that a labeling claim/message would increase the likelihood of block mozzarella purchase whereas options with a negative value signify labeling claims/messages that would not increase the likelihood of purchase. Different letters indicate significant differences ($p<0.05$).

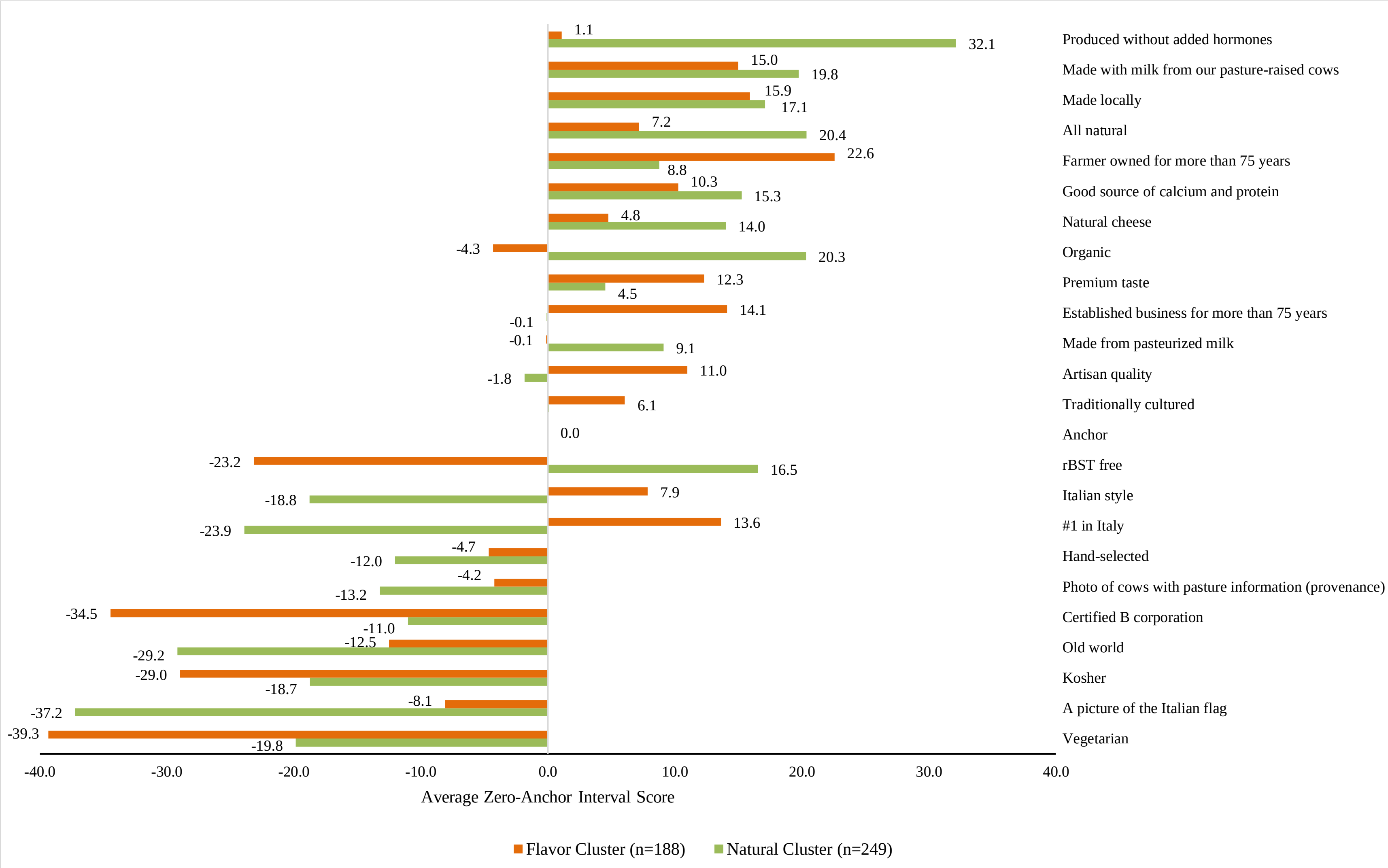

Figure 3.5. Average zero-anchored interval utility scores for block mozzarella labeling claims and messages MXD exercise for the natural cluster (n=249) and flavor cluster (n=188). A higher score indicates higher appeal. Options with a positive value signify that a labeling claim/message would increase the likelihood of block mozzarella purchase whereas options with a negative value signify labeling claims/messages that would not increase the likelihood of purchase.

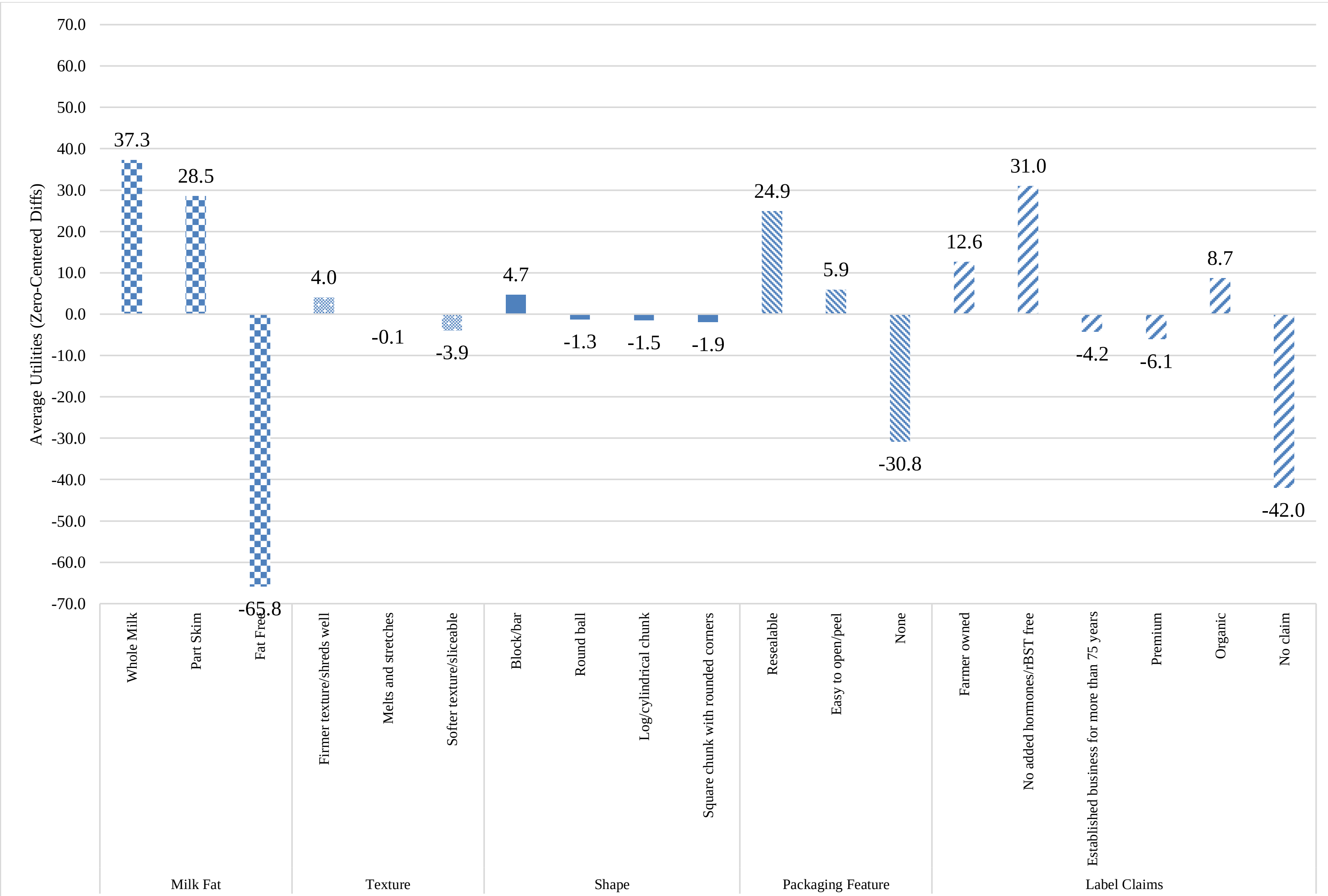

Figure 3.6. ACBC average utility scores for attribute levels for block mozzarella for the natural cluster (n=249). Attribute levels are separated by different fill patterns. Utility scores can only be compared within each attribute.

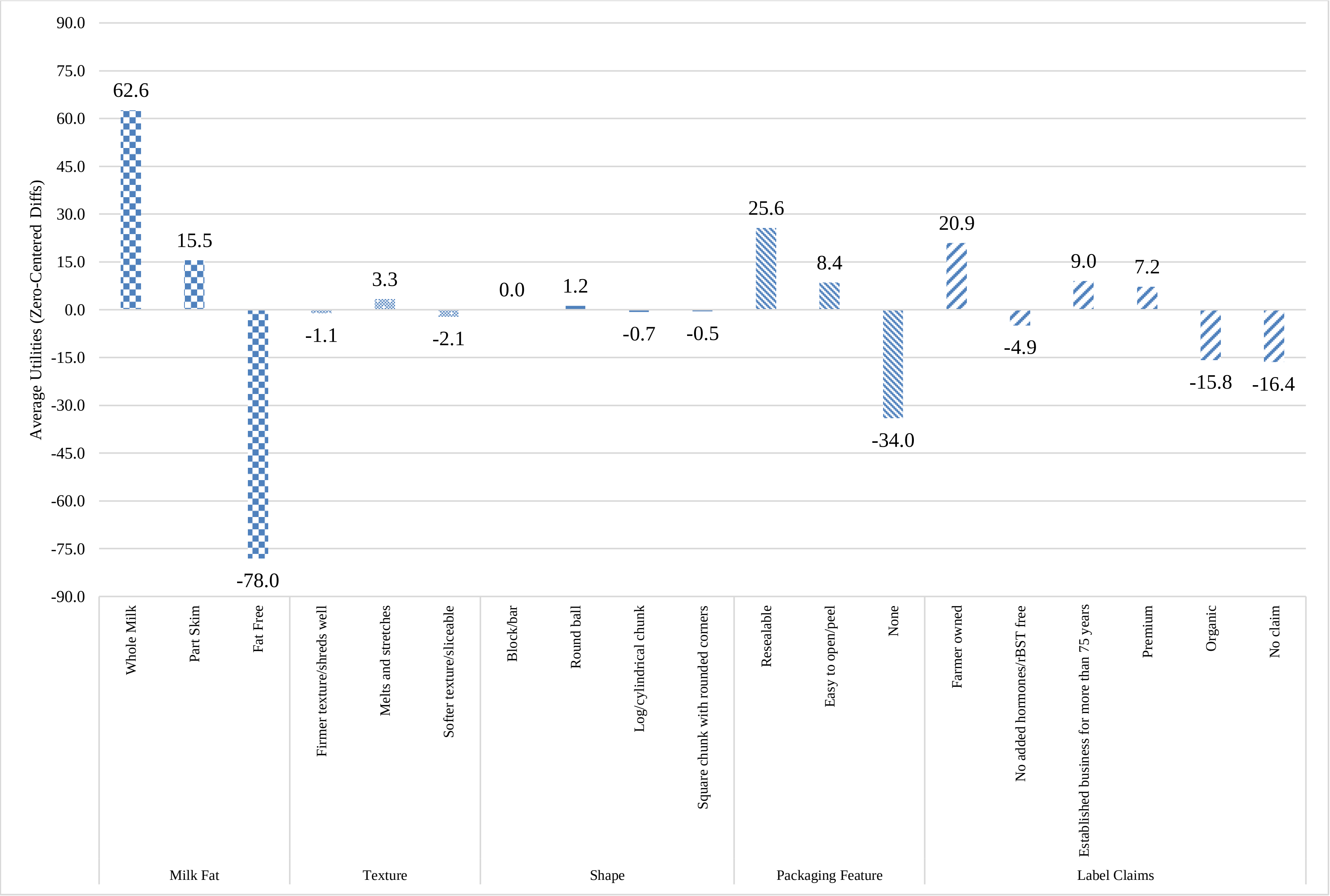

Figure 3.7. ACBC average utility scores for attributes levels for block mozzarella for the flavor cluster (n=188). Attribute levels are separated by different fill patterns. Utility scores can only be compared within each attribute.

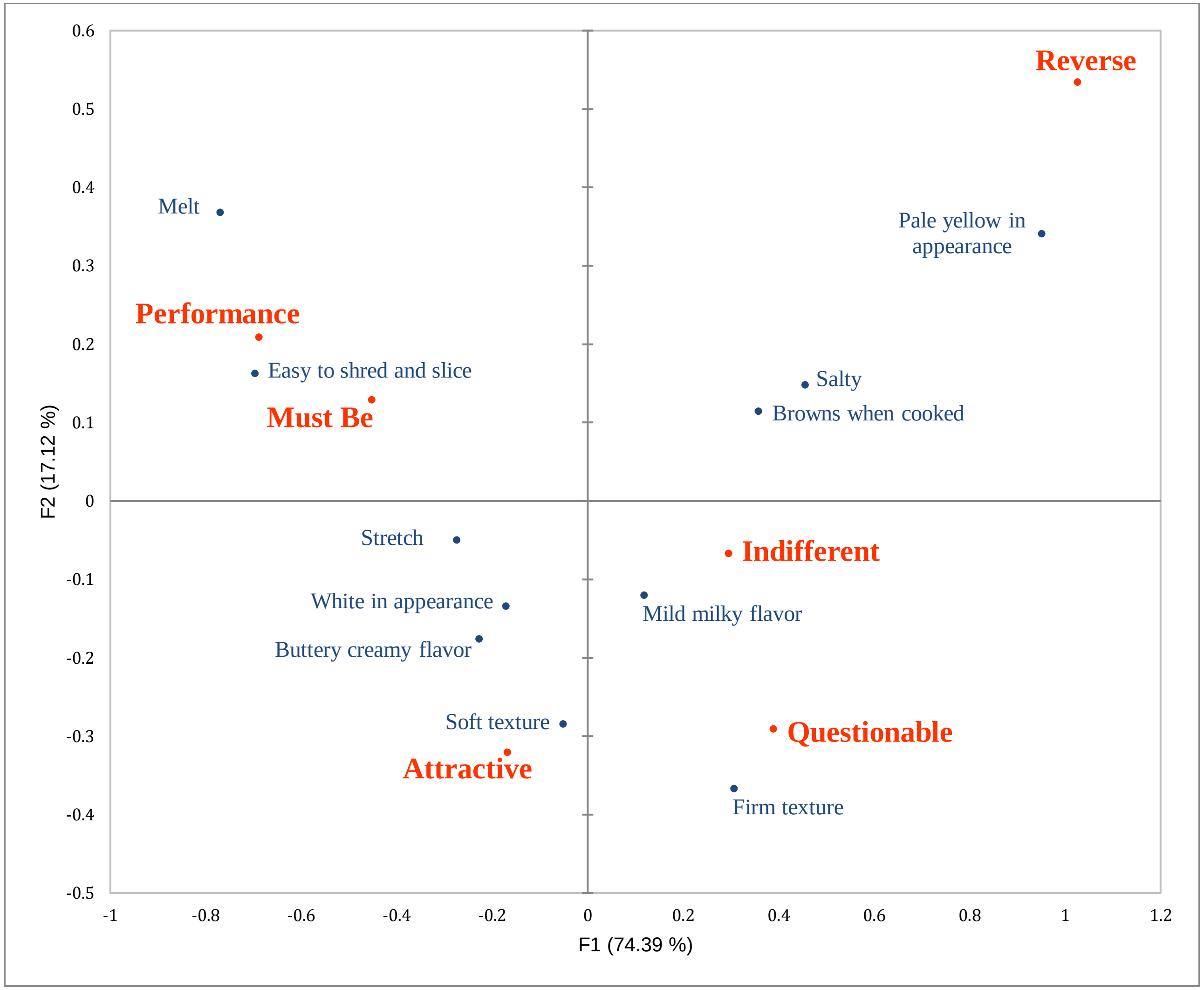

Figure 3.8. Correspondence analysis biplot of Kano modeling classification of block mozzarella functionality for all participant (n=437).

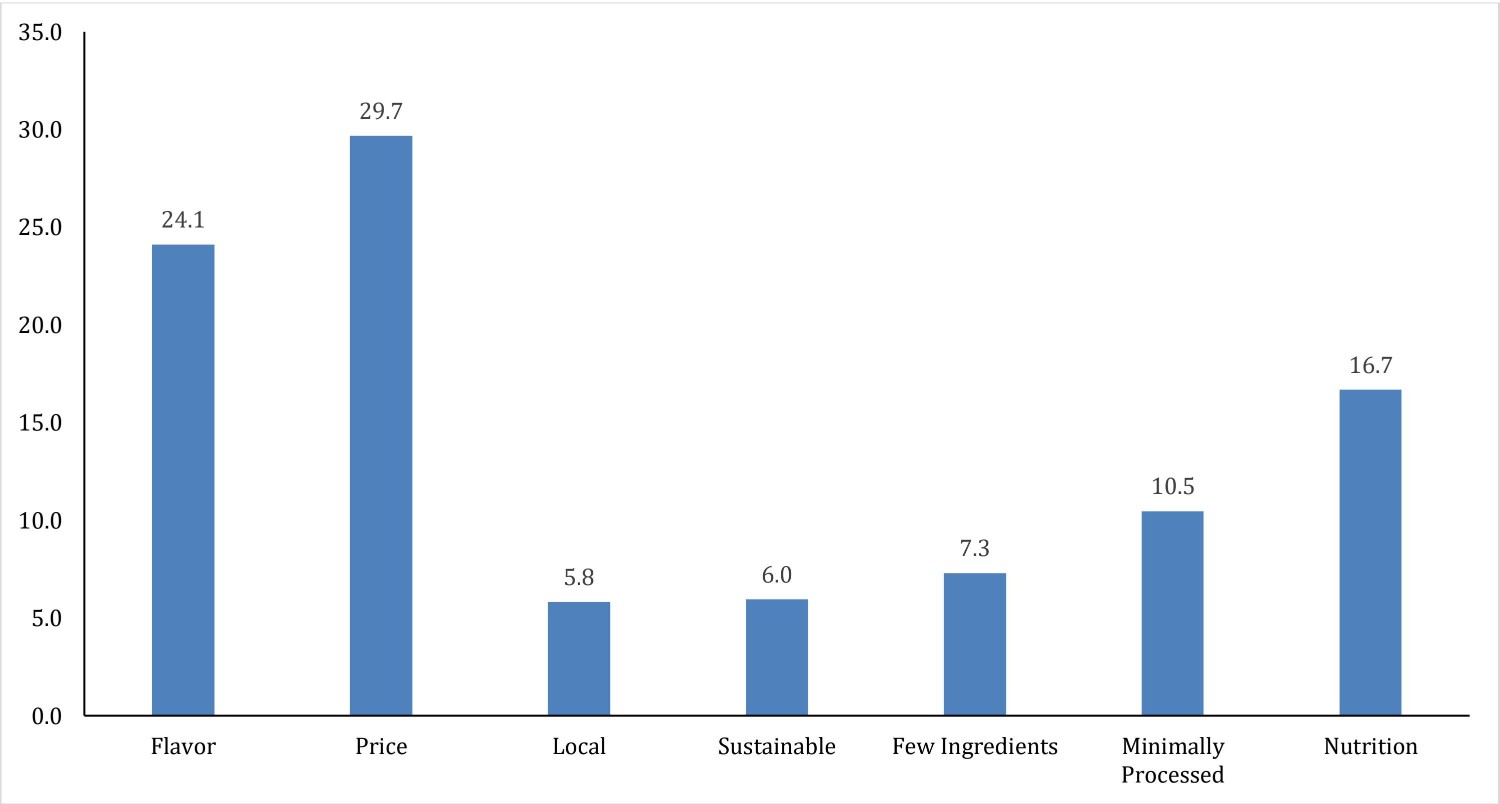

Figure 3.9. Chip allocation on the importance of each factor when purchasing all food products (n=437). Consumers were asked to allocate chips to each factor based on importance. The points allocated add to 100. Consumers were asked to assign 0 if something was not important.

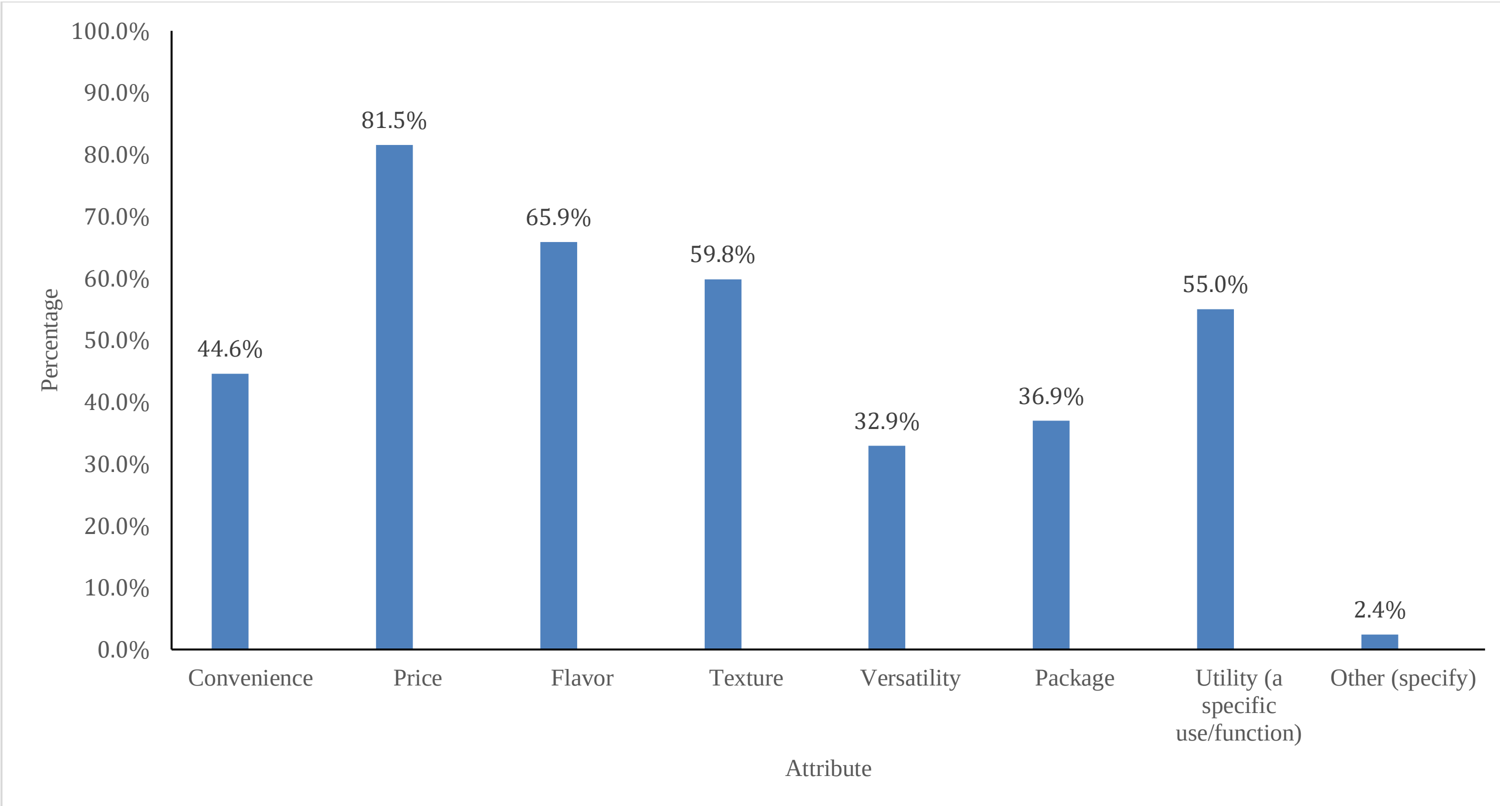

Figure 3.10. Bar chart of check all that apply (CATA) motivations to purchase block mozzarella for current block users (n=249).

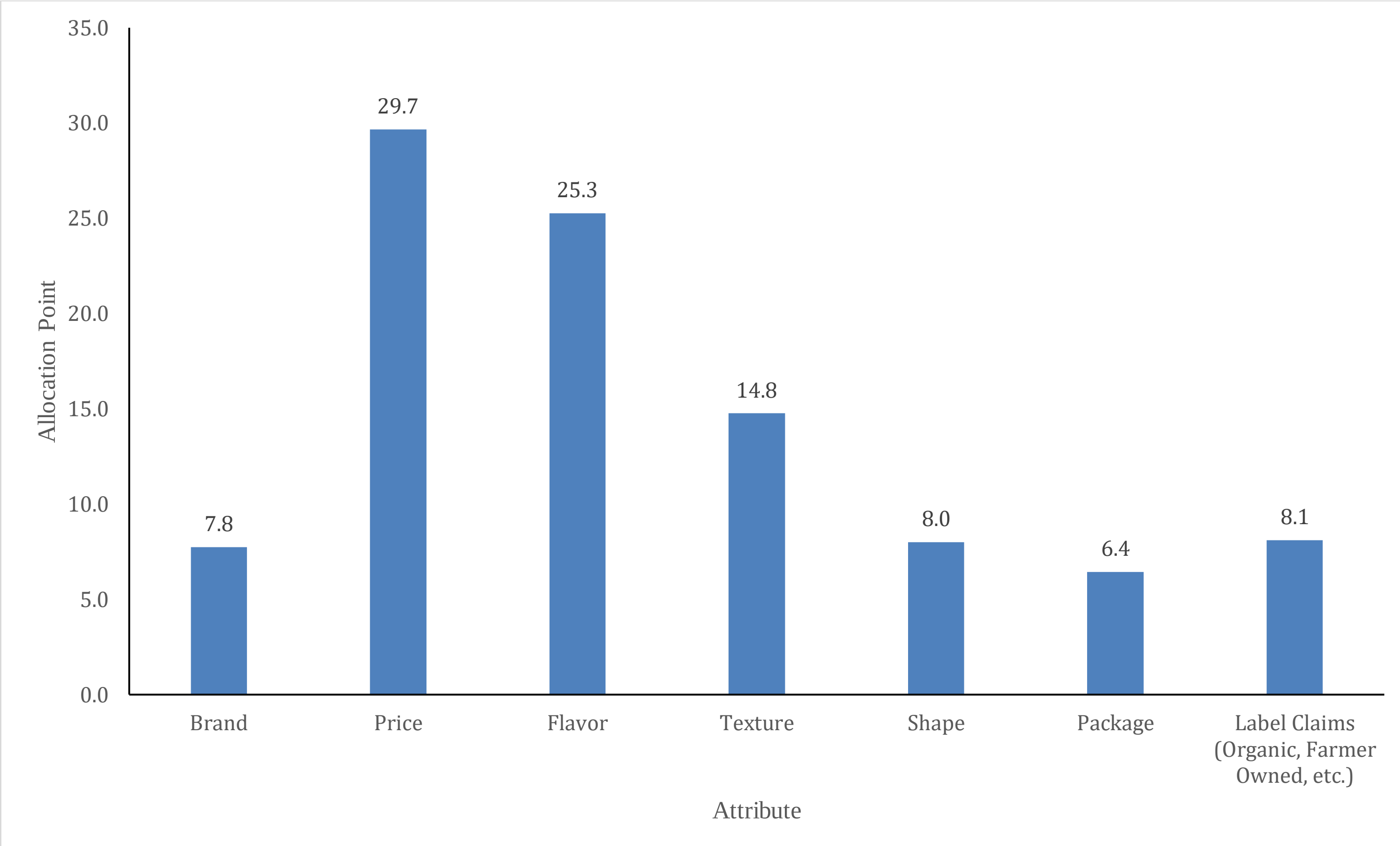

Figure 3.11. Chip allocation on the importance of each factor when purchasing block mozzarella for current block users (n=249). Consumers were asked to allocate chips to each factor based on importance. The points allocated add to 100. Consumers were asked to assign 0 if something was not important.

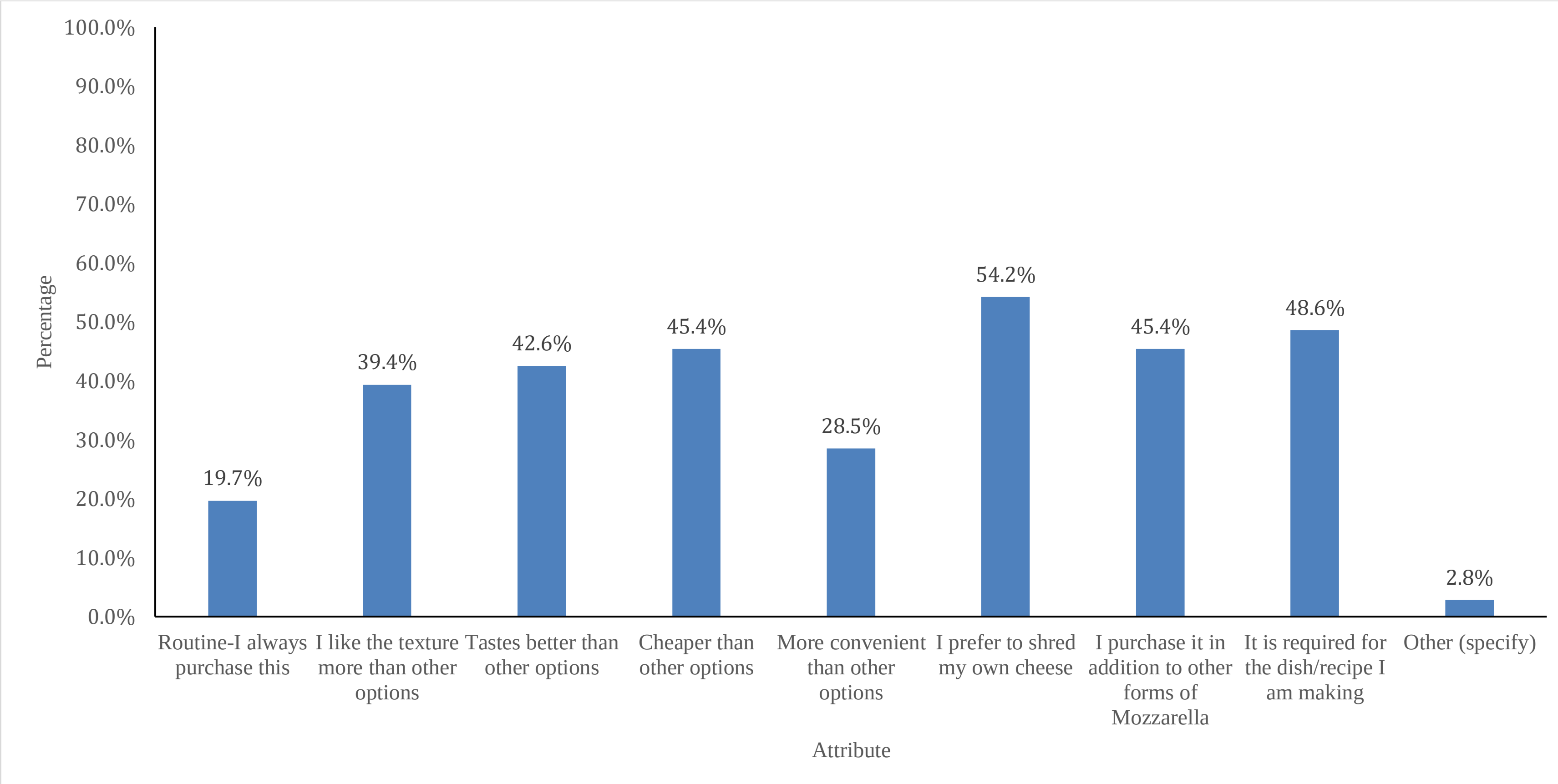

Figure 3.12. Bar chart of check all that apply (CATA) motivations to purchase block mozzarella instead of other forms of mozzarella for current block mozzarella users (n=249).

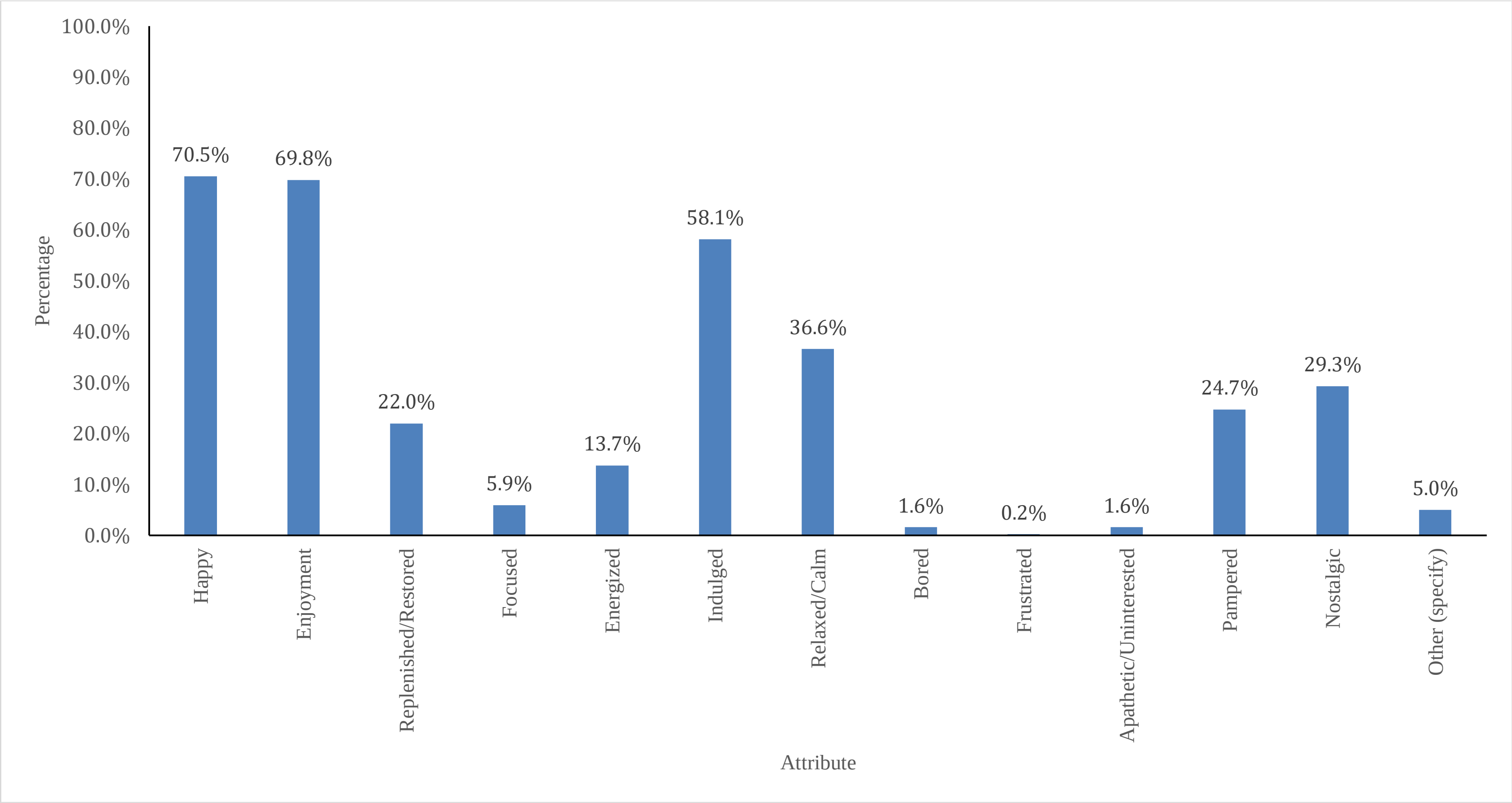

Figure 3.13. Check all that apply (CATA) on emotions/feelings associated with consuming mozzarella alone or with other foods (n=437).

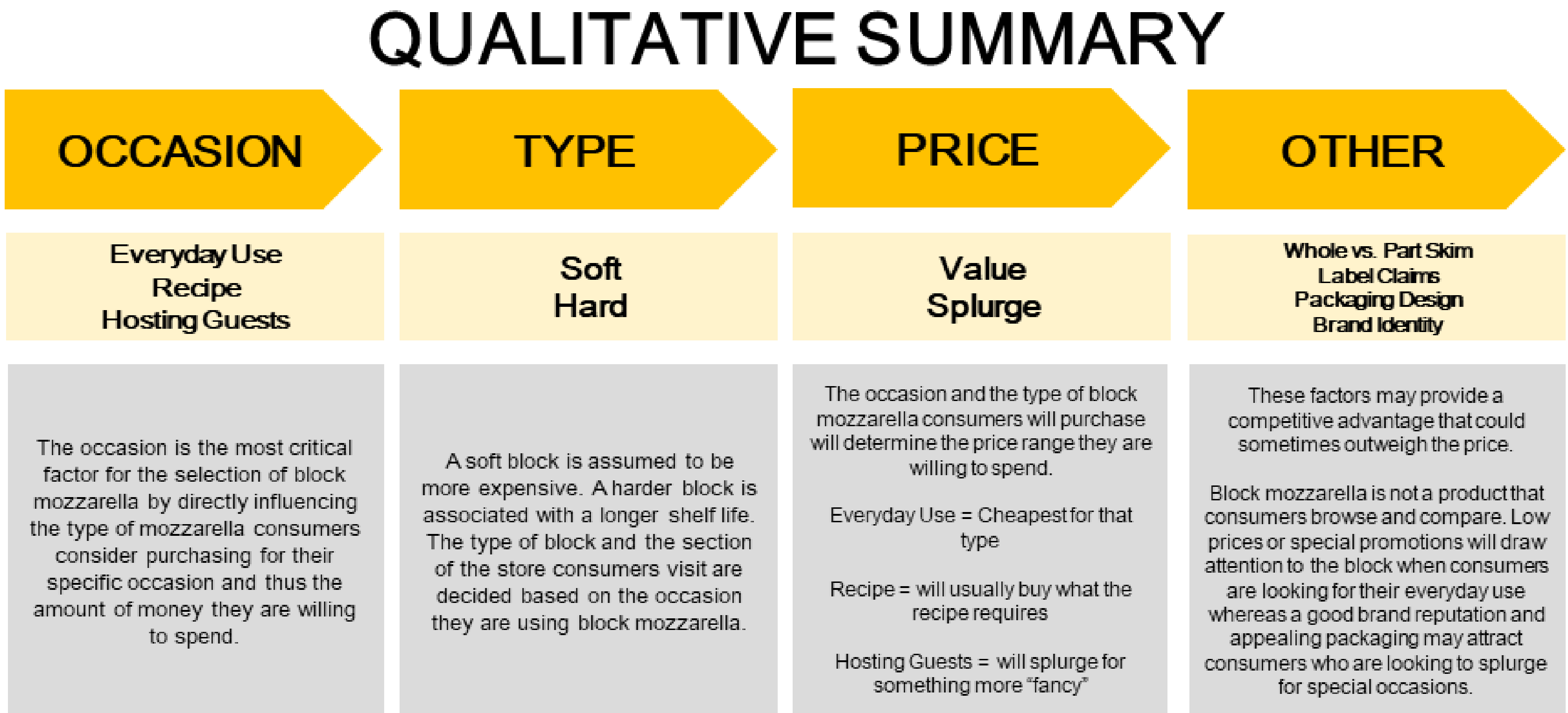

Figure 3.14. Qualitative themes summary from focus group.

APPENDIX

Table 3.4 Attributes and levels used in the adaptive choice-based conjoint (ACBC).

Milk Fat	**Texture Quality**	**Shape**	**Package Feature**	**Label Claim**
Whole milk	Melts and stretches		Easy to open/peel	Established business for more than 75 years
Part skim	Firmer texture/shreds well		Resealable	Premium
Fat free	Softer texture/sliceable		None	Organic
				No aded hormones/rBST free
				Farmer owned
				None

BLOCK MOZZARELLA MODERATOR GUIDE

I. MOZZARELLA USAGE OCCASIONS/BLOCK MOZZARELLA IDENTIFICATION

- Please write down occasions when you would think of putting mozzarella on your grocery list.
- What do you expect from mozzarella cheese?
- How does mozzarella cheese make you feel?
- Can you list off different types of mozzarella you can recall?
- What shape should each of them be?
- What do you use the block mozzarella for?
- Do you use block mozzarella for multiple occasions?
- Which section of the grocery store do you visit to find the block mozzarella that you typically purchase?

II. BLOCK MOZZARELLA SORTING

- Imagine you are at the store you typically shop at, and you need a block of mozzarella. If these are the products that are available at the store, what are you going to buy? Order them from most likely to purchase to least likely to purchase.
- Describe to me your order.
- Why are you most likely to buy the first one?
- Why are you least likely to buy the last one?
- Was it difficult for you to sort these?
- Did you make assumptions about how these would taste or function?
- Do you compare block mozzarella like this when you are shopping?
- Tell me what you look for when you are at the store.
- Is there something missing on the label or in the appearance or feel of the cheese that you would have liked to see?

III. LABEL

- What are some of the labels that you like to see?
- Which ones do no not like?
- Are there any other label claims that you would like to see?

IV. BLOCK MOZZARELLA TASTING

- Now we are going to taste some of the mozzarella that you just ranked earlier.
- What do you think about these mozzarella?
- Thinking back to when you sorted these earlier, will your order change now that you have tried all of these?
- Do you think these are different types of mozzarella or are they the same? Would they be for the same usage occasions?

V. MISCELLANEOUS

- Have you heard of the term pasta filata? What do you think it means?
- Have you heard of the term stirred curd style?
- Is block mozzarella healthy? Does it need to be healthy?
- What ingredients do you expect in a block mozzarella?

Figure 3.15. Focus group moderator guide for block mozzarella.

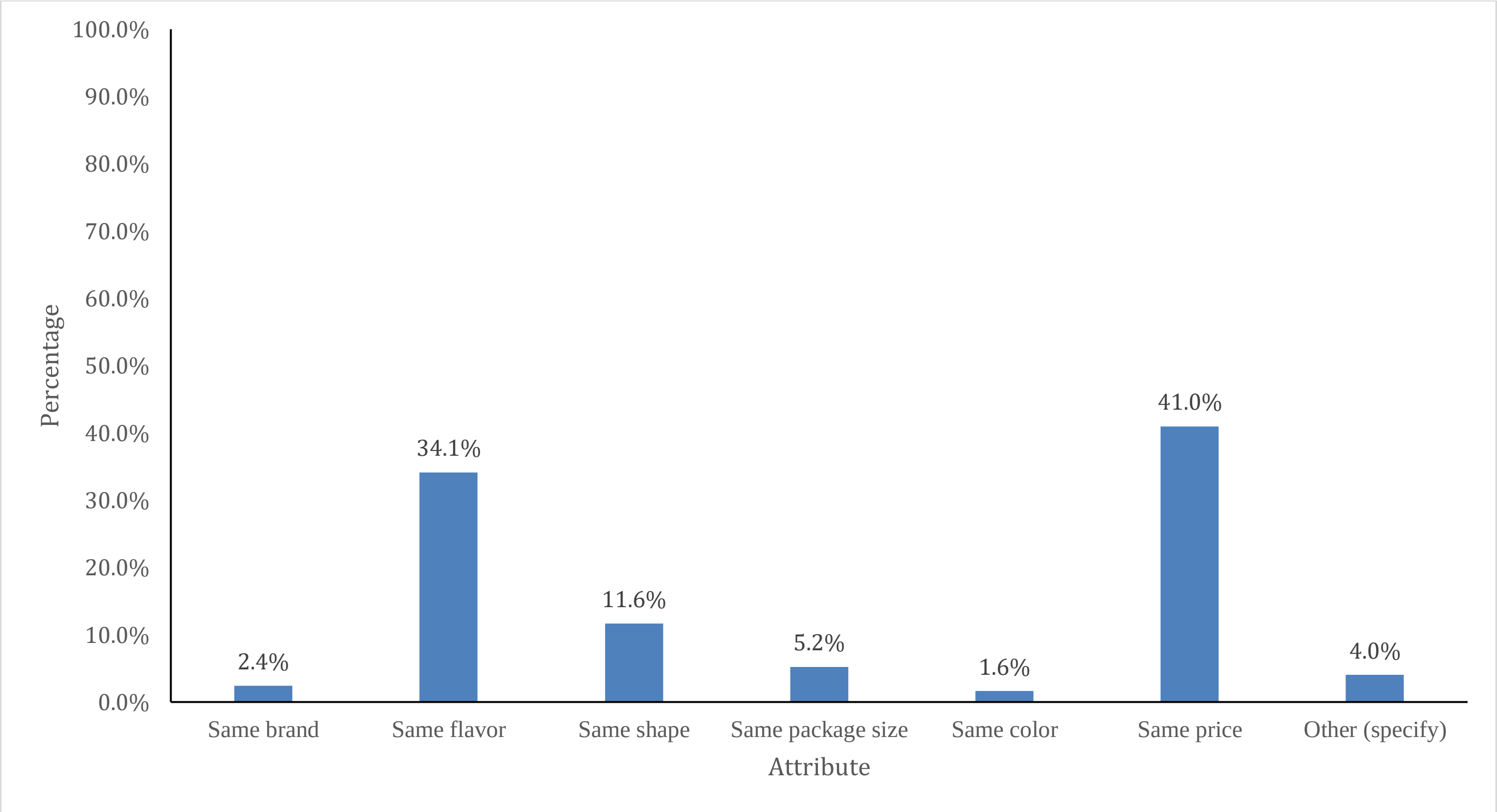

Figure 3.16. Bar chart of percentages when asking block mozzarella users to select the most important factor when choosing an alternative block mozzarella (n=249).

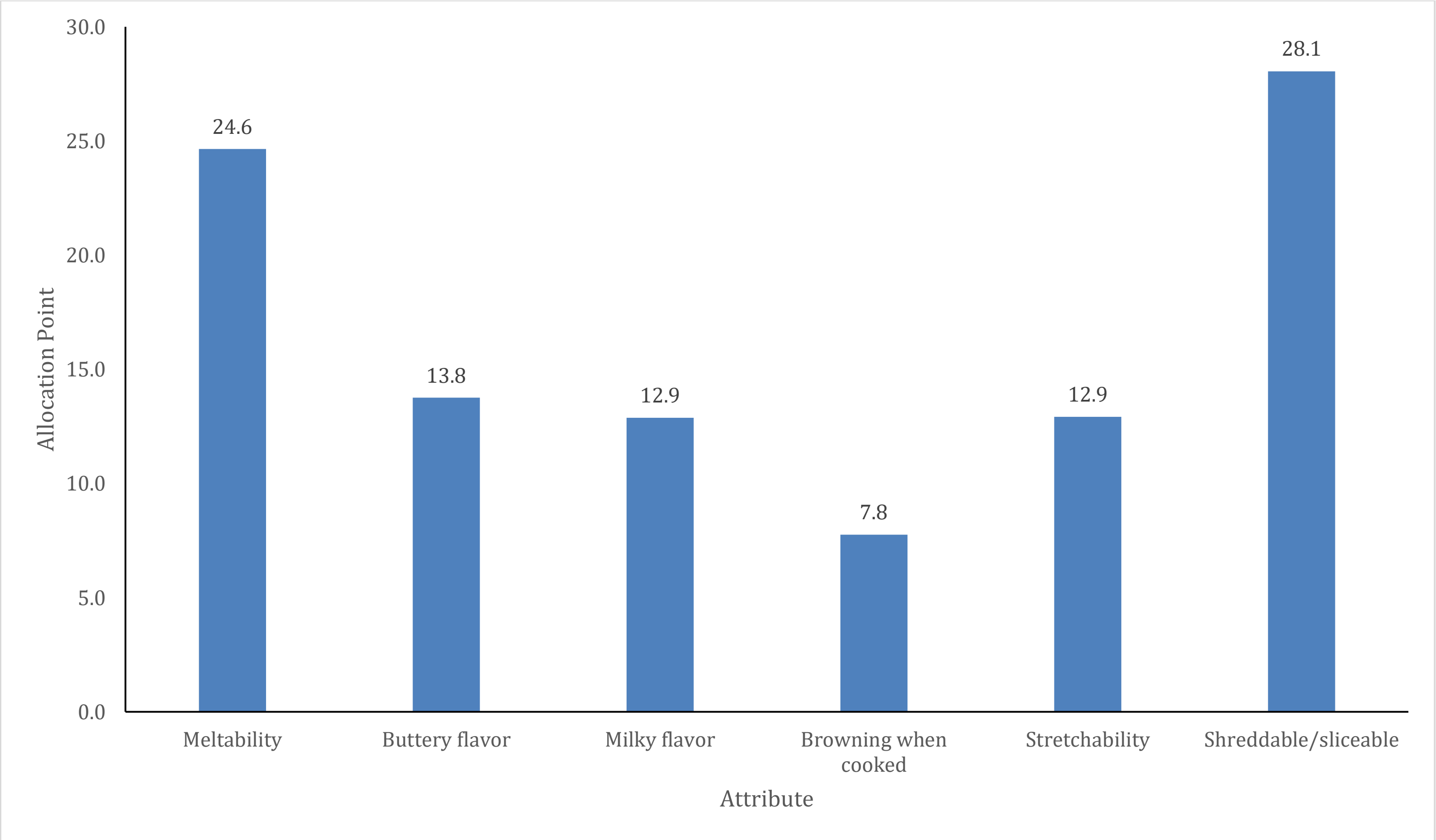

Figure 3.17. Bar chart of chip allocation for the importance of each attribute when consuming block mozzarella for current block users (n=249). Consumers were asked to allocate chips to each attribute based on importance. The points allocated add to 100. Consumers were asked to assign 0 if something was not at all important.

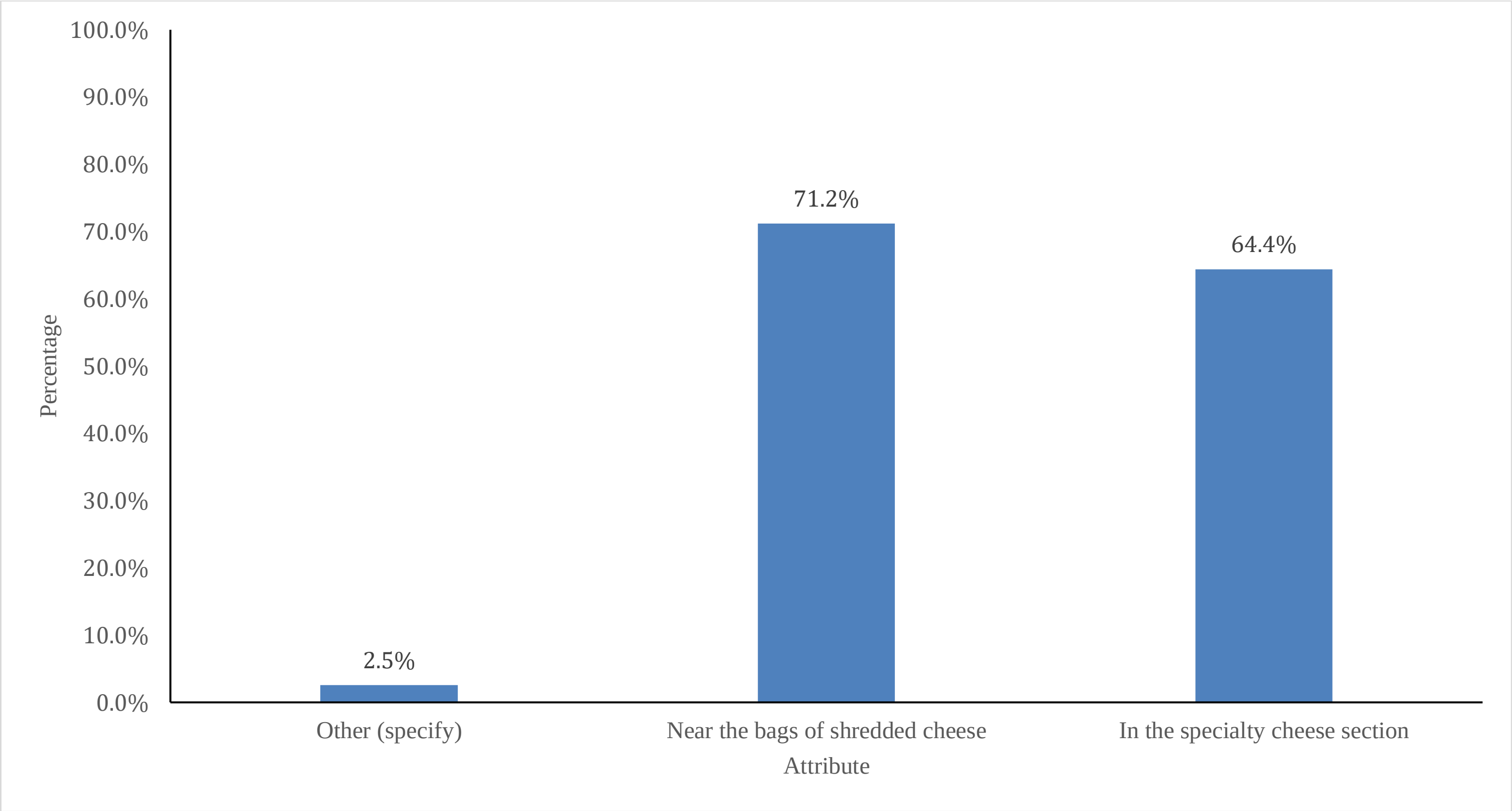

Figure 3.18. Bar chart on the section of the store were consumers shop for block mozzarella (n=249) (check all that apply, CATA).

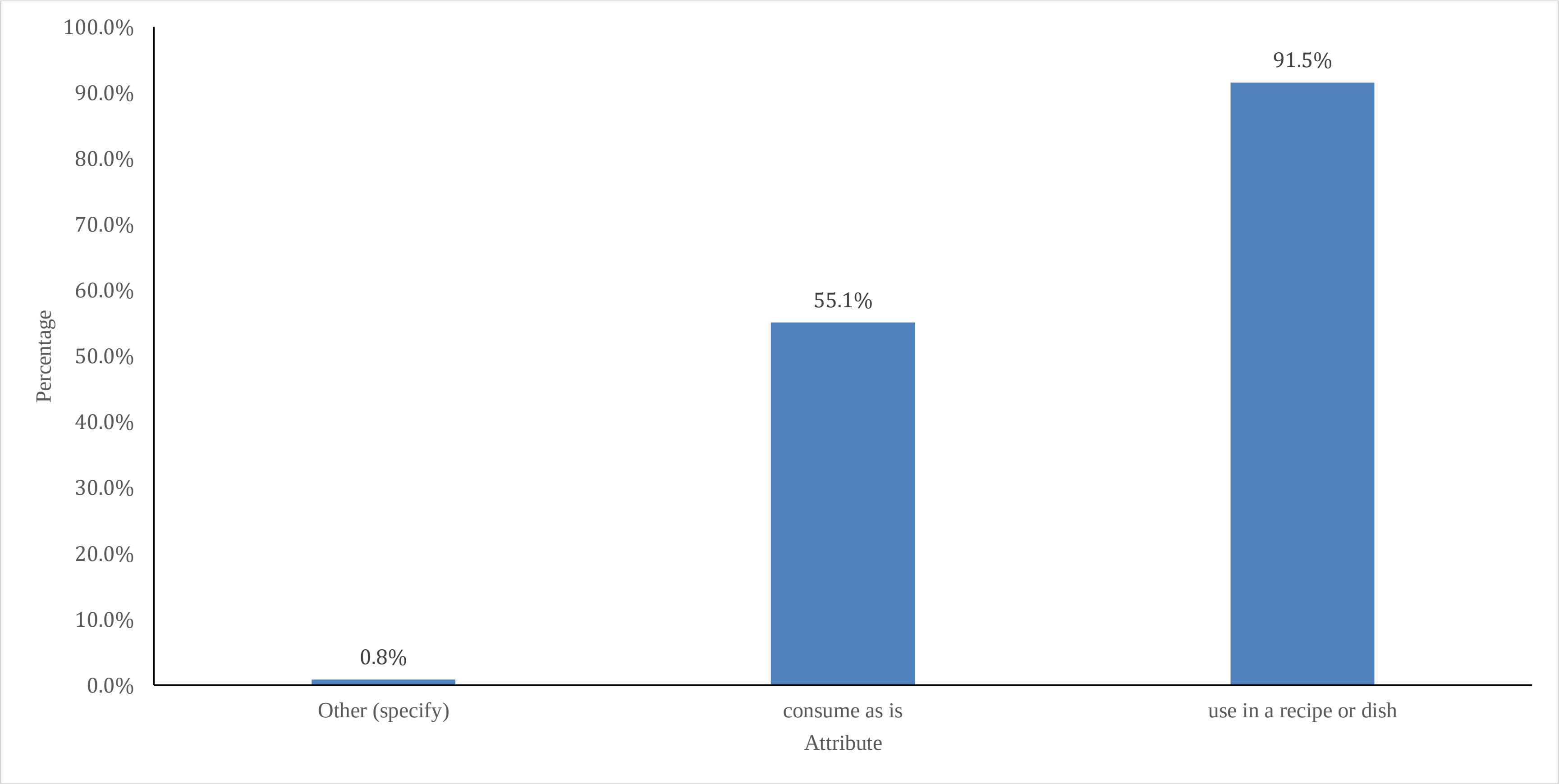

Figure 3.19. Bar chart of check all that apply (CATA) of typical ways current block consumers use block mozzarella (n=249).

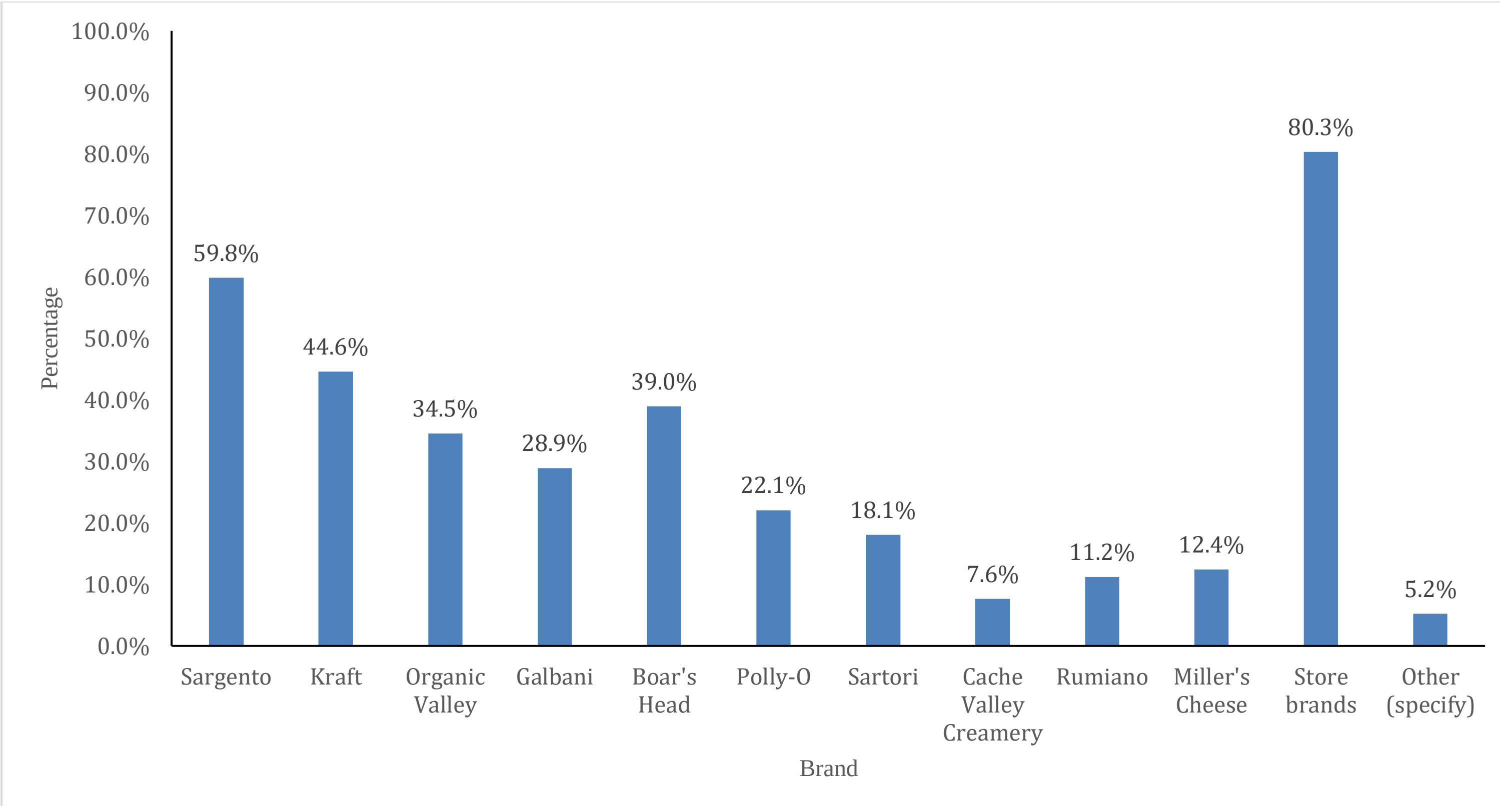

Figure 3.20. Bar chart of check all that apply (CATA) for brands that block mozzarella consumers typically purchased (n=249).

Table 3.5. Kano modeling classification of block mozzarella functionality for the natural cluster (n=249). Attractive indicates that the attribute is not expected by consumers but are satisfied if this attribute is present. Indifferent indicates that consumers do not care about the attribute. Must be indicates that the attribute is essential. Performance indicates that when present, consumer liking increases. Questionable indicates conflicting responses from consumers. Reverse indicates decreased consumer liking when present.

	Attractive	Indifferent	Must Be	Performance	Questionable	Reverse
A Mozzarella that has a mild milky flavor	12.0%	43.4%	20.1%	9.6%	10.4%	4.4%
A Mozzarella that has a buttery creamy flavor	26.5%	27.3%	15.7%	21.7%	6.0%	2.8%
A Mozzarella that has a firm texture	19.3%	49.0%	8.0%	6.8%	13.3%	3.6%
A Mozzarella that has a soft texture	20.1%	38.6%	16.1%	13.3%	10.0%	2.0%
A Mozzarella that is easy to shred and slice	15.3%	14.1%	26.9%	41.8%	2.0%	0.0%
A Mozzarella that melts	8.0%	14.5%	38.6%	37.3%	0.8%	0.8%
A Mozzarella that stretches	15.3%	35.7%	22.1%	21.7%	4.4%	0.8%
A Mozzarella that browns when cooked	11.6%	49.4%	10.4%	7.2%	6.8%	14.5%
A Mozzarella that is salty	12.4%	41.0%	11.6%	4.0%	11.2%	19.7%
A Mozzarella that is white in appearance	14.9%	41.4%	21.7%	16.1%	5.6%	0.4%
A Mozzarella that is pale yellow in appearance	2.8%	51.8%	4.4%	0.8%	8.8%	31.3%

Table 3.6. Kano modeling classification of block mozzarella functionality for the flavor cluster (n=188). Attractive indicates that the attribute is not expected by consumers but are satisfied if this attribute is present. Indifferent indicates that consumers do not care about the attribute. Must be indicates that the attribute is essential. Performance indicates that when present, consumer liking increases. Questionable indicates conflicting responses from consumers. Reverse indicates decreased consumer liking when present.

	Attractive	Indifferent	Must Be	Performance	Questionable	Reverse
A Mozzarella that has a mild milky flavor	16.0%	47.9%	16.0%	7.4%	5.9%	6.9%
A Mozzarella that has a buttery creamy flavor	22.9%	38.3%	14.9%	18.1%	3.7%	2.1%
A Mozzarella that has a firm texture	23.4%	38.8%	9.6%	7.4%	10.6%	10.1%
A Mozzarella that has a soft texture	25.5%	35.1%	17.6%	10.1%	9.0%	2.7%
A Mozzarella that is easy to shred and slice	22.3%	15.4%	24.5%	30.9%	4.8%	2.1%
A Mozzarella that melts	9.6%	15.4%	36.2%	34.6%	3.2%	1.1%
A Mozzarella that stretches	20.2%	33.5%	23.4%	17.0%	3.2%	2.7%
A Mozzarella that browns when cooked	8.0%	48.9%	16.5%	10.1%	3.7%	12.8%
A Mozzarella that is salty	9.6%	39.9%	15.4%	10.1%	9.0%	16.0%
A Mozzarella that is white in appearance	16.5%	44.7%	18.6%	16.5%	3.7%	0.0%
A Mozzarella that is pale yellow in appearance	5.3%	58.0%	1.1%	1.1%	10.6%	23.9%

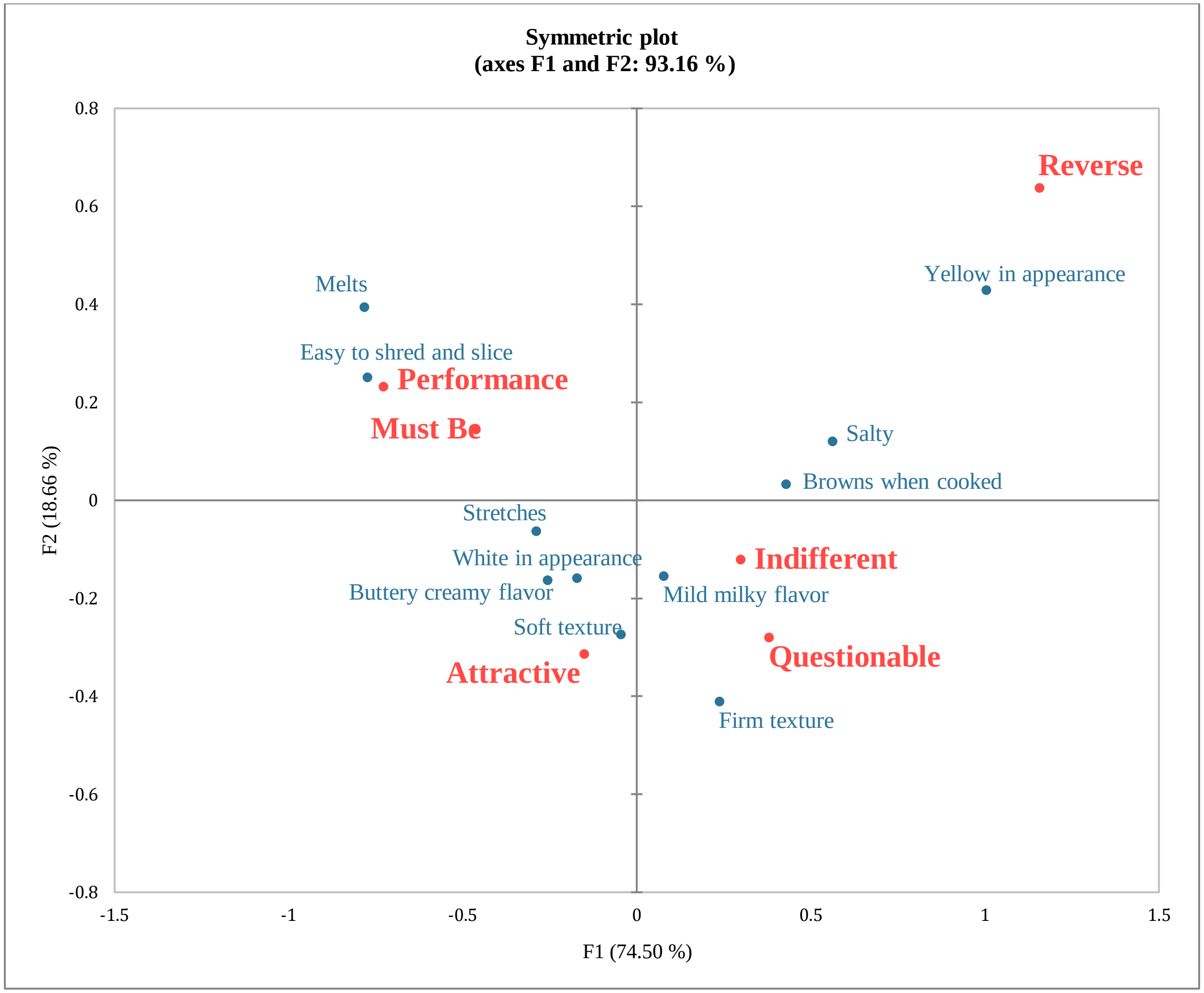

Figure 3.21. Correspondence analysis biplot of Kano modeling classification of block mozzarella functionality for the natural cluster (n=249).

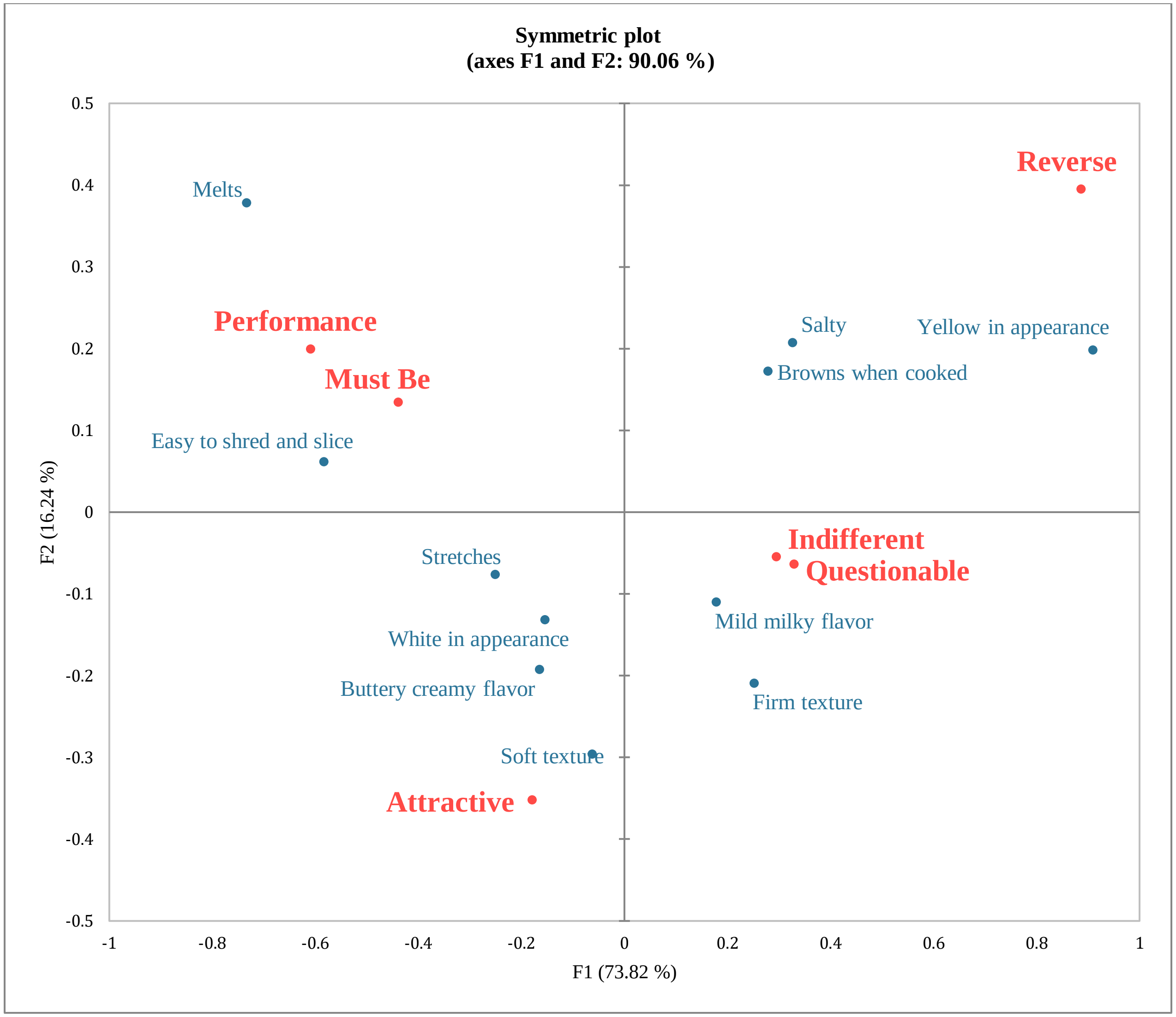

Figure 3.22. Correspondence analysis biplot of Kano modeling classification of block mozzarella functionality for the flavor cluster (n=188).