ABSTRACT

MEALS, STEPHANIE ELAINE. Drivers of Liking of Cheddar Cheese Shreds and Consumer Perception of Anticake Agents on Cheddar Cheese Shreds. (Under the direction of Dr. MaryAnne Drake).

The pre-packaged cheese shred category has steadily increased over the past few years and Cheddar shreds represent the highest volume within this category. Recent studies have established extrinsic attributes that drive purchase of this category, but no published studies have addressed the intrinsic flavor and texture properties that drive consumer liking.

In the first study, consumer drivers of liking for Cheddar cheese shreds were investigated. The objective of this study was to determine the desirable flavor and functional attributes for Cheddar cheese shreds. Sensory properties (shred appearance, flavor, texture and hot texture) of 25 Cheddar cheese shreds were documented using a trained sensory panel. Analytical instrumental tests performed included shred size distribution, proximate analysis, sugars (lactose, glucose, galactose), lactic acid, Cheddar meltability, pH, and color. Representative shreds (n=10) were subsequently evaluated by cheese shred consumers (n=151) in a central location test (CLT). Analysis of variance, principle component analysis, and external preference mapping were used to interpret results. Shreds were differentiated by color, whey, diacetyl, sulfur, nutty, and brothy flavors as well as hot and cold texture attributes and instrumental tests ($p<0.05$). Three consumer clusters were identified and were defined by high acceptance for all Cheddar shreds or preferences for either sharp or mild shreds. Bitterness was an overall driver of dislike. Visible powder negatively impacted appearance and overall liking for some consumers.

In the second study, consumer perception of the addition of anticake agents on shredded Cheddar cheese was evaluated. Three common anticake agents (potato/cellulose blend, potato, and potato/ corn/ calcium sulfate) were applied to duplicate lots of Cheddar cheese shreds at 1, 2, 3, 4, and 5 % (w/w). Control Cheddar cheese shreds with no anticake were included. Sensory properties (appearance, flavor, texture, and hot texture) were documented using a trained sensory panel. Three consumer acceptance tests were conducted. In test one, Consumers (n=110) evaluated liking of cold shred appearance. In test two, consumers (n=100) evaluated melted shreds on a flour tortilla for overall, appearance, flavor and texture liking. Finally, consumers (n=49) participated in a home usage test (HUT). Two-way analysis of variance (anticake x anticake application rate) was used to interpret the collected data. Visual appearance of shreds was the primary attribute impacted by anticake application rate and anticake agent ($p<0.05$). Results from trained panelists demonstrated that the potato anticake agent had minimal effects on visual appearance. The other two agents (80/20 potato/cellulose and potato/corn/ calcium sulfate) resulted in increased visible powder on shreds at > 3% (w/w). Consistent with trained panelists, higher anticake application rates decreased consumer appearance and color liking for shreds with 80/20 potato/cellulose and potato/corn/ calcium sulfate blends at > 2 or 3% (w/w), respectively. Consumer appearance liking of melted shreds decreased with increased anticake application rate but decreased the most for potato anticake at greater than 1% (w/w) application. Overall liking, flavor, and texture liking attributes for shreds were negatively impacted in melted cheese consumer liking at >3% (w/w) application but were not specific to anticake agent. These results demonstrate that anticake agents can be applied to Cheddar cheese shreds at up to 3% (w/w) with minimal impact on consumer perception.

Sensory properties strongly impact consumer acceptance and purchase intent of Cheddar cheese shreds with the largest sensory impact being the appearance of the shreds prior to use or consumption. Insights from this study can be utilized to optimize intrinsic sensory properties of Cheddar cheese shreds.

Drivers of Liking of Cheddar Cheese Shreds and Consumer Perception of Anticake Agents on Cheddar Cheese Shreds

by

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BIOGRAPHY

Stephanie Elaine Meals was born on March 14, 1993 to Mercedes and Stephen Meals. Stephanie grew up in Coppell, Texas and attended Ursuline Academy of Dallas for high school. Upon graduating high school, Stephanie attended Texas A&M University and graduated cum laude in 2014 with a B.S. in Food Science and Technology. In March of 2015, Stephanie began working at International Flavors and Fragrances in Carrollton, Texas as a Sensory Evaluator. She worked there until July 2016 when she was accepted into graduate school at North Carolina State University. In September 2016, Stephanie began pursing a M.S. degree in Food Science under the direction of Dr. MaryAnne Drake. Away from school, Stephanie enjoys crafting, painting, trying out different local breweries and spending time with her friends and childhood dog, Avery.

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INTRODUCTION

Cheese sales increased by 10% between 2012 and 2017, and total category sales are predicted to rise an additional 8%, reaching $25.5 billion of annual sales by 2022 (Mintel Group Ltd, 2017). In 2016, Cheddar cheese had the second highest consumption per capita in the US with roughly 4.7 kg consumed per year, slightly less than mozzarella at roughly 5.3 kg per year (National Agricultural Statistic Service, 2018). While flavor is an important factor for most foods, roughly eight in every ten cheese consumers cited purchasing cheese for the taste, significantly more often than the next most frequently cited drivers – easy snacking and food-pairing versatility (Mintel Group Ltd, 2017). Cheese is available in a variety of prepackaged forms, driven by consumer desire for versatility and convenient healthy snacking.

Several studies have addressed consumer preferences for Cheddar cheese including flavor and texture (Young et al., 2004; Caspia et al., 2006; Drake et al., 2008, 2009). However, few studies have specifically focused on consumer preferences for pre-packaged Cheddar cheese shreds. Understanding consumer liking for pre-packaged Cheddar cheese is essential for continued growth in this category. Recent research indicated that price, flavor, color and performance/meltability were primary drivers of purchase for Cheddar cheese shreds (Speight et al., 2019). This study addressed extrinsic Cheddar shred attributes. Actual consumer perception of cheese shred appearance, flavor, and texture is also critical information to establish preferred intrinsic properties. To our knowledge, previous studies have not examined consumers drivers of liking for Cheddar cheese shreds using a central location test (CLT).

Cheddar Manufacture

Cheddar manufacturing ultimately is a dehydration process via rennet coagulation of milk to concentrate fat and casein by roughly 6 to 12 fold (Singh et al., 2003). The process can be broken down into two distinct phases: conversion of milk to curd and ripening of the curd. The milk conversion phase consists of the majority of the Cheddar manufacturing steps including milk preparation, milk ripening, setting and curd cutting, curd cooking, cheddaring, milling, salting, molding. Although raw milk can be used to create Cheddar cheese, pasteurized milk is more common. Raw milk Cheddars develop characteristic Cheddar flavors much faster than pasteurized milk Cheddars (Fox, 1993). However, they must be aged for more than 60 days to be safe for human consumption (Price and Call, 1969, Partridge, 2009).

After pasteurization of milk, the next step, milk ripening, a starter culture, typically *Lactococcus lactis* ssp *cremoris* and ssp *lactis*, is added which acidifies the milk (Singh et al. 2003); although other cultures can be added to diversify flavor characteristics or accelerate ripening. At this point annatto can be added if a yellow or orange Cheddar cheese is desired. After 30-60 minutes of ripening, the milk is set using a protease: rennet. Rennet coagulation is a two-step process that, simply put, is the hydrolysis and coagulation of casein. The chymosin in rennet cleaves casein on the surface of the micelle resulting in the release of the hydrophilic peptides. Therefore, the casein micelles become unstable, and the milk coagulates at 30 ˚C (Singh et al., 2003). Setting typically takes 25-35 minutes to produce a milk gel, which is then cut into individual curds. Cutting the milk gel causes rapid syneresis and whey expulsion (Fox, 1993).

The curds are then heated with gentle agitation to continue to expel whey and begin to develop a more cohesive body and texture. The curds are heated to 37.8-40.0˚C, which is called scalding or cooking. After the curd has been cooked and whey has been drained, the curd is put through the cheddaring process, which involves cutting the curd into blocks, which are then stacked and flipped every 15-20 minutes. During this period, lactic acid bacteria continue to ferment lactose into lactic acid, while the weight of the stacked curds continues to press whey out of the curds. Occasionally the stack is rotated or flipped to allow for even moisture regulation and distribution throughout the curds. The cheddaring process also develops characteristic texture. Once the curd blocks have achieved the appropriate texture and acidity, they are cut into smaller pieces (milling), roughly 0.75” x 0.75” x 3” (Partridge, 2009). Salt is the last ingredient added to cheese prior to molding. Salting arrests acid development and aids in moisture control and flavor. After salting, the cheese is molded and pressed to achieve characteristic texture. Once molded, the cheese is coated or packaged to provide an oxygen and moisture barrier. The cheese is aged at 8˚C to further develop characteristic Cheddar flavors. There is no legal definition of “age” or “sharp”, so aging time and Cheddar flavor varies greatly among manufacturers. Typically for traditional manufacturing, mild Cheddars age for 2-3 months, medium for 4-7 months, sharp for 8-12 months, and extra sharp for over a year (Clark et al., 2009).

CHEESE COMPOSITION

The majority of Cheddar cheese flavor development occurs during aging or ripening and is directly impacted by the composition of the cheese (Walstra et al., 1999; Singh et al., 2003). In regards to prepackaged shredded Cheddar cheese, the FDA requires that the products must meet the same definitions and standards of identity for block Cheddar cheese. Cheddar cheese, in the United States, is legally required to contain a minimum of 50% milkfat by weight of solids, a maximum moisture content of 39%, a pH not exceeding 5.35, and be cured for at least 10 days if it is made from pasteurized milk (FDA, 1993; USDA, 2001). The flavor, texture, and functionality of a cheese stem from milk components and their degradation. Ideal cheese manufacture depends on the ratios of lactose, calcium, fats, and proteins before and during ripening. Additionally, the pH, water content, and salt of cheese throughout the manufacture process directly impact the development of flavor and texture. Through glycolysis, lipolysis, and proteolysis under particular environments and physical parameters, milk components degrade and contribute to the majority of cheese flavors and textures.

Acid

Acidification is one of the first steps in the manufacture of Cheddar cheese and almost all other cheeses. Acidity is a result of lactose fermentation by lactic acid producing bacteria which have either been added or are indigenous to the milk or enviroment in traditional cheese making (Fox et al., 2004). Acidification impacts every aspect of cheese during manufacture and directly impacts the composition, texture, and flavor. In Cheddar cheese, most acid is produced before molding and hooping, while other acidification occurs after molding. For Cheddar, typical pH is between 5.2 and 5.3 to inhibit the growth of undesirable organisms (Walstra et al., 1999; Fox et al., 2004). At a higher pH, the growth of harmful organisms, such as coliforms, becomes a quality and health risk. Additionally a high pH causes the protein-to-protein interactions to decrease resulting in a softer cheese (Pastorino et al., 2003). Conversely, a reduced pH increases the content of soluble calcium and slightly decreases the total calcium content of cheese causing a contraction of the protein matrix experience. This results in textural and functional effects such as reduced cheese hardness and cohesiveness and increased crumbliness and potentially lower water content due to increased syneresis.

Moisture

Throughout the Cheddar manufacturing process, water content plays a key role to the texture and flavor of Cheddar. Once the milk has been coagulated by rennet into a milk gel, the mass is cut into curds to expel water and whey through rapid syneresis. External factors like stirring, heat, and time, as well as milk composition, particularly calcium, protein, and acid, influence the rate and extent of syneresis. The cheddaring process reduces water content in two main ways: physically pressing out the water and allowing time for acid increase from lactose fermentation which in turn increases syneresis. This Cheddar manufacturing process aims to have a product with a final moisture content of 39% and a water activity of 0.95 (US Code of Federal Regulations, 2000). The unique characteristics of cheeses develop during ripening, but most importantly during the manufacturing when the composition of the cheeses is controlled. Generally, ripening time is inversely related to the moisture content of the cheese. Increasing moisture content decreases protein crosslinking in the curd, thus weakening the body and increasing likelihood of undesirable bacteria and off flavors (Singh, 2003). Moisture content of a final product is typically measured gravimetrically by drying the cheese sample (AOAC 926.08) This method is applicable to most solid foods and consists of dehydrating a sample in a vacuum oven (100˚C). The sample is weighed before and after drying, and the moisture content is reported as the percentage of mass lost during dehydration.

Fat

Fat also plays a vital role Cheddar texture and flavor, especially for aged Cheddar cheeses. For texture, the protein to fat ratio affects texture, particularly firmness. The ideal protein to fat ratio for Cheddar cheese is between 0.67 and 0.72 (Fox et al., 2004). The more fat present in cheese milk, the more difficult it is to remove the proper amount of moisture because fat interferes directly with the syneresis processes (Fox et al., 2004). Higher fat content in cheeses leads to a less firm and more elastic body, while low-fat products tend to be harder, more crumbly, and less smooth that standard full fat Cheddar cheese (Emmons et al., 1980; Kheadr et al., 2002; Rogers et al., 2009). Fat is also an important factor for Cheddar cheese flavor development. Fat dissolves and holds flavor compounds (Foda et al., 1974; Marilley and Casey, 2004). Cheddar cheese without fat, even after aging, does not develop full aroma or flavor (Milo and Reineccius, 1997; Drake et al., 2010), but substitution of removed milkfat with other non-dairy fats aided aroma development in Cheddar (Ohren and Tuckey, 1969; Foda et al., 1974; Fox et al., 2004). This indicates that fat is necessary to dissolve and hold the flavor components. Fat is also important for melting functionality and breakdown in the mouth. As fat in Cheddar cheeses decreases, hardness and cohesiveness increase, while springiness and adhesiveness decrease (Bryant et al., 1995; Rogers et al., 2009). Standard Cheddar cheese is required to contain 50% milkfat by weight of the solids, which can be determined using multiple methods including Gerber, Babcock, and Mojonnier (Wehr and Frank, 2004). Gerber and Babcock methods involve digesting proteins and carbohydrates and releasing fat. After centrifugation, the fat is separated into a graduated portion of the test bottle to be measured volumetrically (Nielsen, 2010). The Mojonnier method, on the other hand, uses organic solvents to extract, separate, and dry the fat, which is then expressed by percentage of weight (Nielsen, 2010). Although these methods differ, all are official AOAC methods to determine fat content.

Protein

Milk protein is a predominant driver of structure and flavor development during cheese manufacture. Casein accounts for about 80% of the protein in milk. The individual casein proteins exist as large colloidal clusters known as micelles which are stabilized by both electrostatic and steric repulsion. κ-casein forms the outer layer of the micelle and is critical to the stability, however during cheese manufacture, an acid protease (rennet) cleaves a portion of the κ-casein forming para-casein and casein-glycomacropeptide (CGMP). The CGMP disperses into the whey while the casein micelles, now destabilized, are free to aggregate through Ca^{2+} bridging and hydrophobic protein-protein interactions, resulting in coagulation and syneresis.

During this process, casein continues to breakdown to form flavor active compounds and precursors to flavor active compounds that are crucial flavor characteristics of Cheddar cheese. Through a cascade of proteolysis of α-caseins by chymosin, proteinases, and cell envelope-associated proteinases (CEP) from starter and non-starter bacterial enzymes, young Cheddar cheese curds transform from a rubbery texture to a smooth and homogeneous product. The byproducts of the cleaved proteins such as valine, leucine, isoleucine, phenylalanine, tyrosine, tryptophan, and methionine, are known precursors of Cheddar flavors including sulfur and malty/nutty flavors, as well as some off flavors like boiled potato, almond, and mothball (Singh et al., 2003). The final protein content of Cheddar cheese is usually 25.5% (Fox et al., 2000). For all dairy foods, the Kjeldahl principle has been used as the standard method since 1883 (Wehr and Frank, 2004). Kjeldahl measures crude protein content in food through a series of digestions, neutralizations, and distillations. This process is the gold standard but can be time consuming and requires strong acids. Multiple other verified methods have emerged to measure protein that are equivalent with Kjeldahl, like the Sprint rapid protein analyzer and Fourier-transform infrared spectroscopy (FTIR). The Sprint rapid analyzer utilizes a dye-binding agent to tag proteins. A known amount of azo dye is added to bind with protein, and protein content is determined by measuring the amount of unbound dye in solution by measuring its absorbance at 480 nm (Moser and Herman, 2011). FTIR uses infrared spectroscopy to determine the absorption of radiation by the molecules in the food. The resulting signal at the detector is a spectrum representing the molecular components of the food. Proteins and peptides have characteristic bonds that can be used to estimate the protein content in a food. The peptide bonds consist of C=O, C-N, and N-H, and the vibrations of those bonds can be used to identify the unique structure of proteins (Singh, 1999).

Lactose

Throughout cheesemaking, the cheese curds lose roughly 98% of the total milk lactose to the whey leaving roughly 0.8 to 1.5% in the curds at the end of manufacture. Lactic acid is created by fermenting lactose by the mesophilic starter culture, and for Cheddar cheese, the majority of lactic acid is produced in the vat before molding. The starter culture is primarily responsible for the production of lactic acid. Acid production, in turn, has three main fuctions: promoting rennet activity, aids in whey expulsion from the curd, and helps prevent growth of undesirable microflora (Fox et al., 2000). The starter culture for Cheddar usually consists of a mixture of *Lactococcus lactis ssp lactis* and *Lactococcus lactis ssp cremoris* as they grow at the standard cooking temperature of Cheddar (38˚C) and are relatively salt tolerant (4% and 2% NaCl, respectively) (Fox et al., 2004). These homofermentative bacteria ferment lactose with lactic acid being the primary by-product. Heterofemative bacteria, such as *Lactobacillus brevis* and *Leuconostoc ssp*., produce ethanol and carbon dioxide in addition to lactic acid, which can adulterate cheeses during improper manufacturing. Defects resulting from heterofermentation are slits in hard cheeses or, in other dairy products, bloated packaging.

As the cheese continues to age, the remaining lactose is fermented into L-lactate by the lactic acid bacteria. Cheddar cheese also contains D-lactate which is formed by fermentation of residual lactose by lactic acid bacteria or by racemization of L-lactate (Fox et al., 1990). D-lactate concentrations have no significant impact on flavor, but may cause calcium crystallization in cheese, especially on cut surfaces, which will likely reduce consumer liking (Dybing et al., 1988). Lactose fermentation is also important as it metabolizes simple sugars like glucose and galactose. These sugars are of key importance for non-enzymatic browning when cheese is heated. Galactose, in particular, is more reactive in the browning reaction than glucose (Bley et al., 1985). As the cheese ages, bacterial enzymes convert more and more of the simple sugars into lactic acid causing aged cheeses to brown less than younger cheeses. These sugars can be quantified enzymatically or with the use of high pressure liquid chromatography (HPLC) (Wehr and Frank, 2004). However, using HPLC may be more advantageous as lactic acid, the main byproduct of lactose fermentation, can also be quantified using the same method (Zeppa et al., 2001).

Salt

Salt is important to cheese manufacture because it directly modifies flavor, promotes curd syneresis, regulates the moisture content and aw, influences the activity of lactic acid bacteria and enzymes, and suppresses growth of undesirable microorganisms. All of the mentioned effects impact unique flavor, texture, and aroma characteristics of a Cheddar cheese during ripening. Dry-salting, the process of adding dry salt to the broken or milled curds prior to pressing, was developed in the county of Cheshire in England (Fox et al., 2004). Dry-salting resolves the problem of blowing, undesirable openness in cheese, from unwanted bacteria growth that is common for traditional brine-salting; however, it does pose its own unique problems. When salt is added to the curds, the crystals dissolve in the moisture of curds to form a brine, causing the curds to shrink and expel whey (Fox et al., 2004). Because dry salting relies on the moisture and surface area of the curd to disperse, it is vital that the cheesemaker must monitor curd shape, moisture content, particle size, acidity, temperature, and salt distribution before and during dry salting to be able to minimize variations (Fox et al., 2004). During the salting procedure, it is important to let the salted curds rest or mellow prior to hooping to allow complete absorption on the curd surface and additional whey drainage. Without time to mellow, excessive whey would be trapped in the cheese resulting in excess moisture and uneven coloring (Fox et al., 2004).

The salt-in-moisture (S/M) value of the curds directly impacts the activity of the mesophilic starter cultures during ripening. The bacteria continues to lower the pH of the cheese as long as the S/M is less than 5%, but if the S/M is above 5% start activity is drastically decreased, which ultimately negatively affects quality grading scores (Fox et al., 1990; Singh et al., 2003). S/M directly effects the water activity of cheese thus influencing the growth of lactic acid bacteria (Upreti et al., 2006). *Lactococcus lactis* ssp. *Lactis* and cremoris, common Cheddar cheese starter cultures, are very salt sensitive and are inhibited at high S/M values. Non-starter lactic acid bacteria (NSLAB), primarily *Lactobacillus casei*, *Lactobacillus plantarum*, *Lactobacillus brevis*, and occasionally, *Streptococcus thermophilus*, are less affected by salt and will ferment residual lactose into DL-lactate and acetate (Singh et al., 2003; Upreti et al., 2006). Several studies have shown that Cheddars with higher S/M have greater amounts of unfermented residual lactose and less lactic acid than those with low S/M (Turner and Thomas, 1980; Schroeder et al., 1988; Upreti et al., 2006). Salt concentration is also a primary controller of the enzymatic activities of rennet, plasmin, and bacterial proteinases (Singh et al., 2003). At low S/M levels, proteolysis increases resulting in increased bitter taste and other off-flavors (Schroeder et al., 1988; Mistry and Kasperson, 1998; Singh et al., 2003). In addition to bitter taste, proteolysis also affects texture development during ripening.

SHREDDING

Prepackaged shredded cheese is a value added product, so it is of key importance that the shredding provides valuable functionality and appearance benefits for the consumer. However, shredding creates additional aspects to manufacturing, shelf life, and consumer preference.

Typically, cheese is shredded to a standard size of 3.2 to 1.6 mm or in a fancy style, which is 0.8 to 0.4mm (Ni and Guansekaran, 2004). Some companies have begun to offer ‘farmstyle’ cuts which are the thickest of shredded cheese at 9.6mm. Size and length of cheese shreds, which affect melt properties and appearance in meals, are key visual attributes of pre-packaged Cheddar cheese shreds (Ni and Guansekaran, 2004). Ideal cheese shreds should be cut with precision and uniformity to allow for even melting when used with hot dishes (Dubuy, 1980). However, very little research has been done on consumer preference for the length and width of cheese shreds.

Shredding brings variety to a product line, but it in turn brings challenges for manufacturing. Common cheese shredding concerns include reducing crumbs, improving surface smoothness and shred size uniformity, and decreasing shred adhesiveness and perceived oiliness (Serrano et al., 2004). For Cheddar cheese, these concerns can be improved by ripening cheeses for 30 days and evaluating the block prior to shredding for presence of gas holes or openings (Serrano et al., 2004). To evaluate the appearance and tactile performance of shredded cheeses, Serrano et al. (2004) created a sensory lexicon for shredded Cheddar cheeses (Table 1).

Anticake Agents

Shred-to-shred adhesiveness creates concerns for manufacturing and consumer liking. Ideally, cheese shreds should not clump together or agglomerate during storage, as this not only decreases ease of consumer use, but it also poses microbial concerns. To avoid these concerns, it is necessary to add anticake agents in or on the shredded cheese. Anticake agents typically consistent of combinations or sole applications of potato starch, corn starch, calcium sulfate, and powdered cellulose to prevent shreds from clumping and caking. Additionally, a mold inhibitor, typically natamycin, is added as either a liquid suspension or as a powder mixed with cellulose to inhibit mold growth and prolong shelf life (Elayedath and Barringer, 2002). According to the FDA, natamycin can be applied to cheese as an antimycotic at a maximum of 20 ppm of the finished product (21CFR172.115). However, there are multiple drawbacks to the use of anticake agents. They add additional cost, increase dust during manufacturing, possibly create a health hazard to workers, and introduce additional risk of bacterial contamination (Reddy, 1994). For consumers, anticake agents may reduce product functionality and performance and, for colored cheeses like Cheddar, may make the outer shred appearance powdery and discolored. Additionally, consumers have growing skepticism regarding anticake agents after a 2016 Bloomberg article exposed cheese products adulterated with wood shavings, meaning cellulose (Mulvany, 2016). Whole Foods, a popular natural grocery store chain, has placed natamycin on their "Unacceptable Ingredients for Food" list, furthering consumer concerns. Currently, anticake agents are loosely regulated with no specific limits other than that is must be GRAS and the shreds must still adhere to the identity of that cheese (US Code of Federal Regulations, 2000). After the Bloomberg article surfaced, two companies plead guilty to charges of adulterating grated parmesan cheese with fillers, primarily cellulose, in violation of provisions of the Federal Food, Drug, and Cosmetic Act (Department of Justice, 2016). These products were marketed as 100% parmesan but did not conform to the FDA's standards of identity for real parmesan. With the matching standard of identity for the specific cheese being the only guideline, a company can technically add as much of any GRAS product as they want as long as it still meets the criteria of milkfat and moisture content. Many studies and patents have been published on improving the efficiency of anticake agents or investigating alternative anticake agents for shredded cheese (Smith et al., 2013, Galer et al., 2010, Chappell et al., 2005). However, to our knowledge, none have investigated consumer perception of anticake agents applied to cheese shreds.

SENSORY EVALUATION

Grading of Cheddar

The first standardized method to evaluate the sensory qualities of cheese was dairy product grading and judging. The USDA created dairy grading in 1913 by establishing of Agriculture Marketing Service, formally known as the Office of Markets, to ensure quality and consistency of butter and Cheddar cheese (Singh et al., 2003; Clark et al., 2009). Three years later, the National Collegiate Dairy Products Evaluation Contest debuted a USDA developed and American Dairy Science Association (ADSA) approved scorecard, thus establishing dairy product judging (Clark et al., 2009). Scorecards are commonly used in grading and judging to serve as evaluation guidance and competition, manufacturer, or government records (Clark et al., 2009). Evaluators, using the scorecard, attribute numerical values to product quality characteristics, which can consist of flavor, texture, appearance, or instrumental terms (Clark et al., 2009). Judging is defect oriented, with the ideal product having the highest score possible and lowest defects notes by subtraction of points (Clark et al., 2009). This method allows for quickly evaluating a large number of samples, and for this reason, grading is still a common practice in the dairy industry today. According to the USDA, a grade AA Cheddar cheese flavor should be “fine and highly pleasing, free from undesirable flavors and odors” (Agricultural Marketing Service, 1956), and with such a broad definition, grading can be highly subjective. Many cheese attributes contribute to an ideal cheese; however, if those same attributes are out of balance then a cheese would be penalized for defects. Grading and judging were developed for rapid quality assessment, not for specific analytical use. Thus grading and judging scores cannot be analyzed statistically due to the unequal defect score assignments (Drake, 2004). Additionally, cheeses that receive the same score by the same judge may have significantly different flavor and the presence or absence of defects does not have direct relevance to consumer acceptance (Singh et al., 2003; Drake, 2004, 2007).

Descriptive Analysis of Cheddar cheese

Analytical sensory evaluations objectively document sensory profiles, product variability, or other product features without bias due to liking. Descriptive analysis has shown to be more likely to correlate and explain consumer liking compared to traditional dairy judging (Lawless and Claassen, 1993; Drake, 2007). This objective analytical sensory method can be used to profile a wide variety of products.

Sensory evaluation of Cheddar cheese has been well researched to objectively evaluate and establish lexicons for flavor and texture. McEwan et al. (1989) identified five aroma, eight flavor, and five texture attributes in their study to relate Cheddar cheese sensory characteristics to consumer acceptability. Piggot and Mowat (1991) later described twenty-three descriptive aroma and flavor attributes to evaluation Cheddar cheese during maturation. Throughout the 1990's, multiple studies continued to focus on Cheddar cheese descriptive analysis in a variety of different applications and conditions (Muir and Hunter, 1991; Roberts and Vickers, 1994; Muir et al., 1995, 1996, Drake et al., 1996, 1999; Lynch et al., 1999). As the use of descriptive analysis grew, it was important to standardize language used for Cheddar evaluations with precise definitions and references. Standardized lexicons are necessary for panel repeatability over time or across locations (Drake and Civille, 2003). Heisserer and Chambers (1993) had previously established a standard lexicon for aged natural cheeses, but additional studies, specifically for Cheddar cheese, identified standardized the language with definitions and references (Drake et al., 2001; Brown et al., 2003; Rogers et al., 2009). Drake et al. (2002) verified the use of established Cheddar lexicons, showing that different panels in different locations produced similar results when using a defined and anchored descriptive language for flavor.

Drake et al. (2001) reported differences in flavor among Cheddar cheeses. Younger Cheddars were characterized by flavor attributes such as cooked/milky, whey, diacetyl, and milkfat; while more aged Cheddars (typically aged over 1 year) were distinguished by sulfur, brothy, nutty, free fatty acid, and catty notes (Drake et al., 2001). Other studies have also developed texture and performance lexicons for Cheddar cheese shreds which included stretchability, meltability, fracture, amount of crumbles, surface smoothness, shred length, uniformity of shreds, shred-to-shred adhesiveness, visual perception of oiliness, and residual oiliness during shred handling (Brown et al., 2003; Serrano et al., 2004, 2005). Using these established lexicons, a trained panel, typically consisting of 6-12 evaluators, can objectively characterize the appearance, flavor and/or texture attributes of cheeses. Panelists are extensively trained (10-100h, depending on number and complexity of attributes) prior to data collection so that each individual functions as a sensor within the group creating one consistent and sensitive instrument (Chambers et al., 2004). There are several approaches to descriptive analysis (DA) including the Spectrum™ method and the Quantitative Descriptive Analysis (QDA) method (Meilgaard et al., 2007). DA data is objective and quantifiable allowing for simple statistical analysis and can be related to consumer preference results using multivariate statistics.

Descriptive data is commonly analyzed using a multivariate statistical technique called Principle Component Analysis (PCA), wherein the relationships between multiple samples and attributes are simplified into a graphical representation. For sensory data, the graphical space is defined by linear dimensions, also referred to as Principle Components (PC), that represent the correlations between attributes (Lawless and Heymann, 2010). The first PC explains the maximum amount of variance between the samples, with each subsequent PC explaining smaller amounts. The majority (>50%) of the data should ideally be explained by two to three PCs because four or more dimensions is difficult for researchers to mentally visualize and explain (Lawless and Heymann, 2010). When constructing a PCA, it is beneficial to have more samples than attributes. PCA can be conducted by using the data correlation or covariance matrix. The correlation matrix is typically better suited for data where the attribute scales are widely different, like analytical data, because it accounts for scale range, but may also be suitable when attributes vary by differing amounts across a scale range.

Consumer evaluation of Cheddar cheese

The goal of consumer testing is to measure preference and/or acceptance of a product by typical consumers which can be measured both quantitatively and qualitatively (Drake, 2007). Quantitative affective or consumer tests measure subjective consumer responses using hedonic liking scales (Lawless and Heymann, 2010). As such, a large number of consumers (>75 and generally > 100) are required to evaluate and score liking of a product. A variety of consumer testing methods exist to evaluate liking of a final product including central location testing (CLT) and home usage tests (HUT). The results from consumer testing can be linked with descriptive sensory analysis data of the same samples to identify specific flavor profiles that drive consumer preference using a combination of multivariate statistical techniques. Products with complex and diverse flavor profiles, like Cheddar cheese, can create wide variations in consumer concepts and expectations of flavor. By using consumer data in tandem with descriptive analysis data, preferences of complex flavor profiles that are difficult for consumers to identify are easily translated. Consumer perception is related to the descriptive data which notes the intensity and presence of attributes through preference mapping, which enables determination of specific market preferences. This technique is a perceptual mapping method that results in a graphical display of hedonic liking data, wherein data from each consumer is projected into a multi-dimensional space that represents the evaluated products (Lawless and Heymann, 2010). The map represents clear relationships between the products and the individual preferences.

Preference mapping can either be performed as internal or external preference mapping. Internal preference mapping, also referred to as MDPREF consists of creating a perceptual space using only the consumer hedonic liking data. In external preference mapping, also known as PREFMAP, the multi-dimensional space is created using additional sources, typically descriptive analysis data. This dimensional space, called the product space, will then have the consumer hedonic data projected into it using polynomial regression. These two techniques provide different perspectives on the same data where MDPREF may be more beneficial for new product design and PREFMAP may be better suited for understanding existing product market space (Lawless and Heymann, 2010). Several studies have used consumer preference mapping for Cheddar cheese to determine consumer flavor preferences for packaging, sharp Cheddar, mild Cheddar, and with a variety of maturity levels (Murray and Delahunty, 2000; Young et al., 2004; Drake et al., 2008, 2009).

Several studies have evaluated consumer flavor and texture preferences for Cheddar cheese (Caspia et al., 2005; Drake et al., 2008; Drake et al., 2009; Roberts et al., 1994; Wadhani et al., 2012; Young et al., 2004). Previous studies by Drake et al. (2008), Caspia et al. (2005), Young et al. (2004) and Drake et al. (2009) established that consumer preferences for Cheddar flavor and color were related to age. Using preference mapping, Drake et al. (2008) revealed that mild Cheddar had four distinct consumer clusters. These clusters were primarily differentiated by their color preferences for mild Cheddar cheese and the specific balance of mild flavors such as whey, cooked/milky, and milkfat. All consumers clusters in this study scored cheeses characterized by aged Cheddar flavors such as fruity, nutty, and brothy the lowest out of all the cheeses. It was determined that these aged flavors, in particular fruity, were unexpected in Cheddars labeled mild. Additionally, Drake et al. (2008) concluded that Cheddars characterized by an absence of any aged flavor and characterized by flavors of very young cheese (cooked/milky, whey, and milkfat) still performed poorly in liking as a bland profile may also fall outside consumer expectation of mild cheeses. This study also confirmed previous findings from Caspia et al. (2006) that bitterness in Cheddar was a generally undesirable consumer attribute although consumers may associate it with Cheddar age or flavor intensity.

Drake et al. (2009) showed that sharp Cheddar cheese acceptability was defined by five distinct consumer segments with varied preferences for Cheddar flavor and age. Studies by Caspia et al. (2005) and Young et al. (2004) showed similar results in that acceptability of Cheddar cheese varied by consumer cluster in their liking of aged flavors. Young et al. (2004) showed that consumers associated both young and aged Cheddar flavor with high Cheddar cheese flavor intensity, suggesting that consumer expectations for “Cheddar flavor” varies. These studies reported multiple differences between consumer preferences for sharp and mild flavors. Wadhwani and McMahon (2012) found that consumers showed confusion about Cheddar aged flavor label preferences. Their study reported that when asked their aged label preference, most preferred “medium” Cheddars, but after tasting most consumers scored “mild” Cheddars higher in overall liking (Wadhwani and McMahon, 2012). Since there is no legal definition of “sharpness” only typical industry standards, consumers may be confused on flavor expectations and labeled sharpness. With this knowledge of consumer segmentation and their preferences of Cheddar, it is important to investigate if these findings hold true for prepackaged

Cheddar cheese shreds or if consumers have different expectations for shredded Cheddar cheese that are different than block Cheddar cheese.

ROLE OF CHEESE COLOR

Color plays a large role in consumer expectations and liking of Cheddar cheese. Singh (2006) reported that consumers judge food products within the first 90 s of observation, roughly 62 to 90% of their assessment is based on color alone. Consumers perceive the identity, quality, and place in our eating routines based on color and appearance of food, and ultimately these judgements affect purchase decisions (Hutchings, 2003). Cheddar cheese is unique as it can be either white or orange. The color of Cheddar has no impact on the flavor of the cheese because the orange-yellow color is a result of adding annatto, a carotenoid extracted from a plant *Bixa Orellana* (Kang et al., 2010). According to the FDA, annatto extract is exempt from certification and, as such, is permitted to be added to Cheddar cheese milk (FDA, 2011). Colorants provide color uniformity and can add product differentiation in the market ad different shades of yellow/orange can be achieved.

However, the color of Cheddar has been shown to directly affect consumer expectations and liking. Wadhwani and McMahon (2012) observed that overall liking of low-fat cheeses was strongly dependent on color and appearance, and could also influence flavor and sharpness perception. Consumers perceived differences between Cheddars with the same flavor attributes but different colors (Wadhwani and McMahon, 2012). Additionally, low-fat Cheddars with the proper ratio of color additives like annatto and titanium oxide performed equally as well as full fat cheeses in overall liking suggesting that color of Cheddar affected consumer liking and flavor expectations (Wadhwani and McMahon, 2012). Drake et al. (2008) also found consumer preferences between colors of mild Cheddars where mild Cheddar consumers preferred orange

Cheddar over white. It is important to identify consumer preferences for Cheddar color as annatto addition adds additional cost to cheese manufacturing and continues to be a concern for whey protein manufacture and processing (Kang et al., 2010).

CONCLUSION

Considering the growth of convenient forms of cheese, particularly Cheddar cheese shreds, it is vital to understand the commercially available Cheddar cheese shred products and consumer preferences and expectations for those products. The objective of this study was to identify sensory properties of Cheddar cheese shreds and their relationship to consumer drivers of liking, and to investigate the role of anticake agents of consumer perception of Cheddar cheese shreds.

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TABLES

Table 1. Definition of sensory attributes of shredded Cheddar cheese (taken from Serrano et al., 2004).

Descriptor **Definition** **Cheese standards**

Appearance Descriptors

Procedure: Observe at 30 cm from the sample and evaluate without considering the presence of crumbles and fine

Descriptor	Definition	Cheese standards
Visual oiliness	How shiny the sample is	Parmesan fine shred, 6 oz, Lucerne Sharp Cheddar, 2 lb, Tillamook County Creamery Assoc. Swiss, 2 lb, Lucerne
Smooth surface	How smooth the outside of the strip is	Sharp Cheddar, 2 lb, Tillamook County Creamery Assoc. Mild Cheddar, 2 lb, Lucerne, Mozzarella cheese, low moisture, part skim milk, 2 lb, Lucerne
Mean length	Average length of cheese shreds	Yellow paper shreds (1, 2, and 4 cm)
Uniformity of length	How uniform in length the strips are, not considering presence of crumbles and fine	Medium Cheddar, shredded, 8 oz, Lucerne Sharp Cheddar, shredded, 2% milk, reduced fat, 8 oz, Kraft Food North America, Inc. Medium Cheddar, shredded, 2 lb Tillamook County Creamery Assoc.
Amount of crumbles	Amount of pieces that are irregular in shape of size ca. 5 mm or less	Medium Cheddar cheese, shredded, 8 oz, Lucerne Sharp Cheddar, shredded, 2% milk, reduced fat, 8 oz, Kraft Food North America, Inc. Medium Cheddar, shredded, Tillamook County Creamery Assoc.

Tactile descriptors

Procedure: Pick and release the sample 3 times using 5 fingers and feel the oil residue on the fingers. Pick the sample one more time, squeeze it and observe how the strips stick together when you dropped them on the plate.

Descriptor	Definition	Cheese standards
Tactile oiliness	Is there oil on the fingers after pick and release?	Mozzarella cheese, low moisture, part skim milk, 2 lb, Lucerne Mild Cheddar, 2 lb, Lucerne Swiss, 2 lb, Lucerne
Adhesiveness	How much the shreds stick together after dropping them at the height of 15 cm.	Mild Cheddar, 2 lb, Lucerne Sharp Cheddar, 2 lb, Tillamook County Creamery Assoc. Parmesan fine shred, 6 oz, Lucerne

CHAPTER 2:

DRIVERS OF LIKING FOR CHEDDAR CHEESE SHREDS

Drivers of Liking for Cheddar Cheese Shreds

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ABSTRACT

The pre-packaged cheese shred category has steadily increased over the past few years and Cheddar shreds represent the highest volume within this category. Recent studies have established extrinsic attributes that drive purchase of this category, but no published studies have addressed the intrinsic flavor and texture properties that drive consumer liking. The objective of this study was to determine the desirable flavor and functional attributes for Cheddar cheese shreds. A category survey of commercial Cheddar cheese shreds (n=25, collected in duplicate) was conducted. Sensory properties (shred appearance, flavor, texture and hot texture) were documented using a trained sensory panel. Analytical instrumental tests performed included shred size distribution, proximate analysis, sugars (lactose, glucose, galactose), lactic acid, Cheddar meltability, pH, and color. Representative shreds (n=10) were subsequently evaluated by cheese shred consumers (n=151) for overall, appearance, flavor and texture liking. Analysis of variance, principle component analysis, and external preference mapping were used to interpret results. Shreds were differentiated by color, whey, diacetyl, sulfur, nutty, and brothy flavors as well as hot and cold texture attributes and instrumental tests ($p<0.05$). Mild/medium shreds exhibited greater firmness, stretchability and elasticity when hot than sharp shreds ($p<0.05$). Three consumer clusters were identified and were defined by high acceptance for all Cheddar shreds or preferences for either sharp or mild shreds. Bitterness was an overall driver of dislike. Visible powder negatively impacted appearance and overall liking for some consumers. Sensory properties strongly impact consumer acceptance and purchase intent of Cheddar cheese shreds. Results from this study can be utilized to optimize intrinsic sensory properties of Cheddar cheese shreds.

Key words: Cheddar Cheese shreds, Consumer liking, Drivers of liking

INTRODUCTION

Cheese sales increased by 10% between 2012 and 2017, and total category sales are predicted to rise an additional 8%, reaching $25.5 billion of annual sales by 2022 (Mintel Group Ltd, 2017). In 2016, Cheddar cheese had the second highest consumption per capita in the US with roughly 4.7 kg consumed per year, slightly less than mozzarella at roughly 5.3 kg per year (USDA Economic Research Service, 2018). The rate of cheese consumption is primarily driven by flavor, and while this is an important factor for most foods, for cheese, roughly eight in every ten cheese consumers cited purchasing cheese for the taste, significantly more often than the next most frequently cited drivers – easy snacking and food-pairing versatility (Mintel Group Ltd, 2017). Cheese is available in a variety of packaging formats, which is driven by consumer desire for versatility and convenient healthy snacking.

Objective sensory lexicons have been established for Cheddar cheese flavor and texture (Piggott and Mowat, 1991; Roberts and Vickers, 1994a; Drake et al., 2001; Brown et al., 2003; Rogers et al., 2009). Previous studies have also developed texture and performance lexicons for Cheddar cheese shreds which included stretchability, meltability, fracture, amount of crumbles, surface smoothness, shred length, uniformity of shreds, shred-to-shred adhesiveness, visual perception of oiliness, and residual oiliness during shred handling (Brown et al., 2003; Serrano et al., 2004, 2005). Cheese shreds have additional concerns for consumer liking including shred length, width, and anticake agents. Anticake agents are typically combinations or sole applications of potato starch, corn starch, calcium sulfate, and powdered cellulose to prevent shreds from sticking and caking. Additionally, a mold inhibitor, which is typically natamycin, is added to inhibit mold growth and prolong shelf life (Elayedath and Barringer, 2002).

The majority of Cheddar cheese flavor development occurs during aging or ripening (Walstra et al., 1999; Singh et al., 2003). In regards to prepackaged shredded Cheddar cheese, the FDA requires that the products must meet the same definitions and standards of identity for block Cheddar cheese. For Cheddar cheese, a maximum moisture content of 39% and a milkfat requirement of 50% by weight of the solids is required for a standard of identity (21CFR133.113). Standard Cheddar cheese usually has 25.5% protein, which is predominantly casein (O'Callaghan et al., 2000). The ratio of all of these components is highly important to achieve an ideal Cheddar cheese shred product in regards to flavor, texture, and functionality for consumers.

Several studies have addressed consumer preferences for Cheddar cheese including flavor and texture (Roberts and Vickers, 1994b; Young et al., 2004; Caspia et al., 2006; Drake et al., 2008). However, few studies have specifically focused on consumer preferences for pre-packaged Cheddar cheese shreds. Understanding consumer liking for pre-packaged Cheddar cheese is essential for continued growth in this catagory. Recent research indicated that price, flavor, color and performance/meltability were primary drivers of purchase for Cheddar cheese shreds (Speight et al., 2019). This study addressed extrinsic Cheddar shred attributes and drivers for purchase intent in a survey format. Actual consumer perception of Cheddar cheese shred appearance, flavor, and texture is also critical information to establish preferred intrinsic properties. To our knowledge, previous studies have not examined consumers drivers of liking for Cheddar cheese shreds using a central location test (CLT). Given the growing Cheddar cheese shred market, it is pertinent to investigate all intrinsic properties of consumer perception of this product. The objective of this study was to understand the drivers of liking of Cheddar cheese shreds using sensory evaluation by trained panelists and consumers to provide further clarification on key sensory attributes.

MATERIALS AND METHODS

Experimental Overview

Sensory properties of twenty five commercial Cheddar cheese shreds were evaluated by descriptive analysis. Composition and physical properties were also documented. Subsequently, a consumer acceptance test was conducted with representative Cheddar shreds with 151 Cheddar cheese shred consumers.

Cheddar Shreds

Commercial Cheddar cheese shreds (n=25) were purchased locally or online. Samples ranged in brand (national, regional, store), sharpness (mild to extra sharp), color (white, orange, or mixed), and cut thickness (thin, medium, thick). If samples were not purchased locally, they were shipped overnight on ice packs and were examined for damage upon arrival. Products were purchased in multiples (5-10 lbs) on different occasions (ca 3 weeks apart) and subjected to analytical sensory and instrumental evaluations to ensure that representative evaluations were conducted. All shreds were a minimum of 90 days from code date. Cheese shreds were stored in the dark at 4°C and were analyzed within 60 days of receipt.

Proximate Analysis

Moisture, fat, pH, protein, sugar, color, melting quality, and shred size composition were conducted on all Cheddar cheese shreds in triplicate. Moisture content was measured by vacuum oven drying (AOAC 926.08) with 2 g of cheese. The Mojonnier method was used to measure fat content (AOAC, 989.05). A glass electrode (Mettler-Toledo GmbH, Schwerzenbach, Switzerland) was used to measure pH by inserting the pH electrode probe (VWR International, Radnor, PA) into roughly 20 g of shredded cheese pressed into a 50 ml beaker at 25˚C. Prior to testing, the pH meter was calibrated using buffers (Thermo Scientific, Chelmsford, MA) at pH 4, 7 and 10. The pH probe was then inserted into the cheese shreds. Results for each cheese were collected from three different locations and averaged. Protein was determined using a Sprint Rapid Protein Analyzer (CEM Company, Matthews, NC).

Lactic acid and sugar content (lactose, glucose, and galactose) of the Cheddar cheese shreds were measured by High Performance Liquid Chromatography (HPLC) (Zeppa et al., 2001). Cheeses were prepped for analysis by finely shredding five grams of each sample and adding it to 10 mL of 0.0045N H_2SO_4 (Sigma Aldrich, St. Louis, MO) heated to 60° C. Samples were vortexed for 2 min followed by agitation for another 10 min. Mixed samples were centrifuged at 7,000 x g for 10 min. Samples were then cooled at 4° C to solidify the top fat layer which was then removed. The aqueous layer was centrifuged again with a benchtop centrifuge at 21,000 x g for 5 min. Samples were filtered through a 0.45μm nylon filter (VWR International, Radnor, PA) into a 2 mL HPLC sample vial (Phenomenex, Torrance, CA). Extracted sugars were then evaluated using an HPLC (Waters 1525 Binary Pump, Waters, Milford, MA) equipped with an autosampler (Waters 2707 Autosampler) onto a Aminex HPX-87H 300 mm x 7.8 mm ion exclusion column (Bio-Rad Labs, Richmond, CA) heated to 55° C. The mobile phase was 0.0045N H_2SO_4 (Sigma Aldrich, St. Louis, MO) at a flow rate of 0.6mL/min. Injections of 20μL of each sample were performed in duplicate. Sugars were detected using refractive index (Waters 2414 Refractive Index Detector, 35°C). Lactose, glucose, and galactose were detected at 7.32 RI, 8.52 RI, and 9.19 RI, respectively. Lactic acid was detected at 210nm (waters 2998

PDA) at 11.74. Seven-point standard curves were developed for each compound of interest using reference standards (Sigma Aldrich).

Instrumental Color Measurement

Instrumental color was determined by pressing 30g of each cheese into a separate 100 x 15 mm Pyrex glass Petri dish (Olsen, 2011). Color measurements were taken at 25°C both prior to baking and after baking. The L*, a*, and b* values were measured using a handheld colorimeter (Chroma Meter CR-410, Konica Minolta Sensing, Chiyoda, Tokyo, Japan) that was calibrated prior to any measurements. The handheld colorimeter was fitted with a CR-A104 protective cap (Konica Minolta Sensing) and positioned flush against the pressed Cheddar cheese samples to collect four measurements prior to baking. The disks were rotated between each measurement. Following initial color evaluations, shreds were heated at 130°C for 75 min in a conventional oven and then cooled to room temperature (Olson et al., 2011). Four color measurements were collected again on all disks by pressing the handheld colorimeter flush against the cheese samples. The averages of the L*, a*, and b* values were used to calculate the magnitude of the total color difference (ΔE) before and after heating using the following equation (Hunter, 1975): $\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$.

Instrumental Melt and Shred Size

A modified version of the Schreiber Melt Test was used to determine meltability and spread (Kosikowski and Mistry, 1997). Fifteen grams of cheese was weighed out and pressed to a cylinder (4 cm of interior diameter) until shreds formed a uniform solid mass in the middle of a 100 x 15 mm Pyrex glass Petri dish. The cylinder was removed and the glass dish was placed in a convection oven at 232°C for 5 min and then cooled for 30 min. The glass Petri dish was centered over a concentric numbered target-type graph, the outer edge of the flow line was measured along eight evenly spaced points. A value of 1.0 indicates no change in disk diameter, and the value increases by 1.0 for every 1.0 cm increase in diameter. The average of the eight values was meltability (Kosikowski and Mistry, 1997).

Shred size composition was determined by sorting cheese shreds with metal sieves as described by Childs et al. (2007). Cheese shreds were weighed and then placed on top of the 4 sieve plates with openings of 1.27 cm, 0.635 cm, 0.3175 cm, 0.1679 cm, and a bottom plate. The stacked sieves were shaken by hand for 60 sec both vertically and horizontally. The product not passing through the 1.27 cm sieve was classified as long shreds, product not passing through the 0.635 cm sieve was classified as short shreds, product not passing through the 0.3175 cm was classified as fines, product not passing through the 0.1679 cm was classified as crumbs and product collected on the bottom plate was classified as attrition. Results from the test were presented as percentages of the total weight.

Descriptive Sensory Analysis

Flavor, cold texture and hot texture descriptive analysis was performed in compliance with the North Carolina State University Institutional Review Board for Human Subjects approval. Panelists expectorated samples and cleansed palates with room temperature deionized water between samples. Data was collected using Compusense Cloud (Compusense, Guelph, Canada).

Flavor, cold texture and hot texture were evaluated in separate sessions.

For flavor analysis, a trained sensory panel (n = 8, 5 females, 3 males, ages 23-54 y) evaluated the cheeses using an established Cheddar cheese flavor lexicon (Drake et al., 2001) and a 0 to 15 point universal intensity scale Spectrum^{TM} method. Each panelist had at least 150 hours of experience with descriptive analysis of cheese flavors. Cheddar cheese shreds were served in lidded 59 mL clear plastic soufflé cups (Dart Container, Mason, MI) with random three-digit blinding codes and evaluated at 15°C. For texture evaluation, the trained descriptive sensory panel evaluated the cheese shred attributes in triplicate using a 0- to 15-point product-specific scale for both hot and cold Cheddar cheese shreds. The cheese texture lexicon was adapted from several previously published studies: Drake et al. (1999), Gwartney et al. (2002), Asato (2003), Brown et al., (2003) and Rogers et al. (2009). Terms were added and subtracted specific to cheese shreds and the temperature of evaluation (Table 1). Approximately 15g of cold cheese shreds were served at 4˚C in lidded 120-mL soufflé cups with 3-digit blinding codes. For hot texture, approximately 15g of each Cheddar cheese shred was baked in clean metal desiccation dishes 7.62 cm in diameter (VWR International, Radnor, PA) in a conventional oven set to 230ºC for 4 min. Cheese texture were evaluated within 1 min of being removed from the oven.

Consumer Acceptance Test

From the category survey, ten representative Cheddar cheese shreds were selected based on examination of descriptive analysis results using multiple factor analysis, product mean attributes, and market share. Consumer acceptance testing was conducted to determine consumer preferences for flavor and texture attributes of cold Cheddar cheese shreds. Testing was conducted in accordance with the North Carolina State University Institutional Review Board for the Protection of Human Subjects in Research regulations. Consumer acceptance testing was performed over 2 days, with each consumer evaluating a randomized partial presentation of 5 cheese shreds per day. Self-reported Cheddar cheese shred consumers (n = 151) were recruited using a survey launched into an online database of 11,000 individuals maintained by North

Carolina State University. All consumers were primary shoppers with an annual household income >$15,000 who purchased and consumed Cheddar cheese shreds at least once a month. Of the consumers recruited, gender was split equally between men and women, and income was split equally among income range to achieve a broad range of consumers. Panelists were compensated with a $25 gift card to a local store upon completion of the 2 day test. Compusense Cloud (Compusense) was used for data collection.

Shreds for the consumer test were prepped in a similar fashion as for descriptive analysis. Approximately 15-20g of each sample was served in 2 ounce lidded 120-mL soufflé cups with 3-digit blinding codes. Cheeses were served at 8°C. As consumers arrived for their test, they first presented a photo ID in order to ensure the consumers who participated were the consumers screened for the test. Consumers were then verbally instructed. Each day, shreds were presented monadically using a Williams design serving order to balance for sample position throughout the course of the test (Compusense). Panelists were first asked to evaluate overall appearance liking, color liking, color Just-About-Right (JAR) from dark to light, color JAR from yellow to orange, shred size liking, shred size JAR from too short to too long, shred size liking from too thin to too thick, and open ended comment questions regarding product likes and dislikes. After evaluating appearance, consumers consumed several bites and were asked to evaluate cheese flavor and texture. Questions asked included overall liking, overall flavor liking, overall flavor JAR, saltiness liking, saltiness JAR, savory liking, savory JAR, sour liking, sour JAR, texture liking, texture JAR from too soft to too hard, and texture JAR from too crumbly/dry to too rubbery. Additionally, consumers were asked perceived flavor sharpness, check-all-that-apply (CATA) consumption, purchase intent, and CATA Cheddar cheese shred flavor, texture and color attributes. A 2 minute rest was enforced between samples and during this time, consumers were asked to take several bites of unsalted cracker and to drink spring water. After completing all samples, consumers were asked to identify their ideal cheese using a CATA list similar to the attribute question asked previously.

Liking questions were scored on a 9 pt hedonic scale where 1 = dislike extremely and 9 = like extremely. The JAR questions used a 5 pt scale where 1 or 2= too little, 3=JAR, and 4 or 5=too much. Perceived flavor sharpness options included mild, medium, sharp, and extra sharp. Purchase intent was scored on a 5pt scale where 1 or 2=would not buy, 3=may or may not buy, and 4 or 5=would buy. The CATA Cheddar cheese shred attribute question contained milky/dairy, buttery, milkfat (creamy), sulfur/eggy, brothy (meaty), nutty, sour, bitter, salty, sweet, savory, soft, hard, dry/crumbly, rubbery, long shreds, short shreds, thick shreds, thin shreds, orange, yellow, white, and the option of other with a comment box to clarify this selection. The Ideal CATA Cheddar cheese attribute question used the list from the sample specific attribute question but also contained the words powdery and powderless.

Statistical Analysis

Statistical analysis was conducted using XLSTAT software (version 2017; Addinsoft, New York, NY). Compositional, descriptive analysis, and consumer liking scores were analyzed by ANOVA with Fisher's least significant difference test at a significance level of $p < 0.05$. Multiple factor analysis (MFA) was applied to descriptive analysis to determine product differentiation and to select a proper representation of the Cheddar cheese shred market for the consumer test. Consumer JAR scores were evaluated by chi-squared analysis, and purchase intent was evaluated using a Kruskal-Wallis test with Dunn's post hoc test. Penalty analysis was conducted to relate JAR scores with overall liking. Check-all-that-apply questions were analyzed using Cochran's Q test and visualized using correspondence analysis with Chi-square distance.

For consumer segmentation, hierarchical agglomerative clustering and k-means analysis were used to determine the number of clusters. Clusters were validated using discriminant analysis. Partial least squares regression analysis was then conducted on descriptive means and consumer data to identify drivers of liking and disliking for each cluster.

RESULTS

Compositional Analysis

Compositional analysis for moisture, fat, pH, protein, sugar, color, melting quality, and shred size composition varied among the shreds ($p<0.05$) (Table 2). Cheese shreds with higher fat were correlated with increased hand cohesiveness and adhesiveness by cold texture descriptive analysis evaluation ($r = 0.466$ and 0.446, $p<0.05$), as well as increased oiliness to lips, visual oil, and mouthcoat in hot texture texture evaluation ($r =0.525$, 0.435, 0.436, respectively, $p<0.05$). Additionally cheese shreds with a higher percentage of protein were correlated with increased stretchability in hot sensory texture evaluation ($r = 0.571$, $p<0.05$).

Descriptive Analysis

Distinguishing flavor differences among the 25 Cheddar cheese shreds were documented by the trained panel ($p<0.05$) (Figure 1). Three principle components explained 60% of the variability. Based on factor loadings (not shown), PC1 (34%) differentiated shreds by brothy, sulfur, and nutty flavors, and salty, umami, and sweet tastes (all positively loading) and whey and cooked flavors (negatively loading). PC2 (16%) differentiated cheeses by milkfat and diacetyl flavors (positively loading) and grassy flavor (negatively loading). PC3 (not shown) was represented by bitter taste (positively loading). Cheese shreds 3, 4, 6, and 20 were characterized by sulfur, brothy, and nutty flavors and umami and sweet tastes. Drake et al. (2001) classified these flavors as “aged/developed” flavors due to their prevalence in Cheddar cheeses aged over 1 year. Cheese shreds 8, 10, 13, 18, 19, 21, 23, and 25 were characterized by higher intensities of cooked and whey flavors, which are typical of young or mild Cheddar cheeses (Drake et al., 2001). Cheddar cheese shreds 1 and 18 were the only cheeses with grassy flavors, and these shreds were the only organic samples. Grassy flavor has been attributed to pasture-based feeding regimes and might as a result, also be associated with organic cheese (Drake et al., 2005; Croissant et al., 2007). Cheddar cheese shreds varied widely by flavor and texture within the same labeled sharpness category since there is no legal definition for “sharp” or “aged”. The labeled sharpness and color for the Cheddar shreds selected for consumer testing can be seen in Table 2.

Correlation analysis between descriptive flavor and instrumental data demonstrated that cheese shreds with higher intensities of “mild” flavors like cooked and whey tended to have less short shreds ($r = -0.486$ and -0.500, $p<0.05$), suggesting that mild cheeses break less and remain whole. As Cheddar cheese ages, gradual proteolysis alters the protein matrix to become less cohesive resulting in a decrease of rheological fracture strain and springiness (Muthukumarappan and Swamy, 2017). This means that younger Cheddars are more likely to maintain shape during mechanical stress such as shredding. Additionally, cheese shreds with “sharp” flavors such as sulfur and brothy and bitter, salty, sweet, and umami tastes tended to have increased browning (ΔE) ($r = 0.448, 0.550, 0.536, 0.517, 0.478, 0.420$, respectively, $p<0.05$). As Cheddar cheese ages, the proteolysis that occurs results in increased free amino acids and peptides, thus affecting Maillard browning (Kelly and Fox, 2012).

The cold texture sensory data was explained with 3 PCs (85% of the variability) (Figure 2). Principle component one (PC1) (58%) differentiated shreds by hand cohesiveness, degree of breakdown, tackiness, cohesiveness in mouth, adhesiveness, smoothness of mass, and smoothness of mouthcoating (positively loading). Principle component two (16%) differentiated cheese shreds by degree of mouthcoating and visible powder (positively loading). Principle component three (12%) differentiated shreds by color intensity (positively loading). Hot shred texture data was explained with 3 PCs (79% of the variability) (Figure 3). Principle component one (40%) differentiated shreds by visible surface moisture, meltedness, oiliness to the lips, and visual oiliness (positively loading) and stretchability and hardness (negatively loading). Principle component two (26%) differentiated shreds by adhesiveness (positively loading) and tackiness and cohesiveness (negatively loading). Principle component three (not shown) (13%) differentiated samples by smoothness of chewed mass (positively loading).

By hot texture sensory evaluation, “mild” cheese shreds tended to be less oily to the lips and oily in mouthfeel than “sharp” cheeses (Table 3). Cheddar cheese shreds with increased “sharp” flavor intensities and sour, salty, sweet, or umami basic tastes tended to be have decreased stretchability in hot texture evaluation. Cheese shreds with higher visible powder tended to be less cohesive and adhesive in mouth during cold texture evaluation. Increased visible powder on cheese shreds was also correlated with increased hardness and reduced mouthcoating and oiliness to the lips and in mouth. Hand cohesiveness, degree of breakdown, tackiness, cohesiveness, adhesiveness, smoothness of mass, and smoothness of mouthcoat for cold texture evaluation and oiliness to the lips, oiliness in mouth, and mouthcoating for hot texture evaluation were all positively correlated. These terms were negatively correlated to hot texture stretchability and hardness. Fat and protein content are the most influential components to the texture of cheese. Bryant et al. (1995) reported that reducing fat in Cheddar cheese altered the protein microstructure resulting in reduced adhesiveness and cohesiveness. Rogers et al. (2009) similarly reported that decreased fat in Cheddar cheese increased hand springiness, rate of recovery, and bite fracture. These authors also reported that as full fat cheeses aged, cheese firmness and associated terms (hand springiness, rate of recovery, and bite fracture) decreased (Rogers et al., 2009). It is well established that cheese aging degrades the casein network over time resulting in a less firm and easily deformable cheese (Tunick et al., 1990; Banks, 2007; Rogers et al., 2009).

Consumer Acceptance

The cheese shreds selected for consumer testing (n=10) varied in color, shred size, and labeled sharpness (Table 2) as well as sensory properties (Table 4). Cheddar cheese shred consumers differed in gender, age, income, cheese consumption, types of cheese shreds consumed, and factors influencing Cheddar cheese shred purchase choices (Table 5). Cheese shreds with mild flavors (13, 18, 19, 21) scored lower in overall liking than those with more sharp flavor (4, 12, 20), which suggests that consumers generally preferred some level of "sharp" or "aged" flavor (Table 6). However, penalty analysis showed that shreds with more aged flavors were also penalized for too much overall flavor and savoriness ($p<0.05$) (Table 7). Other Cheddar shreds (6, 11, 13, 12, 18, 19, and 21) were penalized for too mild flavor. Wadhwani and McMahon (2012) reported similar findings in that consumers considered all sharp cheeses too flavorful and all mild cheeses too mild, suggesting, as in this study, segmentation among consumers. Cheese shred 3 was characterized by some of the most intense aged flavors including sulfur, brothy, and nutty flavors and higher intensities of sour, sweet, umami, salt, and bitter tastes. This shred scored the lowest in overall liking out of all samples across all consumers. The overall liking scores for shred 3 showed very clear bimodal distribution, indicating that intense sharp flavors were polarizing to Cheddar cheese shreds consumers (Figure 4).

Analysis of the CATA attribute question showed that consumers struggled to communicate the differences between Cheddar cheese shreds (Table 8). All cheese shreds scored at parity for aromatics (milky/dairy, buttery, milkfat/creamy, sulfur/eggy, brothy/meaty, and nutty). However, consumers did differentiate between cheese shreds by appearance, texture, and some basic tastes: bitter, salty, and umami (savory). Additionally when asked to identify the labeled sharpness of the cheese shreds, the majority of the time consumers were correct. These results were consistent with Wadhwani and McMahon (2012) who found that consumers could distinguish between a mild and sharp cheese when asked to rate the sharpness using a JAR scale. The sharpness evaluation results, as well as differences in overall liking scores, show that consumers can recognize differences among cheese shreds but struggle to communicate what the perceived differences are, which would be expected. These results demonstrate the importance of descriptive sensory analysis with a trained panel. Affective sensory tests only show consumer preference and liking, so descriptive analysis is needed to identify and document intensities of flavors (Singh et al., 2003). Typical consumers have varying concepts on flavor terms which is shaped by prior experience (Lawless and Heymann, 2010). The lack of understanding of Cheddar flavor terms could be the reason why consumers could not differentiate samples in the current study by flavors (aromatics) and relied on basic tastes, appearance and texture. Still, other research has found discrepancies between consumer concepts for preference and actual preference. Haddad et al. (2007) reported that extrinsic factors, such as nutrition, influenced initial purchase of products, but continued purchase was primarily driven by sensory properties. McCarthy et al. (2017) reported that self-reported skim milk consumers consistently preferred 2% milk over skim due to appearance, flavor, and thickness. De Pelsmaeker et al. (2017) compared conjoint tests with a tasting sample versus a description and found that the same clusters existed. However, after tasting, the number of flavor-driven consumers increased. Whether a misunderstanding of flavor or idea driven liking, these studies show that consumer concepts may not match actual consumer preferences and that descriptors such as sharp and Cheddar mean different things to different consumers.

Consumers were not prompted or asked directly about anticaking agents on the cheese shreds. However, review of the comments from purchase intent and overall appearance liking showed that many consumers (n=61) mentioned a visible “powder” on some cheese shreds. The words “powder”, “powdery”, “white”, “residue”, “dust”, “dusty”, “mold”, “moldy”, “anti-caking”, “preservative”, “chalk”, “chalkiness”, and “coating” were found multiple times throughout the comments. In the liking and purchase intent (PI) comments, 40.4% of consumers mentioned that they disliked the “powdery” appearance of Cheddar shreds. Several consumers (n=17) mentioned that the lack of the “powdery” appearance positively influenced their liking. Consumers (n=61) who did and did not negatively mention anticaking agents had lower appearance and overall liking scores than consumers who did not mention a powdery appearance (Figure 5). This results suggests that visible anticaking agents negatively impacted liking. Speight et al. (2019) found similar findings in that powdery appearance was a driver of dislike for Cheddar cheese shreds. Of the consumers who mentioned “powdery” appearance negatively in the current study, two attributed the powdery appearance to the presence of mold, indicating that some consumers may not be aware of the purpose of anticaking agents. With these findings, future studies need to specifically address consumer perception of anticaking agents. Analysis of the purchase intent influence question showed that for all cheese shreds, purchase intent was predominately affected by flavor followed by appearance, then texture. However, four out of the ten cheese shreds received penalties for texture. Drake et al. (2008) reported similar findings in that texture did not affect overall liking. However, consumers appeared to value and have specific expectations for Cheddar cheese texture.

Cluster analysis was conducted to determine and refine preferences within particular consumer groups. Cluster analysis revealed three distinct groups of consumers, each with distinct preferences for the ten Cheddar cheese shreds (Figure 6). Partial least squares – regression (PLS-R) analysis with the clusters showed segmentation preferences (Figure 7). The clusters were distinct with no similar drivers of liking between the three. The overall preferred Cheddar shred for consumers in segment 1 (n=35) was a cheese shred characterized primarily by young or mild flavors such as whey, buttery (diacetyl), and cooked. These consumers disliked aged flavors such as the brothy, nutty, and sulfur flavors found in shreds 3, 4, and 20. Cluster 1 also had a high correlation with visible powder, which is not to say that this is a driver of liking, but simply an association with mild flavored cheeses. Conversely, consumers in segment 3 (n=48) preferred Cheddar shreds with aged flavors like brothy, sulfur, and nutty flavors. Shreds 4 and 20 received the highest liking scores from cluster 3 and were both characterized by high sulfur and brothy flavors and sweet and umami tastes. Consumers in segment 2 (n=68) had the broadest acceptance and highest overall liking scores across all consumers and cheese shreds. These consumers liked profiles of all Cheddar shreds and their only correlated driver of liking was savoriness (umami). These results are similar to Caspia et al. (2006) who found 6 consumer clusters for Cheddar cheese liking which were broken down into consumers who preferred "sharp" flavor, consumers who preferred "mild" flavors, and consumers with high liking scores of all cheeses tested. Several studies have addressed consumer perception of Cheddar cheese flavor and have found wide variations in consumer preferences for Cheddar cheese (Young et al., 2004; Drake et al., 2008, 2009). The diversity of flavors, colors, and textures among Cheddar cheeses, even among cheeses with the same flavor designation ("mild", "sharp"), means that ideal Cheddar flavor has different meanings between consumers. These findings indicate that descriptive analysis is paramount when discussing consumer preferences and drivers. Consumers address their like or dislike of products, while a trained sensory panel identifies and describes flavor and textural differences that consumers may not be able to communicate.

Segmented overall liking scores and PLS-R suggested distinct differences in preference between the clusters (Figure 7). However, when the ideal Cheddar shred CATA responses were analyzed, there were no significant differences found between any of the clusters, consistent with consumers were unable to specifically describe likes and dislikes for Cheddar shred flavor (Table 8, Figure 8). In particular, consumers in cluster 1, who indicated a preference for "sharp" flavored Cheddar cheese shreds, were statistically at parity with cluster 3, who preferred "mild" cheese shreds. Analysis of the frequencies of ideal cheese shred CATA selections for all consumers indicated that for cheese flavor, consumers selected the basic tastes "savory" and "salty" and "milky/dairy" most frequently (Figure 8). These results illustrate again that consumers struggle to communicate specific flavor attribute preferences for Cheddar cheese shreds. Young et al. (2004) reported clear differences in consumer liking for Cheddars of varying ages and flavors, but consumers struggled to identify the intensity of the aged flavors. Aged Cheddar is complex and varies within the market, thus resulting in varying consumer concepts and expectations for Cheddar aged flavor. Dacremont and Vickers (1994) reported this same concept: consumer experience with Cheddar varieties shaped their concepts of Cheddar flavor, odor and texture.

Across all consumers, bitterness was a driver of dislike. Traditionally bitterness in Cheddar is considered a defect. However, Drake et al. (2009) found that at low levels (<1 on Spectrum™ trained panel intensity scale), bitterness may not necessarily affect liking, and for some consumers may be a desired "sharp" flavor attribute. In this study, grassiness was only present in one sample for the CLT, so it cannot be suggested as a driver of like or dislike, however, it did not appear to be correlated with any cluster of consumers. In determining drivers of liking for mild Cheddar, Drake et al. (2008) also tested a cheese with grassy notes. They found that U.S. consumers either were indifferent or disliked grassy flavor in Cheddar cheese. More research should be conducted to address consumer perception of grassy flavor that is typical in organic, grass-fed Cheddar cheeses. Analysis of liking means showed variation in shred size preference between groups. Cluster 2 and 3 gave higher scores to feather cut shreds compared to fancy and farm-style ($\bar{x}$ = 7.4 and 6.7, respectively) ($p<0.05$), while cluster 1 scored fancy shreds the highest ($\bar{x}$ = 6.0) ($p<0.05$). All three clusters scored farm-style the lowest out of the three cuts with ($\bar{x}$=4.9) ($p<0.05$). Since shred 21 was the only "farm-style" shred in the CLT, it cannot be suggested as a driver of dislike. Additional research should be conducted to determine the effect of shred with on consumer liking.

Additionally, clustering and PLS-R suggested a slight correlation between segmentation and cheese shred color for cluster 3 (Figure 7). Consumers in cluster 3 were positively correlated with white shred color (r = 0.359) and negatively correlated with yellow/orange shred color (r = -0.315). Further investigation showed that cluster 3 was the only segment that consistently had higher scores for white cheeses over orange cheeses in overall appearance liking, color liking, and overall liking (6.6 to 6.0, 6.6 to 6.3, and 6.3 to 5.6, respectively, $p<0.05$). Cluster 3 was marked by a preference for cheese shreds with "sharp" flavors, which are commonly found in commercially available white cheeses. This correlation for cluster 3 in the current study may simply be an association, not a driver of liking, as white mild non-organic Cheddar shreds are not common on the market and were not included in the test. Drake et al. (2008) reported that U.S. Cheddar consumers that preferred sulfur and brothy flavors also preferred white colored cheeses.

On the other hand, Wadhwani and McMahon (2012) found that as the whiteness of Cheddar increased, flavor perception tended to decrease and the cheese was considered not flavorful enough. Similar to the current study, some consumers in the Wadhwani and McMahon (2012) study commented that the white cheese might be mozzarella and cause confusion. Additionally, Speight et al. (2019) reported that white Cheddar shreds were typically associated with "all-natural" products, and as a result, may be associated with high cost. These multiple studies indicate that consumers may be confused by white Cheddar cheese since yellow and orange Cheddar cheeses colored with annatto are more common in the United States. Additional research is required to investigate the impact of color on consumer preference and flavor expectations.

CONCLUSIONS

The current study demonstrated that there was wide variability in the composition, flavor, and texture of Cheddar cheese shreds. As a result, consumer preference and expectations also vary. Specific consumer clusters (1 and 3) were identified by preference for sharp or mild cheese shreds, with cluster 3 preferring "sharp" Cheddar flavors and cluster 1 preferring "mild" Cheddar flavors. Some consumers (cluster 2) were defined for their broad acceptance and high liking scores of Cheddar shreds in general. Bitterness was a consistent driver of dislike for all clusters. Consumers struggled to understand and communicate specific flavor differences between shreds regardless of preference and primarily relied on basic tastes. White colored Cheddar cheese shreds may play an important role for consumers who prefer "sharp" flavored cheese shreds. Anticaking agents ("powdery" appearance) decreased overall liking for some consumers. These finding can help manufacturers create optimized Cheddar cheese shreds that will reach the broadest amount of consumers.

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TABLES

Table 1. Cheese shred sensory texture attributes (adapted from Drake et al., 1999; Gwartney et al., 2002; Asato, 2003; Brown et al., 2003).

	Term	Definition
Visual color intensity and Cold Texture	Color intensity	Degree of color intensity from light to dark
	Visible Powder	Amount of visible powder on the shreds where 0= no visible powder and 10 = every shred surface is coated in powder
	Hand cohesiveness	Degree to which the sample forms a mass and does not break apart after applying compressing 30% and release
	Degree of breakdown	Degree to which the sample breaks down during mastication
	Tackiness	Amount of force required to pull teeth apart after biting down into the sample during first bite
	Cohesiveness	Degree to which the sample forms a mass and does not break apart after 5 chews
	Adhesiveness	Degree to which the sample sticks to any of the mouth surfaces during mastication
	Smoothness of mass	Lack of gritty or grainy particles perceived in the mass while chewing
	Smoothness of mouthcoat	Degree of smoothness felt in the mouth after expectoration
	Mouthcoat	Amount of any mouthcoating (particles, oil, moisture) remaining after swallowing or expectorating
Hot Texture	Visible surface moisture	Amount of visible oil on the surface
	Meltedness	Homogeneity of the sample (Higher number=more melted)
	Stretchability	Length the melted cheese will stretch with a plastic fork within a minute of oven removal
	Oiliness to lips	Amount of oil felt on lips
	Hardness	Amount of force to bite between molars during first bite
	Tackiness	Amount of force required to pull teeth apart after biting down into the sample during first bite
	Cohesiveness	Degree to which the sample forms a mass and does not break apart after 5 chews
	Adhesiveness	Degree to which the sample sticks to any of the mouth surfaces during mastication
	Oiliness	Amount of oil or any coating perceived in the mouth
	Smoothness of mass	Lack of gritty or grainy particles perceived in the mass while chewing
	Mouthcoat	Amount of any mouthcoating (particles, oil, moisture) remaining after swallowing or expectorating

Table 2. Sieve pan percentage, moisture, pH, fat, instrumental color, protein, melt, and sugar content values of Cheddar cheese shreds.

				Sieve Pans %					Moisture %	pH	Fat %	Li[5]	Ai[5]	Bi[5]	Δ E[6]	Protein %	Melt	Lactose g/ cheese g	Glucose g/ cheese g	Galactose g/ cheese g	Lactic Acid g/ cheese g
#[1]	Cut	Sharp[2]	Color[3]	1.27[4]	0.635[4]	0.3175[4]	0.1679[4]	pan													
1	Feather	M	W	2.0	49.7	40.2	6.3	1.9	39.5	5.36	31.7	80.7	-4.1	36.4	45.7	23.2	16.9	0.020	ND[7]	0.017	0.128
2	Fancy	M	Y/O	1.0	18.9	42.8	32.5	4.9	37.7	5.14	30.3	39.3	16.7	22.2	48.1	23.5	15.6	0.021	0.030	0.042	0.121
3	**Fancy**	**S**	**Y/O**	**0.0**	**2.0**	**30.9**	**60.3**	**6.9**	**37.1**	**4.91**	**31.8**	**38.8**	**14.6**	**19.4**	**45.7**	**21.7**	**15.1**	**0.026**	**0.041**	**0.011**	**0.159**
4	**Feather**	**S**	**W**	**0.3**	**14.6**	**62.4**	**19.2**	**3.5**	**42.2**	**5.35**	**33.1**	**83.7**	**-3.3**	**25.0**	**54.2**	**22.1**	**17.4**	**0.044**	**0.026**	**0.013**	**0.115**
5	Fancy	M	Y/O	7.4	31.1	33.6	24.3	3.6	36.0	5.43	32.5	71.6	14.6	61.8	45.3	24.5	12.5	0.026	ND	0.043	0.107
6	**Feather**	**S**	**Y/O**	**32.1**	**39.6**	**25.4**	**2.2**	**0.6**	**39.0**	**5.39**	**33.0**	**69.9**	**15.8**	**58.9**	**52.5**	**23.0**	**15.4**	**0.022**	**ND**	**0.032**	**0.127**
7	Fancy	S	Y/O	0.6	32.6	34.1	28.4	4.3	36.6	5.21	31.6	71.4	15.8	58.2	43.1	23.4	13.6	0.040	0.040	0.013	0.152
8	Feather	M	Y/O	0.3	31.1	58.0	9.4	1.2	37.8	5.41	32.2	70.7	12.9	49.3	15.4	23.2	13.1	0.041	0.032	0.013	0.131
9	Feather	ES	Y/O	2.2	48.4	45.1	3.6	0.7	38.4	5.37	31.6	71.4	15.0	59.9	53.6	22.4	14.8	0.027	0.011	0.038	0.122
10	Feather	Me	Y/O	3.7	59.3	33.8	2.4	0.8	39.2	5.29	32.5	71.5	14.5	58.0	47.8	23.6	14.9	0.035	ND	0.027	0.124
11	**Feather**	**S**	**W**	**3.0**	**58.9**	**35.3**	**2.3**	**0.5**	**39.8**	**5.34**	**30.8**	**79.9**	**-3.7**	**27.9**	**47.3**	**23.1**	**16.6**	**0.025**	**ND**	**0.036**	**0.129**
12	**Fancy**	**S**	**Y/O**	**3.0**	**26.1**	**33.7**	**29.9**	**7.3**	**35.6**	**5.20**	**32.7**	**74.0**	**13.7**	**57.3**	**30.8**	**21.6**	**14.3**	**0.017**	**ND**	**0.022**	**0.122**
13	**Feather**	**M**	**Y/O**	**3.5**	**56.2**	**34.8**	**4.4**	**1.0**	**40.6**	**5.25**	**28.6**	**74.5**	**6.0**	**43.0**	**37.9**	**24.6**	**12.9**	**0.022**	**ND**	**0.031**	**0.103**
14	Feather	S	Y/O	0.4	18.3	63.3	14.8	3.1	35.3	5.25	33.1	71.2	14.2	56.1	36.5	23.5	15.9	0.026	ND	0.035	0.135
15	Fancy	S	W	1.5	30.8	36.6	27.7	3.4	35.1	5.45	33.4	81.1	-3.6	26.1	41.7	21.8	13.8	0.016	0.014	0.032	0.126
16	Feather	M	Y/O	3.5	45.9	39.9	9.2	1.5	37.3	5.25	31.3	70.3	18.2	59.1	49.9	22.5	17.6	0.033	ND	0.032	0.155
17	Feather	M	Y/O	0.2	16.3	67.7	13.8	2.0	37.6	5.11	33.2	56.2	17.1	43.0	72.8	23.8	16.6	0.013	ND	0.005	0.075
18	**Fancy**	**M**	**W**	**0.4**	**18.3**	**63.3**	**14.8**	**3.1**	**36.9**	**5.29**	**32.3**	**81.6**	**-4.2**	**34.4**	**17.6**	**23.7**	**16.4**	**0.017**	**ND**	**0.038**	**0.113**
19	**Feather**	**Me**	**M**	**2.0**	**43.1**	**41.1**	**12.2**	**1.6**	**37.0**	**5.32**	**31.7**	**75.1**	**10.8**	**45.1**	**29.2**	**22.6**	**17.3**	**0.039**	**0.023**	**0.010**	**0.134**
20	**Feather**	**S**	**Y/O**	**3.4**	**52.2**	**40.5**	**3.0**	**0.9**	**37.5**	**5.25**	**32.0**	**71.2**	**14.4**	**57.8**	**47.4**	**22.0**	**16.5**	**0.019**	**0.017**	**0.030**	**0.127**
21	**Farm**	**Me**	**Y/O**	**7.1**	**68.5**	**19.2**	**3.8**	**1.4**	**35.6**	**4.91**	**33.9**	**52.0**	**16.1**	**35.0**	**66.6**	**24.1**	**16.2**	**0.027**	**0.014**	**ND**	**0.167**
22	Farm	S	Y/O	9.1	64.4	20.5	4.4	1.6	34.9	5.11	34.1	44.2	16.6	25.4	53.6	23.4	18.0	0.013	0.010	ND	0.070
23	Feather	M	Y/O	65.7	4.2	11.8	15.2	3.1	36.9	5.16	32.2	38.4	17.4	21.4	47.3	22.9	15.3	0.012	0.023	0.012	0.068
24	Feather	S	Y/O	0.4	19.7	65.3	12.6	2.0	36.3	5.03	31.7	52.8	19.6	40.4	69.3	23.7	16.5	0.015	ND	0.007	0.074
25	Feather	Me	Y/O	1.6	61.7	30.7	4.8	1.2	37.6	5.36	33.8	70.0	16.3	59.7	48.7	23.2	13.8	0.029	0.0098	0.037	0.117
LSD[8]				*4.2*	*12.1*	*8.2*	*5.8*	*1.7*	*1.2*	*0.04*	*2.2*	*0.8*	*0.4*	*0.9*	*3.5*	*0.5*	*2.3*	*0.0026*	*0.0016*	*0.0011*	*0.0031*

1 Numbers represent commercial Cheddar cheese shreds. Bolded lines represent samples selected for consumer testing.
2 Sharp represents the labeled sharpness on the packaging where M = “mild”, Me = “medium”, S = “sharp”, and ES = “extra sharp”.
3 Color represents the color of each cheese shred where W= white, Y/O = yellow/orange, and M = mixed white and yellow/orange.
4 Sieve pans openings were reported in diameters (cm). Results in each column represent the percentage by weight of cheese left on each sieve.
5 Initial color measurements of cheese shreds
6 Color change measurement after baking. Equation from Hunter (1975).
7 ND = Not detected.
8 LSD= least significant difference. Means that differ by the LSD are different ($p<0.05$)

Table 3. Pearson correlation matrix (r) between hot and cold texture descriptive analysis data.

		visible powder	color	hand cohesiv eness	degree of breakdo wn	tackiness	cohesiveness	adhesiveness	smoothness of mass	smoothness of mouthcoat	degree of mouthcoat	Visible surface moisture	meltedness	stretchability	oiliness to lips	hardness	tackiness	cohesiveness	adhesiveness	oiliness	smoothness of mass	mouthcoating
Cold Texture	visible powder	**1.00**	0.13	-0.36	-0.37	-0.13	**-0.45**	**-0.52**	-0.18	-0.09	0.34	-0.28	-0.15	0.36	**-0.50**	**0.50**	-0.20	0.32	-0.27	**-0.64**	-0.23	**-0.61**
	color		**1.00**	-0.12	-0.02	-0.14	-0.09	-0.07	0.06	0.05	-0.15	-0.30	-0.35	0.26	**-0.46**	-0.12	-0.14	-0.27	0.05	-0.28	-0.08	-0.02
	hand cohesiveness			**1.00**	**0.87**	**0.50**	**0.87**	**0.83**	**0.73**	**0.65**	0.15	0.34	0.21	**-0.47**	**0.66**	**-0.50**	0.21	-0.10	0.03	**0.67**	0.20	**0.65**
	degree of breakdown				**1.00**	**0.76**	**0.95**	**0.89**	**0.86**	**0.79**	0.25	0.35	0.22	**-0.49**	**0.65**	**-0.61**	0.14	-0.03	0.00	**0.67**	0.39	**0.68**
	tackiness					**1.00**	**0.70**	**0.63**	**0.65**	**0.57**	0.17	0.19	0.17	**-0.40**	**0.46**	-0.39	0.24	0.20	-0.15	**0.50**	**0.50**	**0.44**
	cohesiveness						**1.00**	**0.96**	**0.83**	**0.76**	0.09	0.39	0.27	**-0.57**	**0.72**	**-0.68**	0.14	-0.12	0.07	**0.76**	0.39	**0.78**
	adhesiveness							**1.00**	**0.73**	**0.63**	-0.03	**0.43**	0.30	**-0.52**	**0.75**	**-0.67**	0.19	-0.15	0.08	**0.81**	0.36	**0.83**
	smoothness of mass								**1.00**	**0.97**	0.30	0.15	0.13	-0.28	0.35	**-0.48**	0.26	0.04	-0.10	**0.50**	0.39	**0.49**
	smoothness of mouthcoat									**1.00**	0.39	0.14	0.13	-0.27	0.31	**-0.42**	0.18	0.08	-0.14	0.39	0.36	**0.42**
	degree of mouthcoat										**1.00**	0.00	0.07	-0.06	-0.03	0.20	-0.15	0.31	-0.20	-0.26	-0.19	-0.38
Hot Texture	Visible surface moisture											**1.00**	**0.84**	-0.20	**0.78**	-0.04	0.15	0.05	-0.20	**0.55**	0.22	**0.58**
	meltedness												**1.00**	-0.16	**0.64**	0.02	0.21	-0.02	-0.11	**0.54**	0.15	**0.43**
	stretchability													**1.00**	**-0.54**	**0.61**	0.00	0.10	-0.17	**-0.50**	-0.16	**-0.40**
	oiliness to lips														**1.00**	**-0.42**	0.10	-0.06	0.04	**0.81**	0.27	**0.77**
	hardness															**1.00**	0.20	**0.52**	**-0.57**	**-0.54**	-0.24	**-0.56**
	tackiness																**1.00**	0.36	**-0.55**	0.36	0.22	0.20
	cohesiveness																	**1.00**	**-0.90**	-0.30	**0.48**	-0.25
	adhesiveness																		**1.00**	0.19	**-0.41**	0.08
	oiliness																			**1.00**	0.28	**0.86**
	smoothness of mass																				**1.00**	0.40
	mouthcoating																					**1.00**

Values in bold are significant ($p<0.05$).

Table 4. Descriptive flavor attribute means for Cheddar cheese shreds selected for consumer testing.

	Sensory Attribute[1]												
	Aromatics								Basic Tastes				
Sample[2]	Cooked	Whey	Diacetyl	Milk Fat	Sulfur	Brothy	Nutty	Grassy	Sour	Bitter	Salty	Sweet	Umami
3	3.3	1.5	ND[3]	3.1	2.3	2.4	1.7	ND	3.9	1.1	4.1	2.8	2.9
4	3.1	1.5	ND	3.8	1.8	2.9	2.9	ND	3.3	ND	3.9	3.0	3.4
6	3.3	2.6	ND	3.1	2.9	3.1	ND	ND	3.1	1.0	3.7	2.7	2.8
11	3.5	2.1	ND	3.1	1.2	2.1	1.4	ND	3.0	0.6	3.6	2.5	2.7
12	3.8	3.1	1.4	3.7	1.3	1.3	0.0	ND	4.0	ND	3.8	2.4	3.1
13	4.0	3.8	1.4	3.7	ND	ND	ND	ND	3.7	ND	3.8	2.0	3.0
18	3.3	2.5	ND	3.2	ND	ND	ND	1.4	2.8	ND	3.1	2.0	2.0
19	3.8	2.8	1.2	3.3	ND	ND	ND	ND	3.2	ND	3.3	2.1	2.3
20	2.7	2.0	ND	3.1	2.6	2.6	ND	ND	3.0	ND	3.6	2.9	3.5
21	4.2	3.5	1.0	3.1	ND	1.1	ND	ND	3.1	ND	3.6	2.1	2.8
LSD	*0.22*	*0.19*	*0.11*	*0.17*	*0.15*	*0.21*	*0.20*	*0.10*	*0.20*	*0.07*	*0.18*	*0.17*	*0.19*

Cheddar cheese flavors fall between 0 and 5 on this scale (Drake et al., 2001, 2008, 2009)

1 Intensities scored on a 0 to 15-point universal scale consistent with the Spectrum™ intensity scale.

2 Numbers represent commercial Cheddar cheese shreds.

3 ND = Not detected.

Table 5. Demographic information and consumption characteristics of Cheddar cheese shred consumers (n=151)

Gender	Male	48.3%
	Female	51.7%
Age (y)	18-24	19.2%
	25-34	33.8%
	35-44	17.2%
	45-54	17.2%
	55-64	12.6%
Income ($K)	15-24.9	7.3%
	25-34.9	9.9%
	35-49.9	17.2%
	50-69.9	22.5%
	70-99.9	21.9%
	>100	21.2%
Type of Cheese Shreds Purchased[1]	Cheddar/Cheddar Jack	100.0%
	Monterey Jack	49.7%
	Colby Jack	44.4%
	Nacho Cheese	21.2%
	Parmesan	69.5%
	Gouda	21.9%
	Mozzerella	87.4%
	4 Cheese Mexican	76.8%
	Pepper Jack	52.3%
	Queso Chihuahua	9.3%
	Swiss	43.0%
	Italian Blend	47.7%
	Other	0.7%
Typical sharpness purchased	Mild	4.0%
	Medium	21.2%
	Sharp	57%
	Extra Sharp	17.9%
Cut	Fancy/Fine	17.9%
	Regular/Traditional	79.5%
	Farmstyle/Extra-Thick	2.6%
How do you typically consume Cheddar cheese shreds [1]	Eat it straight	59.6%
	Cold as a compliment/condiment	84.1%
	Cold as an ingredient	76.2%
	Hot as a compliment/condiment	95.4%
	Hot as an ingredient	90.7%
Purchase influence Factors[1]	Cost	80.1%
	Convenience	35.8%
	Flavor	89.4%
	Sharpness	72.2%
	Brand	45.0%
	Texture	52.3%
	Health/Nutritional Value	36.4%

Table 5 (continued).

	Availability	53.0%
	Organic	9.9%
	Appearance	55.0%
	Package Size	49.0%
	Package Type	12.6%
Brands[1]	Sargento	78.8%
	Kraft	86.1%
	Organic Valley	35.1%
	Borden	30.5%
	Horizon	29.1%
	Tillamook	9.9%
	Cabot	21.2%
	Velveeta	23.2%
	Store Brand	51.7%
	Other	2.6%
Ethnicity	Caucasian	70.9%
	African American	13.2%
	Asian	8.6%
	Hispanic	4.6%
	Other	2.6%

1 Check-all-that-apply (CATA) question. Consumers were allowed to choose more than 1 category so category percentages do not add up to 100.

Table 6. Consumer liking means for Cheddar cheese shreds (n=151).

Descriptive flavor Attributes[1]	Cheddar Cheese Shreds[2]										LSD[3]
	3	**4**	**6**	**11**	**12**	**13**	**18**	**19**	**20**	**21**	
Overall Appearance Liking	6.8	7.0	6.1	6.8	6.9	6.8	6.8	6.9	6.9	5.1	*0.4*
Color Liking attribute	7.2	7.0	6.6	6.8	7.0	7.1	6.8	6.9	7.1	5.8	*0.3*
Shred Size Liking	6.5	6.9	6.9	6.9	6.7	6.7	6.6	7.0	6.8	4.9	*0.4*
Overall Liking	5.7	6.9	6.2	6.6	6.8	5.9	6.0	6.6	7.1	6.1	*0.4*
Flavor Liking	5.6	6.9	6.3	6.6	6.7	5.9	5.9	6.5	7.0	6.3	*0.4*
Saltiness Liking	6.0	6.6	6.4	6.5	6.5	5.9	6.3	6.6	6.9	6.5	*0.4*
Savory Liking	5.8	6.8	6.2	6.6	6.6	5.7	6.1	6.5	7.0	6.5	*0.4*
Sour Liking	5.5	6.3	6.2	6.3	6.3	5.7	5.8	6.3	6.5	6.1	*0.4*
Texture Liking	6.7	7.0	6.6	7.0	6.9	6.6	6.5	6.8	7.1	6.2	*0.3*

1 Attributes were scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.
2 Numbers represent commercial Cheddar cheese shreds.
3 LSD = least significant difference.

Table 7. Consumer JAR scores and CATA results for Cheddar cheese shreds (n=151)

JAR Attributes and Levels[2]		**Cheddar Cheese Shreds[1]**									
		3	**4**	**6**	**11**	**13**	**12**	**18**	**19**	**20**	**21**
Color JAR light	**Too Dark**	6.6%ab	3.9%ab	7.2%ab	2%b	17.8%a	2%b	3.9%ab	5.2%ab	11%ab	1.3%b
	JAR	87.5%a	71.9%a	79.6%a	71.7%a	78.9%a	81.7%a	75.8%a	86.9%a	83.1%a	41.8%b
	Too Light	5.9%de	24.2%bc*	13.2%bcde	26.3%b	3.3%e	16.3%bcde	20.3%bcd*	7.8%cde	5.8%de	56.9%a
Shred Size JAR length	**Too Short**	11.2%a	10.5%a	2.0%ab	3.3%ab	0.0%b	11.8%a	14.4%a	5.2%ab	3.2%ab	9.8%ab
	JAR	81.6%a	83.7%a	84.2%a	87.5%a	77.6%ab	79.7%ab	81.7%a	82.4%a	89.0%a	60.8%b
	Too Long	7.2%bc	5.9%c	13.8%abc	9.2%bc*	22.4%ab	8.5%bc	3.9%c	12.4%abc	7.8%bc	29.4%a*
Shred Size JAR width	**Too Thin**	49.3%a	5.2%cd	11.8%c	9.2%cd	0.7%d	34%ab	47.1%a	15%bc	0%d	4.6%cd
	JAR	50.7%c	73.9%ab	75%a	77.6%a	69.1%abc	65.4%abc	52.9%bc	79.7%a	60.4%abc	27.5%d
	Too Thick	0%e	20.9%bc*	13.2%cd	13.2%cd*	30.3%bc	0.7%e	0%e	5.2%de	39.6%b*	68.0%a*
Overall Flavor JAR	**Too Mild**	13.2%cd	3.9%d	44.7%ab*	34.9%b*	63.2%a	37.9%b*	35.9%b*	32.0%bc*	5.2%d	25.5%bc*
	JAR	49.3%bc	69.9%ab	52%bc	58.6%ab	34.2%c	55.6%bc	50.3%bc	63.4%ab	77.9%a	63.4%ab
	Too Strong	37.5%a*	26.1%ab*	3.3%cd	6.6%cd	2.6%d	6.5%cd	13.7%bcd	4.6%cd	16.9%bc	11.1%bcd
Saltiness JAR	**Too little**	15.8%bc	5.2%c	19.7%abc	13.8%bc*	36.8%a	20.9%ab*	19%abc	13.1%bc	6.5%bc	11.1%bc
	JAR	64.5%ab	75.2%ab	77%ab	75%ab	57.9%b	72.5%ab	69.9%ab	77.1%ab	79.9%a	80.4%a
	Too much	19.7%a	19.6%a	3.3%b	11.2%ab	5.3%ab	6.5%ab	11.1%ab	9.8%ab	13.6%ab	8.5%ab
Savory JAR	**Too little**	19.1%bcd	7.8%cd	31.6%ab*	23%bc*	49.3%a	26.1%b*	28.8%ab*	25.5%b*	5.8%d	17%bcd
	JAR	54.6%cd	74.5%abc	65.1%bcd	72.4%abc	48%d	69.9%abcd	60.8%bcd	69.3%abcd	85.1%a	76.5%ab
	Too much	26.3%a*	17.6%ab	3.3%c	4.6%bc	2.6%c	3.9%bc	10.5%abc	5.2%bc	9.1%abc	6.5%bc
Sour JAR	**Too little**	9.9%bc	2.6%c	15.8%abc	19.7%ab*	28.9%a	15.7%abc	15.7%abc	13.7%abc	7.1%bc	4.6%c
	JAR	55.3%a	69.3%a	75.7%a	69.7%a	53.9%a	75.2%a	65.4%a	72.5%a	74%a	73.9%a
	Too much	34.9%a*	28.1%ab*	8.6%c	10.5%bc	17.1%abc	9.2%c	19%abc	13.7%bc	18.8%abc	21.6%abc*
Firmness JAR	**Too Soft**	8.6%a	3.9%a	17.1%a	7.9%a	7.9%a	12.4%a	10.5%a	9.2%a	7.1%a	5.2%a
	JAR	84.9%a	75.2%a	80.3%a	86.8%a	82.9%a	81.7%a	78.4%a	81.7%a	82.5%a	68.0%a
	Too Hard	6.6%bc	20.9%ab*	2.6%c	5.3%c	9.2%abc	5.9%bc	11.1%abc	9.2%bc	10.4%abc	26.8%a*
Crumbly JAR	**Too Crumbly**	10.5%abc	7.8%abc	13.8%ab	9.9%abc	1.3%c	5.2%bc	21.6%a*	9.8%abc	1.3%c	5.9%abc
	JAR	82.2%a	81.7%a	72.4%a	75%a	70.4%a	85%a	71.2%a	78.4%a	87%a	69.3%a
	Too Rubbery	7.2%c	10.5%abc	13.8%abc	15.1%abc	28.3%a*	9.8%bc	7.2%c	11.8%abc	11.7%abc	24.8%ab*

Table 7 (continued).

Sharpness[3]	**Mild**	19.7%cd	4.6%e	43.4%b	33.6%bc	67.8%a	36.6%bc	45.1%ab	30.7%bc	7.1%de	19.6%cd
	Medium	25.7%abc	15.7%c	42.1%ab	39.5%ab	23%bc	40.5%ab	28.1%abc	43.8%ab	24.7%abc	45.8%a
	Sharp	38.8%abc	45.8%ab	13.8%de	25.7%abcde	8.6%e	19%cde	15.7%de	24.8%bcde	47.4%a	27.5%abcd
	Extra Sharp	15.8%abc	34%a	0.7%d	1.3%d	0.7%d	3.9%cd	11.1%bcd	0.7%d	20.8%ab	7.2%bcd
Consume[2,5]	**Straight**	25%a	48.4%cb	34.9%ba	41.4%cba	38.2%cba	38.6%cba	32.7%ba	34%ba	58.4%c	43.1%cba
	Cold Condiment	59.9%a	64.1%a	61.8%a	69.7%a	57.2%a	71.9%a	63.4%a	66%a	71.4%a	54.9%a
	Cold Ingredient	59.2%a	64.1%a	59.9%a	64.5%a	52.6%a	66.7%a	56.9%a	65.4%a	70.1%a	54.9%a
	Hot Condiment	78.9%ba	82.4%ba	79.6%ba	75.7%ba	67.8%a	85%ba	71.2%ba	88.2%b	84.4%ba	69.3%a
	Hot Ingredient	67.1%a	81.7%a	71.7%a	80.3%a	67.1%a	73.9%a	68.6%a	79.7%a	83.8%a	75.8%a
PI influence[4,5]	**Appearance**	50.7%a	61.4%a	55.9%a	54.6%a	50.7%a	53.6%a	49%a	57.5%a	59.1%a	54.9%a
	Flavor	70.4%a	77.1%a	72.4%a	76.3%a	69.7%a	74.5%a	68%a	73.2%a	87%a	68.0%a
	Texture	30.9%a	39.2%a	36.8%a	37.5%a	37.5%a	35.3%a	30.7%a	36.6%a	40.9%a	35.3%a

1 Numbers represent commercial Cheddar cheese shreds.
2 JAR questions were scored on a 5-point scale where 1 or 2 = too little, 3 = just about right, and 4 or 5 = too much. Percentage of consumers that selected these options is presented. If a significant penalty was assigned to liking for a JAR attribute, it is indicated with a *.
3 The sharpness question asked consumers to identify their perceived sharpness of each cheese shred.
4 Purchase intent influence allowed consumers to identify and comment on what characteristics affected their purchase intent for each cheese shred.
5 Check-all-that-apply (CATA) question. Consumers were allowed to choose more than one category so category percentages do not add up to 100.

Table 8. Consumer Check All That Apply (CATA) attribute scores for Cheddar cheese shreds (n=151). Consumers were instructed to select attributes that described each cheese shred.

Attribute[2]	Cheddar Cheese Shreds[1]									
	3	**4**	**6**	**11**	**12**	**13**	**18**	**19**	**20**	**21**
Milky/dairy	54.3%a	61.6%a	70.2%a	71.5%a	64.2%a	65.6%a	60.9%a	65.6%a	66.9%a	61.6%a
Buttery	24.5%a	26.5%a	35.1%a	32.5%a	30.5%a	27.2%a	24.5%a	31.1%a	29.1%a	32.5%a
Milkfat(creamy)	13.9%a	23.8%a	24.5%a	28.5%a	32.5%a	29.1%a	17.2%a	24.5%a	30.5%a	26.5%a
Sulfur/eggy	17.2%a	13.2%a	3.3%a	6%a	4.6%a	5.3%a	11.3%a	6.6%a	11.3%a	6.6%a
Brothy (meaty)	14.6%a	17.9%a	11.3%a	11.3%a	9.3%a	6%a	8.6%a	11.9%a	15.2%a	15.2%a
Nutty	17.9%a	19.9%a	10.6%a	15.9%a	11.3%a	7.3%a	19.2%a	10.6%a	19.2%a	14.6%a
Bitter	28.5%ab	31.8%a	5.3%c	9.9%c	4.6%c	7.9%c	18.5%abc	11.3%bc	11.9%bc	12.6%bc
Salty	39.7%ab	54.3%a	36.4%ab	49.7%a	33.8%ab	21.2%b	41.1%ab	42.4%ab	49.7%a	39.7%ab
Sweet	7.9%a	6.6%a	12.6%a	8.6%a	12.6%a	7.3%a	7.3%a	11.3%a	9.3%a	7.9%a
Savory	43%ab	48.3%a	36.4%ab	40.4%ab	33.8%ab	25.2%b	37.1%ab	36.4%ab	51.7%a	49.7%a
Sour	10.6%a	11.3%a	5.3%a	7.9%a	5.3%a	5.3%a	6.0%a	4.0%a	7.9%a	5.3%a
Soft	45.7%ab	24.5%b	55.0%a	55.0%a	58.9%a	48.3%a	41.7%ab	49.7%a	41.1%ab	25.2%b
Hard	6.6%bc	29.1%a	3.3%c	6.0%c	2.6%c	13.9%abc	11.9%abc	8.6%bc	15.9%abc	22.5%ab
Dry/crumbly	8.6%ab	16.6%ab	17.2%ab	9.9%ab	7.9%b	3.3%b	25.8%a	15.2%ab	5.3%b	13.9%ab
Rubbery	7.3%b	11.3%ab	11.3%ab	15.2%ab	8.6%b	28.5%a	7.9%b	13.9%ab	11.3%ab	22.5%ab
Long shreds	26.5%ab	25.2%ab	37.7%ab	38.4%ab	23.2%ab	41.7%ab	20.5%b	33.1%ab	36.4%ab	44.4%a
Short shreds	25.2%ab	23.8%abc	15.2%abc	11.9%bc	31.8%a	7.9%c	31.8%a	19.2%abc	14.6%abc	9.9%bc
Thick shreds	2.0%d	47.0%b	39.7%bc	45.7%b	1.3%d	70.9%a	1.3%d	21.2%c	83.4%a	86.1%a
Thin shreds	84.8%a	14.6%cd	25.8%bc	15.9%cd	70.2%a	3.3%d	76.8%a	43%b	2.6%d	6.0%d
Orange	73.5%a	0.0%c	70.9%a	0.0%c	61.6%ab	75.5%a	0.7%c	62.9%a	76.2%a	39.1%b
Yellow	20.5%bc	6.0%cd	23.8%b	4.0%d	32.5%ab	18.5%bc	6.6%cd	23.8%b	19.2%bc	46.4%a
White	0.7%c	86.1%ab	2.6%c	91.4%a	0.0%c	0.0%c	85.4%ab	70.2%b	0.7%c	2.6%c

1 Numbers represent commercial Cheddar cheese shreds.

2 Consumers were allowed to select multiple categories to describe each cheese shred, so category percentages do not add up to 100%.

FIGURES

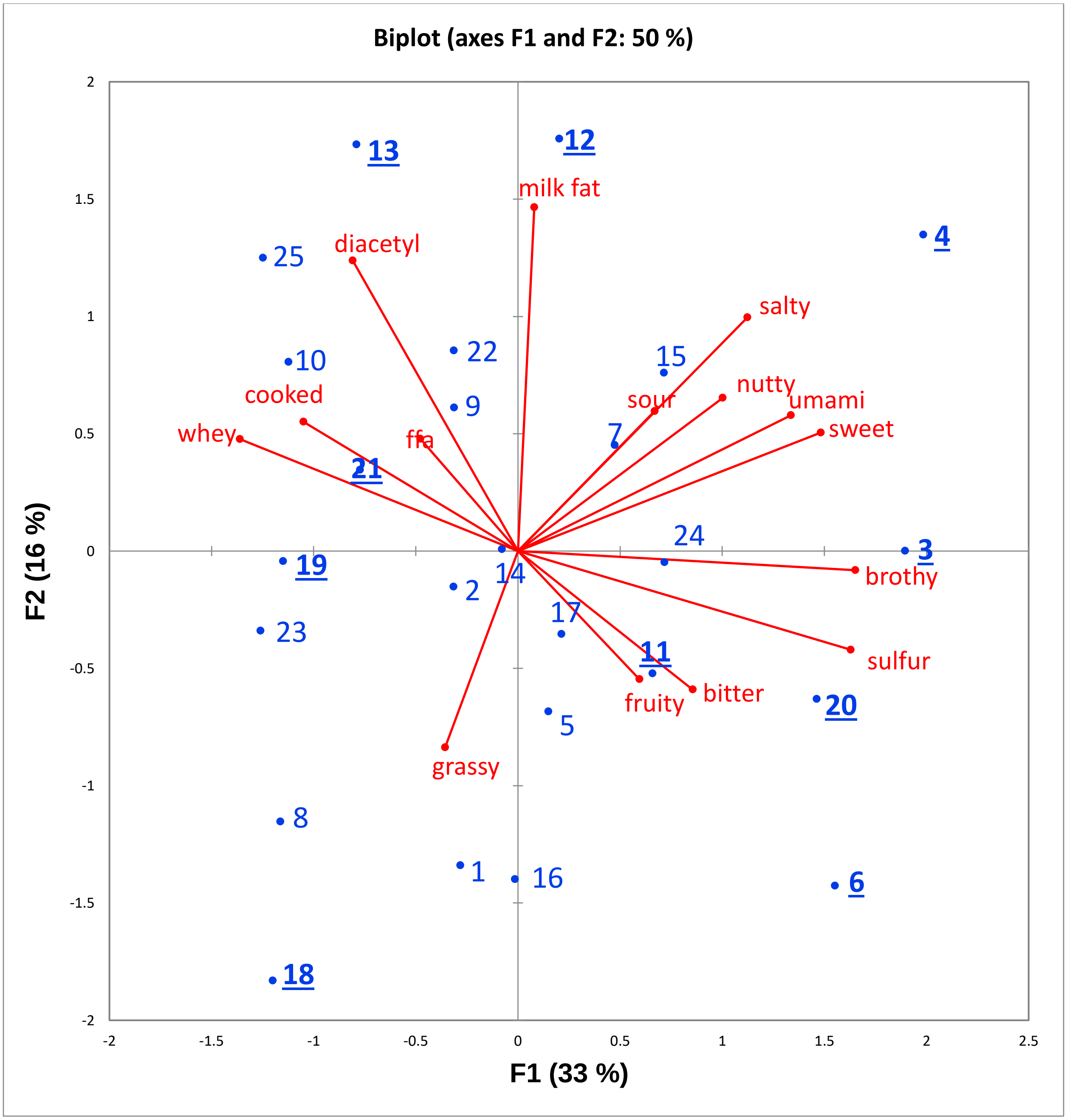

Figure 1. Principle component biplot of descriptive analysis of Cheddar cheese shred flavor.

Numbers represent commercial Cheddar cheese shreds.

Underlined samples represent samples chosen for consumer testing.

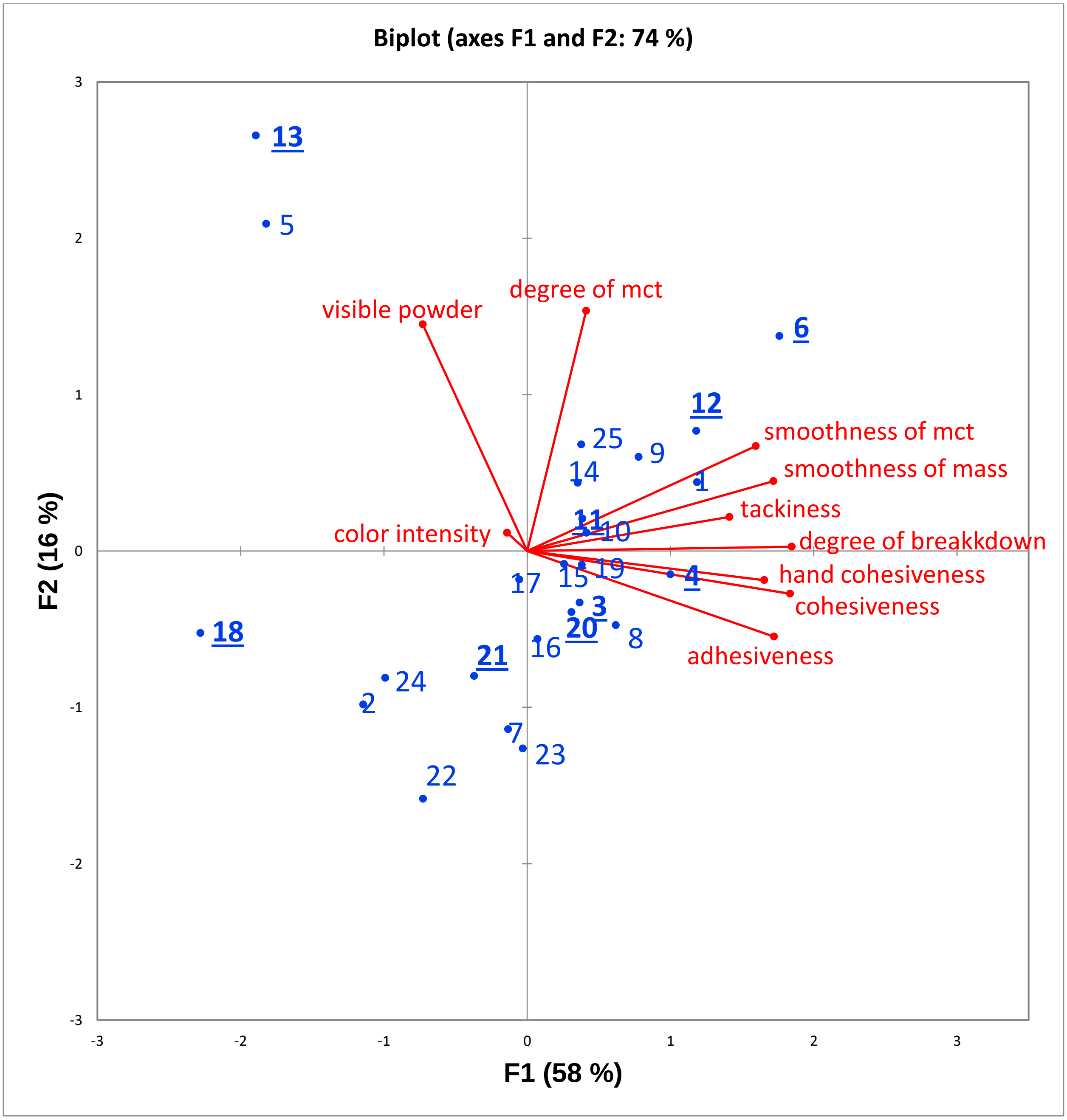

Figure 2. Principle component biplot of descriptive analysis of Cheddar cheese shred cold texture.

Numbers represent commercial Cheddar cheese shreds.

Underlined samples represent shreds chosen for consumer testing.

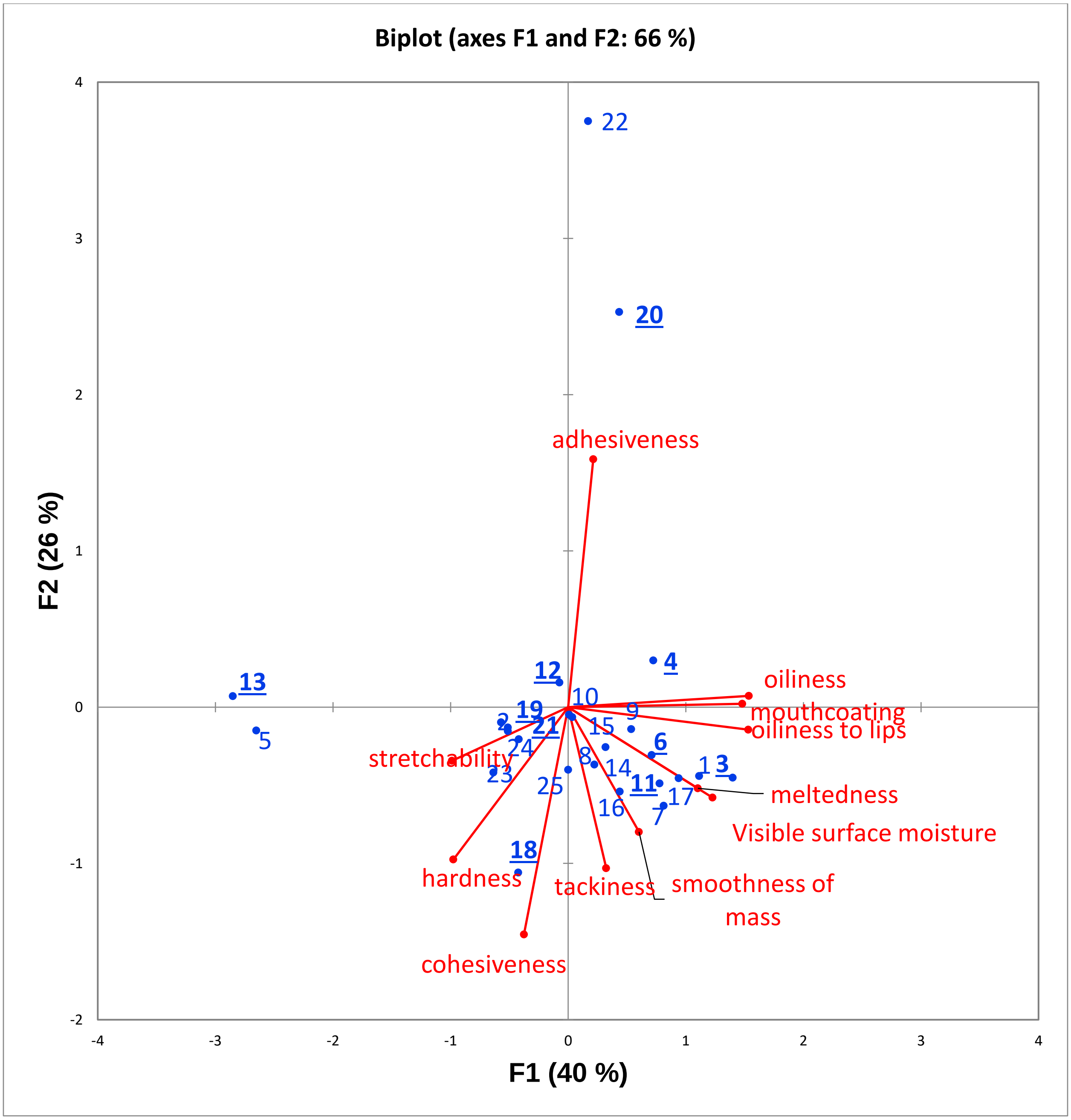

Figure 3. Principle component analysis biplot of descriptive analysis of Cheddar cheese shred hot texture. Numbers represent commercial Cheddar cheese shreds. Underlined samples represent shreds chosen for consumer testing.

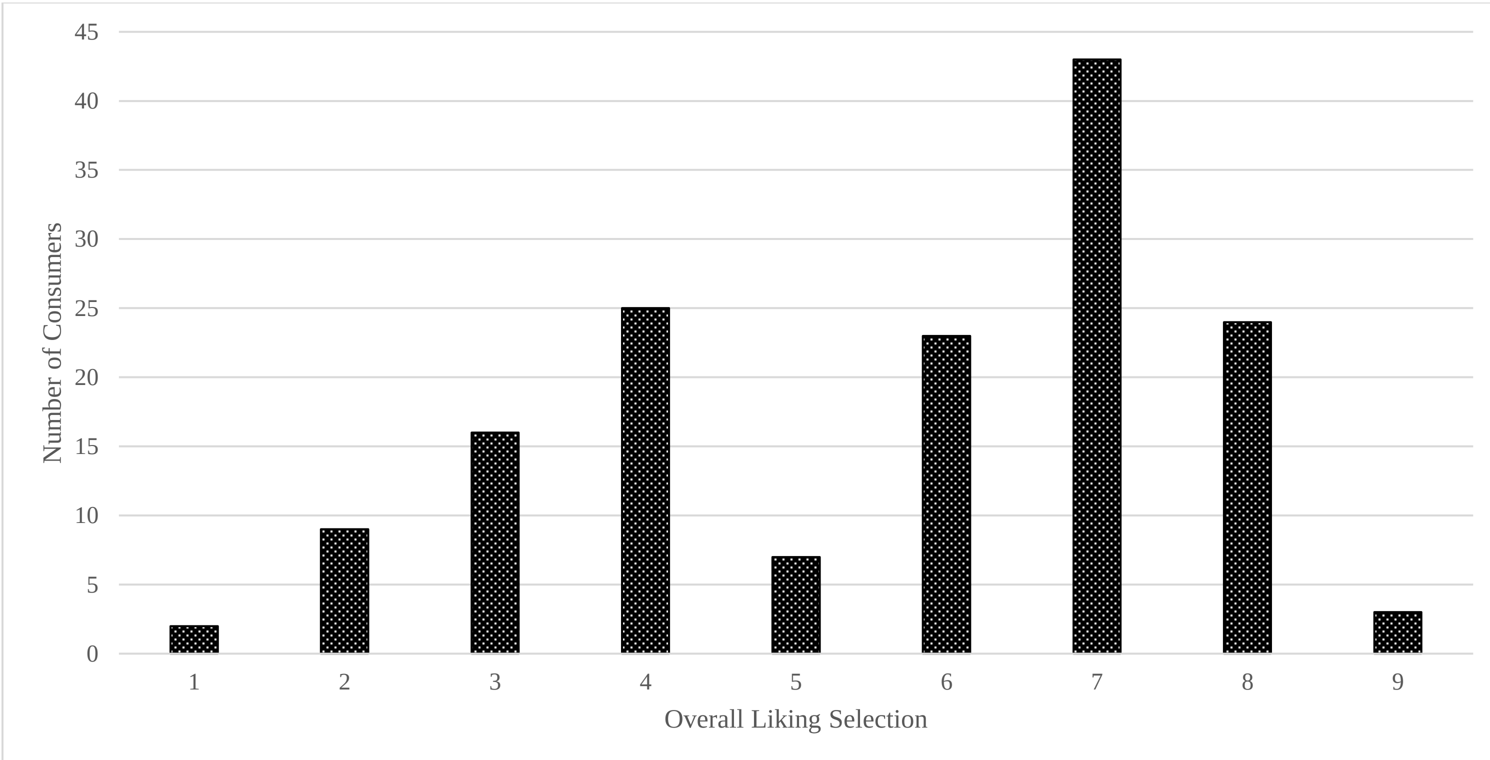

Figure 4. Frequency distribution of overall liking scores for cheese shred 3.

Liking was scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely (n=151).

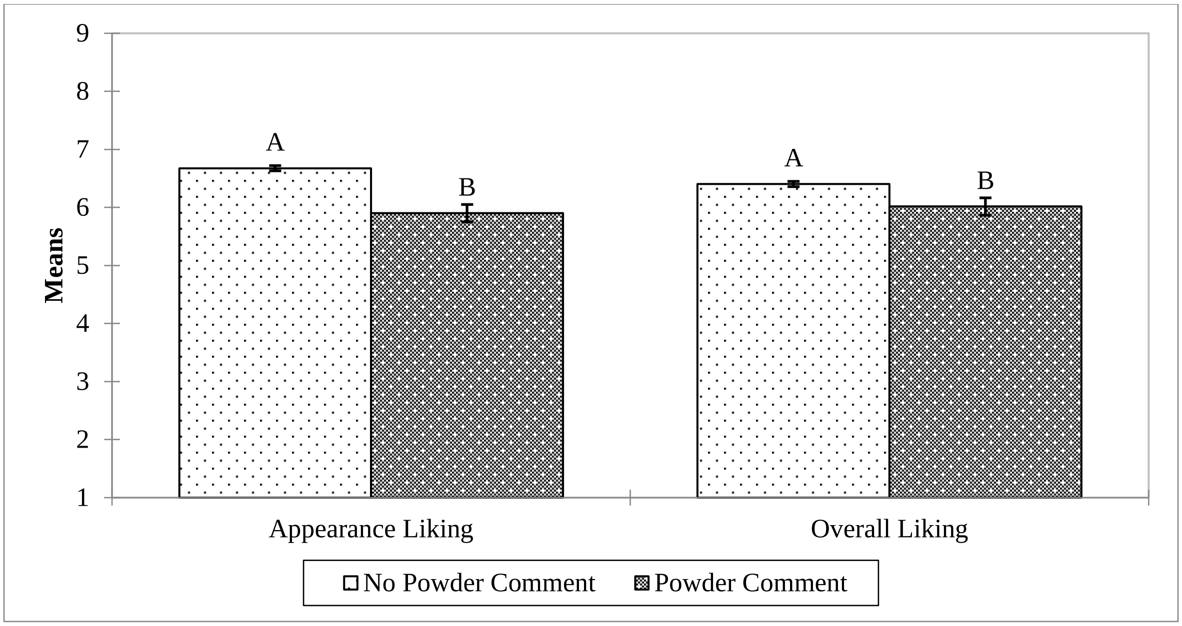

Figure 5. Appearance and overall liking scores of consumers (n=61) who negatively mentioned a "powdery" appearance compared to those who did not (n=90).

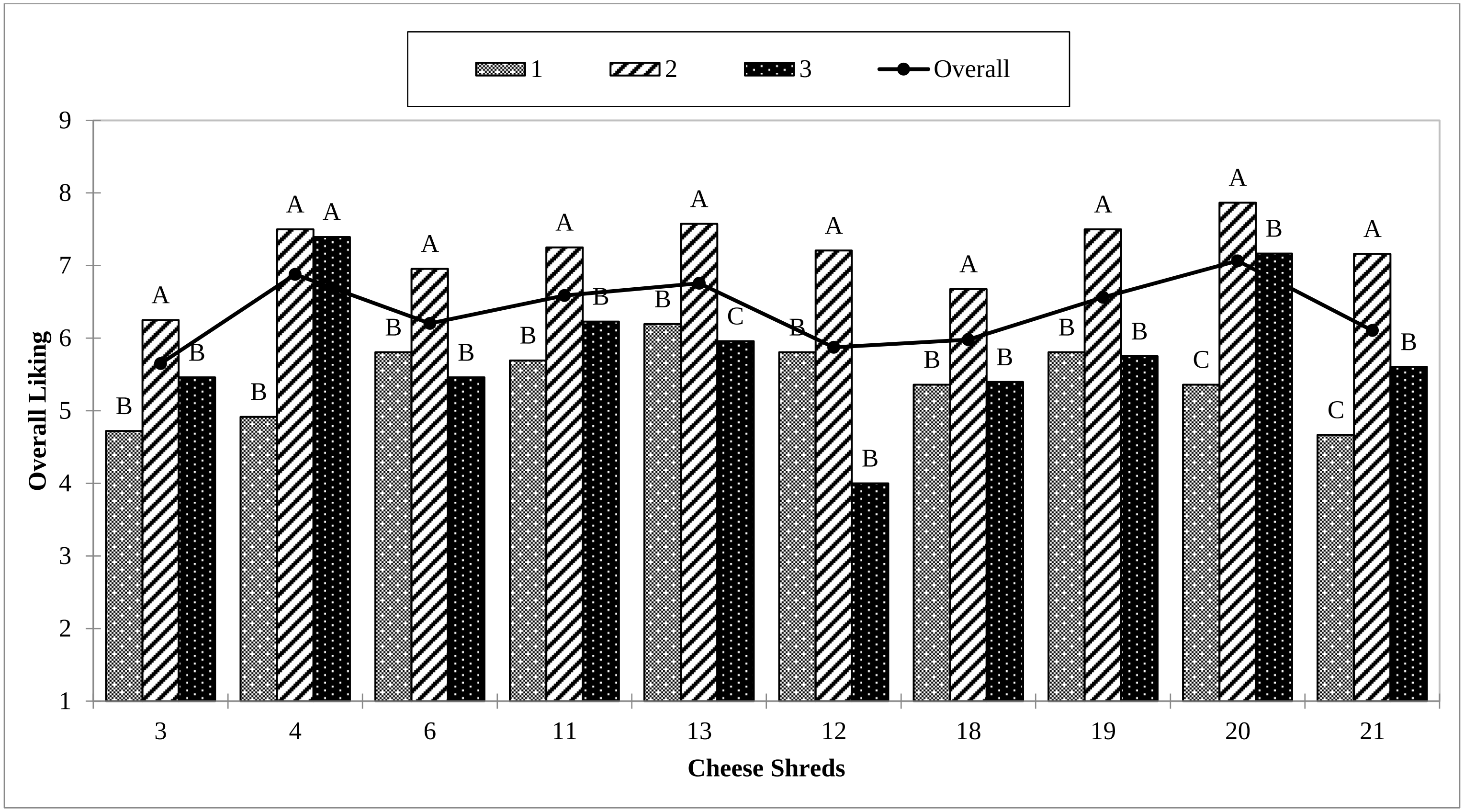

Figure 6. Overall liking scores of all consumers and identified consumer clusters for Cheddar cheese shreds.
Numbers represent commercial Cheddar cheese shreds.
Different letters within each sample signify differences ($p<0.05$).

All consumers (n=151), cluster 1 (n= 35), cluster 2 (n=68), and cluster 3 (n=48).

Liking was scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.

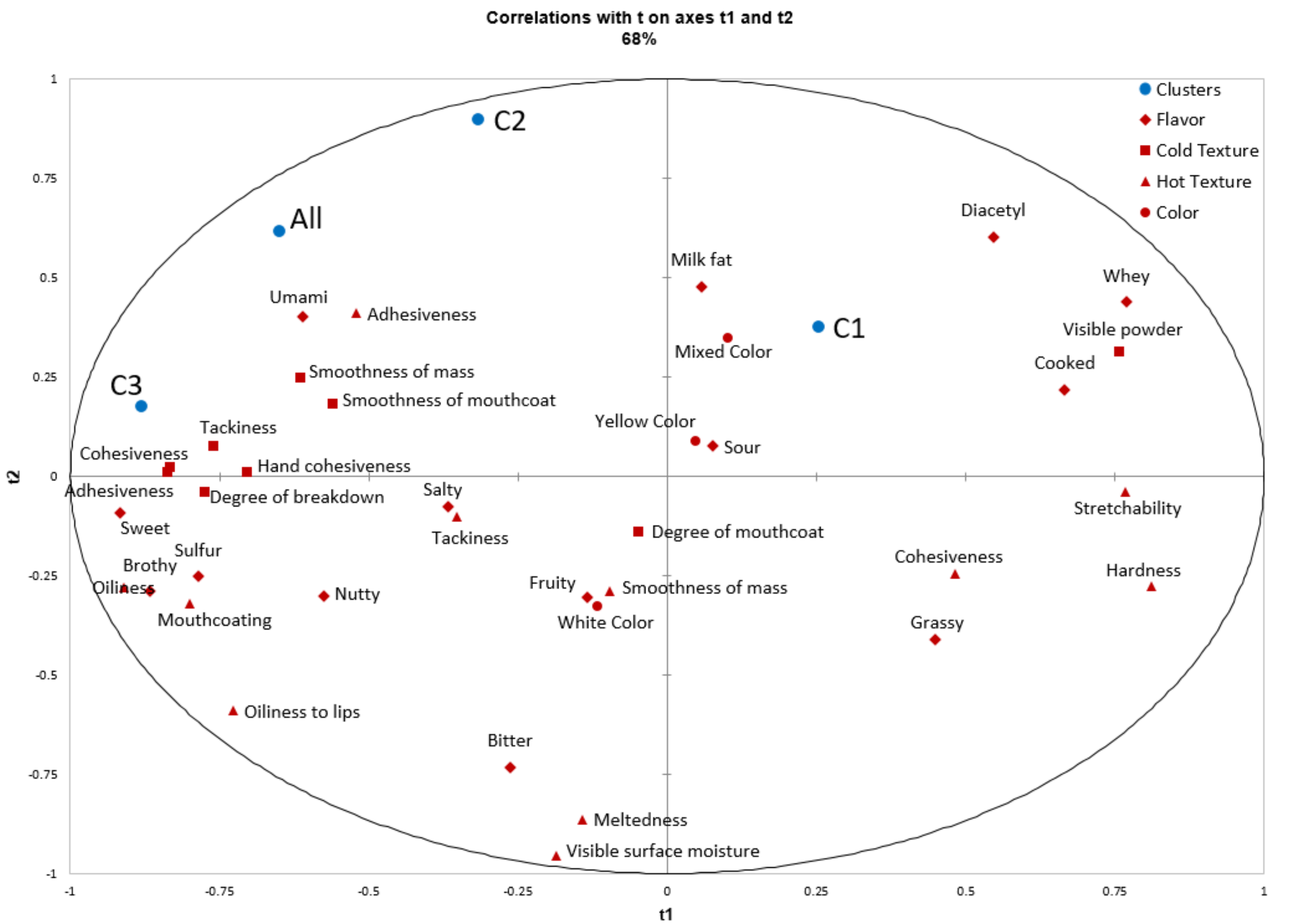

Figure 7. Partial least squares regression for CLT cheese shreds and consumer clusters. All consumers (n=151), cluster 1 (n= 35), cluster 2 (n=68), and cluster 3 (n=48).

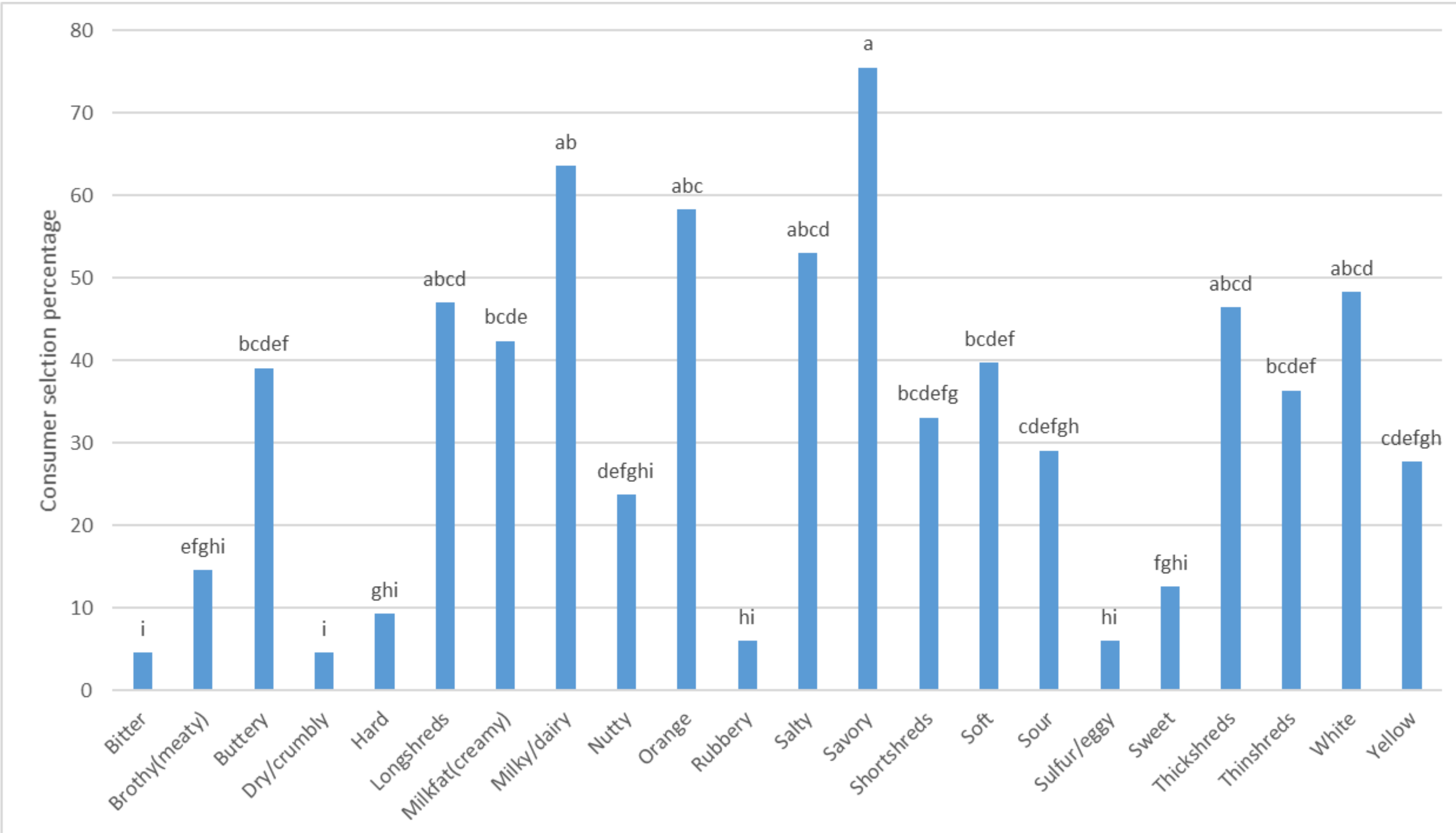

Figure 8. Ideal Cheddar shreds CATA for all consumers. Consumers were instructed to select attributes that described their ideal cheese shred. Consumers were allowed to select multiple categories to describe each cheese shred, so category percentages do not add up to 100%. Different letters signify differences (p<0.05).

CHAPTER 3:

CONSUMER PERCEPTION OF ANTICAKING AGENTS ON SHREDDED CHEDDAR CHEESE

Consumer Perception of Anticake Agents on Cheddar Cheese Shreds

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ABSTRACT

Prepackaged natural cheese shreds are a growing consumer category. Anticake agents are applied to commercial cheese shreds to assist with shelf-life and ease of use. The objective of this study was investigate consumer perception of three anticake agents applied at various levels to Cheddar cheese shreds. Three common anticake agents (potato/cellulose blend, potato, and potato/ corn/ calcium sulfate) were applied to duplicate lots of Cheddar cheese shreds at 1, 2, 3, 4, and 5 % (w/w). Control Cheddar cheese shreds with no anticake were included. Sensory properties (appearance, flavor, texture, and hot texture) were documented using a trained sensory panel. Three consumer acceptance tests were conducted. In test one, Consumers (n=110) visually evaluated liking of cold shred appearance. In test two, consumers (n=100) evaluated melted shreds on a flour tortilla for overall, appearance, flavor and texture liking. Finally, consumers (n=49) participated in a home usage test (HUT). Two-way analysis of variance (anticake x anticake application rate) was used to interpret the collected data.

Visual appearance of shreds was the primary attribute impacted by anticake application and anticake agent ($p<0.05$). Results from trained panelists demonstrated that the potato anticake had minimal effects on visual appearance. The other two agents (80/20 potato/cellulose and potato/corn/ calcium sulfate) had increases in visible powder at > 3% (w/w). Consistent with trained panelists, higher application rates decreased consumer appearance and color liking for Cheddar shreds with 80/20 potato/cellulose and potato/corn/ calcium sulfate blends at > 2 or 3% (w/w), respectively. Consumer appearance liking of melted shreds decreased with increased anticake application percent but decreased the most for potato anticake at greater than 1% (w/w) application. Overall liking, flavor, and texture liking attributes for shreds were negatively impacted in melted cheese consumer liking at >3% (w/w) application but were not specific to anticake agent. These results demonstrate that anticake agents can be applied to Cheddar cheese shreds at up to 3% (w/w) with minimal impact on consumer perception.

Key words: Cheddar Cheese Shreds, Consumer Liking, Anticake agents

INTRODUCTION

From 2012 to 2017, cheese sales increased by 10% with total category sales expected to rise an additional 8%, totaling $25.5 billion of annual sales by 2022 (Mintel Group Ltd, 2017). According to the USDA, Cheddar consumption was second only to mozzarella with approximately 4.7 kg consumed per capita per year versus 5.3 kg per year, respectively (USDA Economic Research Service, 2018). The growth in cheese consumption in the United States over the past few years is primarily driven by flavor with roughly eight in ten cheese consumers citing purchasing cheese for taste (Mintel Group Ltd, 2017). Consumers crave convenience and are willing to pay for it. For the U.S cheese market, convenience has become the most influential trend of 2018 (Canning, 2018). This focus on convenience has increased shredded natural cheese sales to the highest selling subcategory of cheese at $4,735.0 million in 2018 (Canning, 2018). However, manufacture of cheese shreds poses additional challenges compared to their block counter parts.

Cheese shreds have additional characteristics that affect consumer liking including shred length, width, and anticake agents. Anticake agents are ingredients added to the cheese shreds to prevent clumping, also known as agglomeration, during the shred process and during storage/shipping. Clumping decreases ease of consumer use and may pose microbial concerns. Anticake agents are typically combinations or sole applications of potato starch, corn starch, calcium sulfate, and powdered cellulose to prevent shreds from sticking and caking (Elayedath and Barringer, 2002). Additionally, a mold inhibitor which is typically natamycin, is added to inhibit mold growth and prolong shelf life (Elayedath and Barringer, 2002). According to the FDA, natamycin can be applied to cheese as an antimycotic at a maximum of 20 ppm of the finished product (21CFR172.115).

There are multiple concerns regarding the use of anticake agents. They add cost, increase dust during manufacture, possibly create a health hazard to workers, and introduce additional risk of bacterial contamination (Reddy, 1994). For consumers, anticake agents may reduce product functionality and performance and, for colored cheeses like Cheddar, may make the outer shred appearance powdery and discolored. A recent study on consumer perception of commercial Cheddar cheese shreds reported that the powdery coating on Cheddar shreds was a rejecter for consumers, as were shreds that were clumped together (Speight et al., 2019). Meals et al. (2019) also reported that consumers in a traditional consumer acceptance test that commented on the powdery appearance of cheese shreds had lower overall liking scores for Cheddar shreds than those who did not. Some consumers even commented that they thought the powdery appearance was mold (Meals et al., 2019; Speight et al., 2019). These studies suggested that anticake agents for shredded Cheddar cheese provide some confusion for consumers.

Additionally, consumers have growing skepticism regarding cheese shred anticake agents after a 2016 Bloomberg article exposed cheese products adulterated with wood shavings, meaning cellulose (Mulvany, 2016). Whole Foods, a popular natural grocery store chain, has placed natamycin on their “Unacceptable Ingredients for Food” list, furthering consumer concerns. Currently, anticake agents are loosely regulated with no specific limits other than that the agent must be GRAS and the shreds must still adhere to the identity of the specific type of cheese (21CFR133.146). The grated cheese in the 2016 Bloomberg article were marketed as 100% parmesan but did not conform to the FDA standards of identity for parmesan. With the matching standard of identity for the specific cheese being the only guideline, a company can technically add as much of any GRAS product as they want as long as it still meets the criteria of milkfat and moisture content for the specific cheese. Many studies and patents have been published on improving the efficiency of anticake agents or investigating alternative anticake agents for shredded cheese (Chappell et al., 2005; Galer et al., 2011; Smith et al., 2014). However, to our knowledge, none have investigated sensory perception of anticake agents applied to cheese shreds. The objective of this study was to investigate sensory properties of three common anticake mixtures applied at different percentages to Cheddar cheese shreds.

MATERIALS AND METHODS

Experimental overview

Three common anticake agents (potato/cellulose blend, potato, and potato/ corn/ calcium sulfate) were applied to duplicate lots of Cheddar cheese shreds at 1, 2, 3, 4, and 5 % (w/w). Control Cheddar cheese shreds with no added anticake were included. Sensory properties (appearance, flavor, texture, and hot texture) were documented using a trained sensory panel. Consumer acceptance testing and a home usage test were then conducted on selected cheese shreds. All sensory testing was performed was performed in compliance with the North Carolina State University Institutional Review Board for Human Subjects.

Cheese and cheese shreds

Two lots of full fat pasteurized milk Cheddar cheese (291kg) were produced by a commercial stirred curd manufacture facility in Twin Falls, ID. Cheese were manufactured within 24 h of each other using recombinant chymosin and were cooled using forced air coolers at 5˚C for 14 days. These blocks were similar in moisture, fat, and salt content and pH (Table 1). The blocks were cut into multiple 18.14 kg blocks and shipped to a separate facility located in the Midwest United States for shredding. Blocks were shredded at 75 days old.

For shredding, blocks were cut into 5.08 cm cubes and then loaded into a shredder and shredded with a “feather” cut. The resulting shreds were loaded into a tumble drum in 9.07 kg batches where the anticake agent was applied. Three common industry anticake agents were applied at 1, 2, 3, 4, and 5% (w/w) for a total of 15 different application batches on the duplicate lots of cheese. Anticake agents included an 80/20 potato/cellulose blend with natamycin (PCELL) (Free-Flow 206-200, Allied Blending, Keokuk, IA), 100% potato with natamycin (POT) (Free Flow 207-175, Allied Blending), and a potato/corn/calcium sulfate with natamycin (PCOR) (Free Flow 2036 NG-400, Allied Blending). A 9.07 kg batch from each block had no anticake agent applied and served as a control for a total of 16 applications in duplicate (15 anticake applications and 1 no additive control). After anticake application, each batch was packaged into multiple 2.27 kg bags and sealed with a nitrogen/carbon dioxide flush to maintain freshness. Packaged Cheddar cheese shreds were shipped on cold gel packs to Raleigh, NC by overnight carrier. On arrival, cheeses were examined for shipping damage and stored at 5˚C in the dark until analysis. All sensory tests were completed within 21 days of receipt.

Descriptive Analysis: Visible powder, Flavor, Hot and Cold Texture

Visible powder, flavor, cold texture, and hot texture properties of cheese shreds were documented by descriptive sensory analysis. Descriptive analysis approval. Panelists expectorated samples and cleansed palates with room temperature deionized water between samples. Data was collected using Compusense Cloud (Compusense, Guelph, Canada). Visible powder, flavor, cold texture, and hot texture were evaluated in separate sessions.

Visible Powder

For visible powder appearance, a trained sensory panel (n=8, 5 females, 3 males, ages 23-54 y) evaluated the appearance of the cheese shreds. A 0 to 10 point intensity scale was used where 0 represented no visible anticake agent and 10 represented all surfaces of the Cheddar cheese shreds were visibly coated in anticake agent. Approximately 15 g of cheese shreds were presented in 100 mm O.D. x 15 mm Petri dishes (Kimble-chase Solutions, Vineland, NJ) against a black polyethylene tablecloth (Spritz, Minneapolis, MN) under fluorescent lights (F32T8/ADV841/XEW, Phillips, Amsterdam, The Netherlands) at 660 lux. Samples were blinded with random three-digit codes and were evaluated at 4˚C to avoid condensation from affecting the visual appearance. Each panelist evaluated each cheese shred in duplicate. No more than ten samples were evaluated in a session.

Flavor

For flavor analysis, a trained sensory panel (n = 8, 5 females, 3 males, ages 23-54 y) evaluated the cheeses using an established Cheddar cheese flavor lexicon (Drake et al., 2001) and a 0 to 15 point universal intensity scale consistent with the Spectrum™ method (Lawless and Heymann, 2010). Each panelist had at least 150 h of experience with descriptive analysis of cheese flavors. Cheddar cheese shreds (approx. 15 g) were served in lidded 120-mL clear plastic soufflé cups (Dart Container, Mason, MI) with random three-digit blinding codes and evaluated at 15°C. Each panelist evaluated each cheese shred in duplicate. No more than five samples were evaluated in a session.

Hot and Cold Texture

For hot and cold texture evaluation, a trained descriptive sensory panel (n=6 females, ages 35-49 y) evaluated the cheeses in triplicate using a 0- to 15-point product-specific scale. The cheese texture lexicon developed by Drake et al. (1999), Gwartney et al. (2002), Asato (2003), Brown et al. (2003), and Rogers et al. (2009) were used but terms were modified specific to cheese shreds and the temperature of evaluation (Table 2). Hot and cold texture were evaluated in different sessions. Approximately 15g of cold cheese shreds were served at 4˚C in lidded 120-mL soufflé cups (Dart Container, Mason, MI) with 3-digit blinding codes. For hot texture, approximately 15g of each Cheddar cheese shred was baked in clean metal desiccation dishes 7.62 cm in diameter (VWR International, Radnor, PA) in a conventional oven set to 230ºC for 4 min. Cheese texture were evaluated within 1 min of being removed from the oven.

Consumer Testing

Consumer acceptance of the Cheddar shreds were documented with three separate tests: a visual test, a melted test, and a home usage test. For all consumer tests, the Cheddar cheese shred batches were commingled as descriptive analysis showed no differences ($p>0.05$) across lots. Compusense Cloud (Compusense) was used for data collection.

<u>Cold Appearance Liking</u>

Consumer acceptance testing was conducted to investigate consumer visual perception of anticake agents on cold Cheddar cheese shreds. From the descriptive analysis, thirteen shreds were selected as these were significantly different in visible appearance by trained panelists ($p<0.05$). Self-reported Cheddar cheese shred consumers (n=150, 110 through each sample) were recruited the day of the test through an email sent to an online database of 11,000 individuals maintained by North Carolina State University. Recruitment was open to anyone >18y who was a self-reported Cheddar cheese shred consumer. Consumer acceptance testing was performed on a single day with each consumer evaluating visual appearance of ten of thirteen samples in a randomized partial presentation. As consumers arrived for their test, they were provided an iPad loaded with Compusense Cloud (Compusense) and were then verbally instructed. Consumers were asked to evaluate overall appearance liking, color liking, purchase intent, color Just-About-Right question (JAR) (from light to dark and yellow to orange), and check-all-that-apply visual Cheddar cheese attributes for each sample presented. Upon completion of the entire test, consumers were compensated with a $5 gift card to a local store.

Each Cheddar cheese shred sample consisted of approximately 100 g of cheese shreds in 15.24 cm x 20.32 cm clear LDPE bags (Uline, Pleasant Prairie, WI) with random three-digit blinding codes. The testing room was cleared with three tables (152.4 x 45.72 cm) with black polyethylene tablecloths (Spritz, Minneapolis, MN) surrounding the perimeter. A sample bag of each of the thirteen cheeses in the test was displayed at each table under fluorescent lights (F32T8/ADV841/XEW, Phillips, Amsterdam, The Netherlands) at 660 lux. Panelists were allowed to stand to assess samples and were informed that they could pick up the samples to more closely examine the products. Samples were replaced every 30 min to avoid condensation from affecting the visual appearance. Shreds were evaluated monadically using a randomized balanced incomplete block (BIB) design, wherein consumers evaluated ten out of the 13 samples with the goal of 100 consumers through each sample (Compusense, Guelph CA). A one minute rest was enforced between samples.

Liking questions were scored on a 9 pt hedonic scale where 1 = dislike extremely and 9 = like extremely. The JAR questions used a 5 pt scale where 1 or 2= too little, 3=JAR, and 4 or 5=too much. Purchase intent was scored on a 5pt scale where 1 or 2=would not buy, 3=may or may not buy, and 4 or 5=would buy. The CATA Cheddar cheese shred attribute question included soft, hard, dry/crumbly, rubbery, short shreds, long shreds, thick shreds, thin shreds, orange, yellow, white, powdery, and powderless.

Melted Consumer Test

Ten cheese shreds were selected for melted cheese consumer acceptance testing. Shreds selected were control (no anticake agent added), and applications of 1, 3, and 5% (w/w) of each of the three anticake agents. These samples were selected to determine liking of each anticake agent at a high, medium, and low application. The control was added to compare against the anticake samples. Consumer acceptance testing was performed over 2 days with each consumer completing the test in one seating. Consumer evaluated samples in a randomized balanced incomplete block design, meaning consumers evaluated four of the ten samples in one seating (Compusense, Guelph CA). Self-reported Cheddar cheese shred consumers (n = 250, 150 through each shred) were recruited using a survey launched into an online database of 11,000 individuals maintained by North Carolina State University. All consumers were primary shoppers with an annual household income >$15,000 who purchased Cheddar cheese shreds at least once a month. Of the consumers recruited, gender was split equally between men and women, and income was split equally among the recruitment income ranges to achieve a broad range of consumers. Panelists were compensated with a $15 gift card to a local store upon completion of the entire test. As consumers arrived for their test, they first presented a photo ID in order to ensure the consumers who participated were the consumers screened for the test. Consumers were then verbally instructed on the testing method.

Samples consisted of 20 g of cheese shreds melted onto an open face 15.24 cm flour tortilla cut in half (UPC:073731008300 Mission Foods, Irving, TX). Cheese was melted using a Lincoln Impinger Oven model 1301 (Fort Wayne, IN) set to 204˚C (400˚F) with a belt speed to allow for 70 seconds of baking. This length and speed were determined prior to consumer testing by using the control (0%) cheese and adjusting time and temperature to allow for a quick and full melt without burning (Figure 1). For the consumer test, panelists were served only half tortillas, so the tortillas were sliced in half prior to testing and only 20g of cheese were baked. Samples were prepared as consumers needed each sample to prevent any samples from getting cold.

Once a sample was presented, consumers were first asked to evaluate overall appearance liking, visible melt liking, and visible melt JAR. After evaluating appearance, consumers consumed several bites and were asked to evaluate cheese flavor and texture. Questions asked included overall liking, overall flavor liking, texture liking, stretch liking, stretchiness JAR, chewiness JAR, purchase intent, CATA melted Cheddar cheese shred texture and appearance attributes, and purchase intent. A 1 minute rest was enforced between samples and during this time, consumers were asked to take several bites of unsalted cracker and to drink spring water.

Liking, JAR, and purchase intent questions were scaled as described previously. The CATA Cheddar cheese shred question contained different attributes than the cold visual CLT with the list of terms including: soft, hard, dry, burnt, rubbery, melted, cohesive, stringy, greasy, oily, smooth, stretchy, stiff, breakable, and the option of "other" with a comment box to clarify this selection. CATA terms were adapted from descriptive lexicons for cheese texture (Asato, 2003; Brown et al., 2003).

Home Usage Test (HUT)

Seven cheeses were selected for home usage testing. Shreds selected were control (no anticake agent added), and the 1 and 5% (w/w) applications of each of the three anticake agents. These samples were selected to determine liking of each anticake agent at a high and low application during home usage. The control was added to compare against the anticake samples. Consumers (n= 113, 49 through each shred) were randomly recruited from the melted cheese test. Those who chose to participate received a 38 x 30.5 x 15.2 cm thermal bag (Uline, Pleasant

Prairie, WI) with three 15.24 cm x 20.32 cm clear LDPE bags (Uline, Pleasant Prairie, WI) with random three-digit samples consisting of 150 g shreds. A 12.7 x 7 x 2 cm single use ice pack (Uline, Pleasant Prairie, WI) was added to maintain temperature during transport home. The freezer bag included a direction sheet that contained test directions, their individual login, and test website. Consumers evaluated samples in a randomized balanced incomplete block design, evaluating three of the seven shred samples (Compusense, Guelph CA). Consumers were allowed five days to complete the test. There was a 4 h enforced wait period between each sample. Consumers who completed the entire test received a $15 gift card to a local store.

For each sample, consumers first evaluated the shreds prior to consuming, answering an overall appearance liking question, an open ended appearance comment, and expectations question. After evaluation of appearance, consumers prepared a meal or snack with the shreds and evaluated overall appearance liking with an open ended appearance comment, flavor liking, and texture liking. If consumers prepared a hot snack they were asked additional questions regarding melt liking, melt JAR, stretch liking, and chewiness JAR. All consumers then answered questions for purchase intent and similarity to ideal Cheddar shreds. Consumers were required to take pictures of their meal or snack before and after the evaluation as a way to ensure that instructions were followed.

Liking, JAR, and purchase intent questions were scaled as described previously. Expectations was scored on a 5 point scale where 1 and 2 = does not meet expectations, 3 = maybe/maybe not meets expectations, 4 and 5 = meets expectations. Similarity to ideal Cheddar shreds was scored on a 5 point scale where 1 and 2 = not similar, 3 = maybe/maybe not similar, 4 and 5 = similar.

Statistical Analysis

Statistical analysis was conducted using XLSTAT software (version 2017; Addinsoft, New York, NY). Descriptive analysis, and consumers liking scores were analyzed by 2-way analysis of variance (ANOVA) (percent application x anticake agent) with Fisher's least significant difference test at a significance level of $p < 0.05$. One-way ANOVA with Fisher's least significant difference test at a significance level of $p < 0.05$ was also used, where appropriate, to compare to the control. Consumer JAR scores were evaluated by chi-squared analysis, and purchase intent was evaluated using a Kruskal-Wallis test with Dunn's post hoc test.

RESULTS

Descriptive analysis

Distinguishing flavor and texture differences related to the presence and application percent of anticake agents were documented by the trained panel ($p<0.05$) (Tables 3-5). There were no significant differences detected between the lots of cheese ($p>0.05$). Visual analysis of the cheese shreds demonstrated that at 1% (w/w) none of the anticake agents had visible powder on the Cheddar shreds (Table 3). The 100% potato (POT) was least impacted by application rate. Visible powder for all anticake agents increased at 2% (w/w) ($p < 0.05$). However, visible powder on shreds with potato/cellulose blend (PCELL) or potato/corn/calcium sulfate blend (PCOR) increased sharply at 3 and 4% (w/w), respectively ($p<0.05$), compared to POT.

Hand cohesiveness results were similar to visible powder, in that the shreds with added 100% potato (POT) were least impacted by application rate (Table 4). When each treatment was compared to the control with no anticake, POT was at parity with the control at 1 and 2% (w/w) (p>0.05) (results not shown). Two-way analysis of variance between anticake type and percent application showed that both PCELL and PCOR reduced hand cohesiveness more than POT (p<0.05). As expected, as application percentage increased, hand cohesiveness decreased for all the anticake agents (p<0.05).

Cheese shreds were characterized by high intensities of cooked/milky and whey flavors consistent with a characteristic young Cheddar flavor profile (Drake et al., 2001, 2008) (results not shown). Flavor attributes of shreds were consistent (p>0.05) and unaffected by anticake agent except for the flavor attribute plastic/chemical. Cheese shreds with 5% (w/w) of any of the three anticake agents had low but distinct plastic/chemical flavor ($\bar{x}$ = 0.8 ±0.2).

Anticake agents and percent application affected some hot cheese texture terms (Table 5). Firmness, toothpull, oiliness (in-mouth), and mouthcoating were not impacted by anticake agents (p>0.05) (results not shown). When compared to the control (no anticake agent, anticake agent and percent application had variable effects (p<0.05) for visual oil, oiliness to lips, cohesiveness, smoothness, and strech, with some shreds being unaffected by anticake agent up to 3% (w/w) in these attributes. Shreds with PCELL at 1% (w/w) were the only shreds similar to the control for visual oil, and cohesiveness (p>0.05). For smoothness of mass, shreds with POT were scored similar to the control (no anticake agent) until 4% (w/w), all other shreds were impacted by the anticake agents at the percent application range evaluated.

Visible oil, oiliness to lips, cohesiveness, smoothness of mass, and stretch were impacted by anticake agent and percent application (Table 5) (p<0.05). Shreds with PCOR, across the application rates evaluated, were least affected of the three anticake agents in visual oil, and oiliness to the lips (p<0.05), while shreds with POT and PCELL were the most impacted (p<0.05). For smoothness of mass, shreds with PCOR at 5% (w/w) scored lowest (p<0.05). This was a potato with calcium sulfate and corn starch blend anticake, so it could be inferred that this anticake additives may contribute to a rougher mouthfeel. In stretch descriptive analysis, shreds were unaffected by the anticake agents ($p>0.05$) until 3% (w/w) for PCOR and POT and 2% (w/w) for PCELL. At percentage applications > 2% (w/w), shreds with PCOR were least impacted by anticake agents while shreds with PCELL were most impacted ($p<0.05$). For cohesiveness evaluation, shreds with 1 and 2% (w/w) PCELL had the highest intensities, but at 5% (w/w), shreds with PCELL had the lowest scores ($p<0.05$). Shreds with PCOR had the least amount of change as percent application increased with a mean range of 0.2 in the cohesiveness evaluation. Visual meltedness was impacted by percent application, but not specific anticake agent. Shreds with >2% (w/w) anticake agent received lower visual meltedness scores ($p<0.05$) (Table 5).

Differences in descriptive sensory data were explained with two principle components (87% of the variability) (Figure 2). Based on factor loadings, principle component one (PC1) (75%) differentiated shreds by hand cohesiveness, visual meltedness, stretch, cohesiveness, oiliness to lips (positively loading) and plastic flavor and visible powder (negatively loading). Variations of smoothness of mass and visual oil are projected equally PC1 and PC2. PC2 differentiated shreds by visual oil (negatively loading) and smoothness of mass (positively loading). The PC biplot illustrates the effects on sensory attributes for each anticake agent as percentage application increased. The control cheese shreds were characterized with the highest smoothness of mass and hand cohesiveness, visual meltedness, stretch, cohesiveness, oiliness to lips, and visual oil. As percent anticake application increased, shreds become less similar to the control with reduced smoothness of mass, hand cohesiveness, visual meltedness, stretch, cohesiveness, oiliness to lips, and visual oil and increased visible powder, and plastic flavor. As previously stated, shreds with POT were correlated with reduced visible powder and increased smoothness of mass hand cohesiveness, but had reduced oiliness to lips, cohesiveness, and visual oil. Shreds with PCELL or PCOR, on the other hand, had increased visible powder and reduced smoothness of mass and hand cohesiveness, but these shreds with either of these two anticake agents had increased stretch, oiliness to lips, and visual oil compared to shreds with POT.

Consumer Testing

<u>Cold Appearance Liking</u>

Results from consumers were consistent with the trained panel results (Table 6). Cheese shreds with POT (100% potato) anticake were least impacted by percent application, while shreds with PCELL or PCOR decreased in liking at > 4 % (w/w) application. Purchase intent had similar findings in that the control (no anticake) shreds were at parity with shreds with all applications of POT and shreds with applications of 2-3 % (w/w) for the other two anticakes ($p<0.05$) (result not shown). Shreds with POT were the only shreds with anticake agent of the three evaluated that received no penalties at any percent for being “too light” in color ($p>0.05$). The control (no anticake) and shreds with POT at 1% (w/w) were both penalized for being “too orange”, which may suggest that consumers are not used to the appearance of Cheddar shreds without anticake. Analysis of check-all-that-apply (CATA) consumer selections shows that all shreds with POT received selection frequencies at parity with the control (no anticake) (Table 7). Specifically, for powdery and powderless attributes, shreds with POT were similar to the control ($p>0.05$). Shreds with PCELL and PCOR both differed from control in selection frequencies of powdery and powderless ($p<0.05$), again suggesting that these anticake agents had greater impact on consumer liking than shreds with POT under cold (as-is) conditions.

Melted Consumer Liking

Increased percent application had a negative effect on overall liking, cheese flavor liking, cheese texture liking, and stretch liking ($p<0.05$) regardless of anticake agent (Table 8 and Figure 3). Interactions between anticake type and percent application were only significant for the visual liking questions: overall appearance, and melt. Here, shreds with POT had the largest impact on liking, and at 5% (w/w) received the lowest liking scores in those categories ($p<0.05$) (Figure 4). Cheese texture liking was the only category impacted by type of anticake ($p<0.05$) but not percent application. For this liking category, PCELL scored significantly higher than PCOR ($p<0.05$), and shreds with POT were at parity in liking with both (Figure 5) ($p<0.05$). Shreds with the three anticake agents were penalized at 3 and 5% (w/w) for not appearing melted enough (Table 9). Interestingly, the control shreds and PCOR at 1% (w/w) were penalized for being "too stretchy." This may suggest that consumers are not used to the extent of stretch from cheeses without anticake. Cheese shreds with each anticake at 5% (w/w) were penalized for not being stretchy enough.

Home Usage Test

Cold appearance and in-food appearance were the only liking questions that were distinct among the shreds tested by the home usage test ($p<0.05$) (Table 10). Responses for all other liking questions were at parity ($p>0.05$). Analysis of the effects of percent application and anticake type showed that there was no interaction effect for any of the liking questions, and that percent application was a significant effect for cold appearance and in food appearance liking ($p<0.05$). Cheese shreds with 5% (w/w) application of any of the three anticake agents had lower liking scores than 1% (w/w) application ($p<0.05$) (Figure 6) and this result was consistent with the previous cold appearance CLT and trained panel results.

When each shred was individually compared with the control, all three cheese shreds with 5% (w/w) application any of the three anticake agents scored lower than the control for cold appearance liking ($p<0.05$) (Table 10). Of those, shreds with PCOR or PCELL scored significantly lower than shreds with POT ($p<0.05$). Shreds at 1% (w/w) application were at parity with the control ($p>0.05$). For in food appearance liking, shreds with PCELL at 5% (w/w) were the only shreds that scored lower than the control with no anticake added ($p<0.05$). Analysis of the cold expectations, purchase intent, and ideal cheese questions again reiterated that anticake only impacted initial consumer expectations. All shreds scored at parity for post consumption purchase intent and similarity to ideal cheese questions ($p>0.05$) ($\bar{x} = 3.9 \pm 0.1$, 4.0 ± 0.1, respectively, 0 to 5 point scale) (results not shown).

DISCUSSION

Descriptive sensory profiles for Cheddar shreds with three different anticake agents at increasing percent applications varied. Akins (2002) tested mozzarella shreds with 2% (w/w) applications of anticake agents containing varying amounts of cellulose and potato starch. This study reported that anticake agents with potato starch had reduced free oil formation (visual oil/sheen) when melted compared to pure cellulose and primarily cellulose blends. While this study only tested applications of anticake agents at 2% (w/w) for mozzarella, the reduction of free oil for blends with predominately potato starch was similar to the findings in the current study. Shreds with POT (100% potato anticake) received the lowest scores in visual oil by trained panelists. Akins (2002) also reported that at 2% (w/w) application, the blend composition did not affect stretch or meltability. This finding is also consistent with the current study that anticake agents were similar in sensory properties until 3% (w/w) application. Akins (2002) did not investigate consumer perception of the mozzarella shreds with differing anticake agents. In the current study, the trained panel sensory documented specific differences between type of anticake agent applied to cheese shreds, but these differences may not impact consumer liking and purchase intent.

The current study found that the visible appearance of cheese shreds was the most important parameter for consumers. Percent application was a main effect for all liking questions in the cold visual and the melted consumer tests and for the cold appearance and in-food appearance liking questions in the home usage test. As expected, as percent application increased, liking decreased. Unlike the melted consumer central location test (CLT), where percent application effects for consumption and use liking questions were documented, the home usage test (HUT) consumption liking scores (flavor, texture, melt, stretch) were not impacted by anticake agent or percent with all shreds at parity at 95% confidence. Previous studies have documented that consumers tend to be less critical in HUT conditions, both assigning higher liking scores and noting fewer differences in liking (Boutrolle et al., 2005, 2006; Sosa et al., 2008; Sveinsdóttir et al., 2010). In the current study, HUT consumers could evaluate the shreds hot or cold and this might explain the differences between the CLT and the HUT. However, HUT liking scores were not unusually higher than the CLT liking scores (Tables 8 and 9).

The type of anticake agent affected visual liking questions in all three consumer tests. Shreds with POT (100% potato) received higher scores for overall appearance and color liking than the other anticake agents in the CLT with cold shreds ($p<0.05$). Shreds with POT at 5% (w/w) also received the lowest liking scores for overall appearance (when hot) and melt liking ($p<0.05$). The HUT scores for visual liking were less impacted by the type of anticake agent. The effect of anticake agent was significant for cold appearance and in-food appearance liking near 90% confidence, but not at 95%. The differences in significance between consumer tests may be the difference between CLT and HUT methods as well as the sample sizes between the two tests (100 compared to 49).

When evaluating these results, it is important remember the practical benefits that anticake agents provide to cheese shreds. Anticake agents provide a functional benefit for manufacture as well as the consumer supply chain for pre-packaged shreds. Many of the consumer liking scores were significantly different at 95% confidence; however, the degree of difference for some liking categories was as small as 0.6 on a 9 pt hedonic scale. Consumer results should be viewed with the understanding that statistical differences may not be practical differences. The largest impact of anticake agents was regarding the cold visual appearance, which is important for initial purchase intent (Speight et al., 2019) and liking prior to adding the shreds in a food. Industry would benefit from using 100% potato starch anticake agents for commercially available Cheddar shreds since it has the least impact on cold visual appearance. If Cheddar cheese shreds are to be sold to restaurants or as inclusions, manufacturers can reduce cost by using an anticake agent with reduced potato starch since consumer liking during consumption is less affected by the type of anticake agent. However, adding >3% (w/w) anticake agent to Cheddar cheese shreds impacted sensory attributes like cohesiveness (hand and in-mouth), oiliness (visual and to the lips), visual meltedness, smoothness, and stretch, which may lead to a decrease in consumer satisfaction.

CONCLUSION

The current study clarified consumer perception of Cheddar cheese shreds with different percent applications and type of anticake agents. Trained panelists documented small effects on melted texture parameters as well as visible cold and hot appearance at applications of >3% (w/w). These differences were noted by consumers in central location testing and home usage tests by differences in liking scores for shreds with >3% (w/w) application. Visible appearance was the sensory parameter of Cheddar cheese shreds that was most impacted by anticake agents and percent application. A 100% potato starch anticake agent applied to Cheddar shreds had the least impact on cold visible liking and the least impact on visible powder and hand cohesiveness descriptive evaluation. However, the 100% potato starch was the most impacted anticake in the melted consumer test and was scored significantly less than shreds with the other two anticake agents in overall appearance and melt liking for the melted CLT at >3% application (w/w). All three consumer tests suggested that application at any percent and type of anticake agent did not greatly impact consumer liking in categories other than visible attributes. Anticake agents are vital to the shredded cheese industry as they prevent the shreds from agglomerating and aid in microbial concerns. The current study aids cheese manufacturers in understanding consumer perception of anticake agents.

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TABLES

Table 1. Proximate analysis means for duplicate 291 kg blocks of Cheddar cheese.

Analysis	Average
Moisture (%)	38.28 +/-0.03
Fat in Dry Matter (%)	55.01 +/-0.35
Salt (%)	1.75 +/-0.03
pH	5.20 +/-0.08

Table 2. Trained panel cheese shred texture attributes (adapted from Drake et al., 1999; Gwartney et al., 2002; Asato, 2003; Brown et al., 2003; Rogers et al., 2009).

	Attribute	**Definition**
Cold Visual Appearance	Visible powder	Amount of visible powder on the shreds where 0 = no visible powder and 10 = every shred surface is coated in powder
Cold Texture	Hand cohesiveness	Degree to which the sample forms a mass and does not break apart after compressing 30% for 5 seconds then release
Hot Texture	Visible surface moisture	Amount of oil resting on the surface
	Meltedness	Homogeneity of the sample (Higher number=more melted)
	Stretchability	Length the melted cheese will stretch with a plastic fork within a minute of oven removal
	Oiliness to lips	Amount of oil felt on lips
	Hardness	amount of force to bite between molars during first bite
	Tackiness	Amount of force required to pull teeth apart after first bite
	Cohesiveness	Degree to which the sample forms a mass and does not break apart after 5 chews
	Adhesiveness	Degree to which the sample sticks to any of the mouth surfaces during mastication
	Oiliness	Amount of oil or any coating perceived in the mouth
	smoothness of mass	Lack of gritty or grainy particles perceived in the mass while chewing
	Mouthcoat	Amount of any mouthcoating (particles, oil, moisture) remaining after swallowing or expectorating

Table 3. Trained panel visible powder mean intensities of Cheddar cheese shreds with different applications of anticake agents. Intensities were scored on a 0 to 10 point scale where 0 represented no visible anticake agent and 10 represented all surfaces of the Cheddar cheese shreds were visibly coated in anticake agent.

Anticake Agent[1]	**Percent**	**Visible Powder**
PCELL	**1%**	ND
	2%	0.7
	3%	2.7
	4%	5.3
	5%	8.7
POT	**1%**	ND
	2%	0.9
	3%	1.1
	4%	1.1
	5%	3.5
PCOR	**1%**	ND
	2%	0.5
	3%	1.2
	4%	5.2
	5%	7.5
LSD[2]		0.46
***P* value**	**Anticake**	< 0.0001
	%	< 0.0001
	Anticake * %	< 0.0001
Control (No Anticake)[3]		ND

Means that differ by the LSD are significantly different (P < 0.05).

1 Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate

2 LSD = least significant difference

3 Control was excluded from the two-way model.

Table 4. Trained panel hand cohesiveness mean intensities of Cheddar cheese shreds with different applications of anticake agents. Means within a column that differ by the LSD are significantly different ($P < 0.05$).

Anticake Agent[1]	**Percent**	**Hand Cohesiveness**
PCELL	**1%**	5.9
	2%	4.5
	3%	4.3
	4%	3.4
	5%	2.3
POT	**1%**	6.8
	2%	6.7
	3%	5.9
	4%	5.3
	5%	4.5
PCOR	**1%**	5.9
	2%	5.5
	3%	3.7
	4%	3.2
	5%	2.1
LSD[2]		0.47
***P* value**	**Anticake**	< 0.0001
	%	< 0.0001
	Anticake * %	< 0.0001
Control (No Anticake)[3]		6.8

1 Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate

2 LSD = least significant difference

3 Control was excluded from the two-way model.

Table 5. Two-way ANOVA for hot texture descriptive data for Cheddar cheese shreds

Anticake Agent[1]		**Percent**	**Visual oil**	**Visual melted-ness**	**Oily to lips**	**Cohesive-ness**	**Smooth mass**	**Stretch**
PCELL		1%	8.3	11.2	12.7	12.9	10.5	9.9
		2%	7.4	11.1	12.3	12.7	10.7	9.9
		3%	7.1	10.9	12.1	12.5	10.5	9.0
		4%	6.2	10.5	11.9	12.5	10.2	7.2
		5%	5.5	10.3	11.4	11.9	9.8	7.8
POT		1%	6.9	11.4	12.6	12.6	12.0	9.9
		2%	6.9	11.0	12.5	12.6	11.4	9.7
		3%	6.6	10.8	12.3	12.5	11.1	9.7
		4%	6.5	10.7	12.2	12.5	10.9	7.6
		5%	6.2	10.3	11.9	12.2	10.4	7.1
PCOR		1%	7.4	11.1	12.8	12.5	10.6	9.9
		2%	7.5	11.2	12.7	12.5	10.6	9.8
		3%	7.3	10.8	12.6	12.3	10.0	9.8
		4%	7.0	10.7	12.3	12.4	9.9	9.0
		5%	6.7	10.4	12.1	12.4	9.2	7.1
LSD[2] **Anticake*%**			0.27	.13[3]	0.24	0.23	0.33	.13
***P* value**	**Anticake**		< 0.0001	0.979	< 0.0001	0.226	< 0.0001	< 0.0001
	%		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
	Anticake*%		< 0.0001	0.152	0.013	< 0.0001	0.002	< 0.0001
Control[4]			8.2	11.3	12.7	13.0	11.1	9.9

1 Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate

2 LSD = least significant difference

3 LSD for visual meltedness is for percent application main effect

4 Control was excluded from the two-way model.

Table 6. Consumer liking means for cold Cheddar cheese shred appearance evaluation (n=110 through each shred)

Anticake agent[1]	Percent	Appearance Liking	Color Liking
PCELL	2%	6.6	6.7
	3%	6.7	6.7
	4%	6.1	6.4
	5%	5.0	5.5
POT	2%	6.5	6.8
	3%	6.8	6.8
	4%	6.7	6.7
	5%	6.8	6.8
PCOR	2%	6.9	6.9
	3%	6.5	6.7
	4%	6.1	6.3
	5%	4.4	5.2
LSD[2] Anticake*%		0.39	0.37
P value	Anticake	< 0.0001	< 0.0001
	%	< 0.0001	< 0.0001
	Anticake*%	< 0.0001	< 0.0001
Control (No Anticake)[3]		6.6	6.6

Attributes were scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.
1 Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate
2 LSD = least significant difference
3 Control was excluded from the two-way model.

Table 7. Consumer Check All That Apply (CATA) attribute scores for cold Cheddar cheese shreds appearance evaluation (n=110 through each shred).

Anticake Agent[1]	Percent	Attribute[2]												
		Soft	Hard	Dry/ crumbly	Rubbery	Long shreds	Short shreds	Thick shreds	Thin shreds	Orange	Yellow	White	Powdery	Powder-less
PCELL	2%	63.2%ab	16.2%b	12.8%bcd	13.7%a	33.3%ab	41%ab	35.9%a	23.1%a	56.4%ab	24.8%a	0.9%b	8.5%de	27.4%ab
	3%	63.8%ab	13.8%b	15.5%bcd	15.5%a	44%ab	32.8%abc	49.1%a	17.2%a	63.8%ab	22.4%a	2.6%b	16.4%cde	24.1%ab
	4%	36.2%bc	24.1%ab	31%ab	14.7%a	49.1%ab	25.9%abc	38.8%a	21.6%a	54.3%ab	31%a	1.7%b	41.4%bc	10.3%bc
	5%	27%c	31.3%ab	53%a	15.7%a	40%ab	31.3%abc	31.3%a	14.8%a	40.9%b	39.1%a	12.2%ab	66.1%ab	1.7%c
POT	2%	66.1%a	12.2%b	14.8%bcd	20.9%a	23.5%b	44.3%ab	41.7%a	16.5%a	72.2%a	22.6%a	0.9%b	4.3%de	30.4%ab
	3%	72.2%a	10.4%b	6.1%d	12.2%a	39.1%ab	36.5%abc	37.4%a	25.2%a	56.5%ab	29.6%a	0.9%b	4.3%de	37.4%a
	4%	68.1%a	14.7%b	20.7%bcd	19%a	22.4%b	53.4%a	46.6%a	13.8%a	60.3%ab	26.7%a	0.9%b	8.6%de	31.9%ab
	5%	62.6%ab	13.9%b	14.8%bcd	13%a	55.7%a	21.7%bc	47.8%a	20%a	64.3%ab	26.1%a	2.6%b	14.8%de	26.1%ab
PCOR	2%	70.2%a	13.2%b	7.9%cd	12.3%a	40.4%ab	36%abc	39.5%a	18.4%a	60.5%ab	32.5%a	0.0%b	6.1%de	41.2%a
	3%	57.4%ab	17.4%b	27.8%abc	12.2%a	33.9%ab	38.3%abc	33.9%a	25.2%a	53%ab	32.2%a	0.9%b	11.3%de	24.3%ab
	4%	48.7%abc	21.7%ab	33%ab	15.7%a	32.2%ab	42.6%ab	35.7%a	17.4%a	46.1%ab	31.3%a	5.2%ab	23.5%cd	20%ab
	5%	25.6%c	44.4%a	53%a	17.1%a	59.8%a	14.5%c	41.9%a	7.7%a	39.3%b	31.6%a	23.1%a	77.8%a	0.9%c
Control		64.9%ab	11.4%b	7.9%cd	32.5%a	52.6%a	28.1%abc	44.7%a	23.7%a	72.8%a	20.2%a	0.0%b	3.5%e	36%a

Consumers were instructed to select attributes that described each cheese shred.

1 Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate

2 Consumers were allowed to select multiple categories to describe each cheese shred, so category percentages do not add up to 100%.

Table 8. Consumer liking means for melted Cheddar cheese shred CLT (n=100 through each shred)

Anticake agent[1]	Percent	Overall Appearance	Melt Liking	Overall Liking	Cheese Flavor Liking	Cheese Texture Liking	Stretch Liking
PCELL	**1%**	6.6	6.6	7.1	7.0	7.1	6.8
	3%	6.2	6.1	6.8	6.7	6.8	6.6
	5%	6.4	6.1	6.7	6.5	6.8	6.5
POT	**1%**	6.9	7.1	7.0	6.8	7.0	6.8
	3%	6.5	6.6	6.9	6.7	6.9	6.9
	5%	5.8	5.5	6.5	6.6	6.4	6.4
PCOR	**1%**	6.5	6.7	6.9	7.0	6.6	6.8
	3%	6.3	6.2	6.7	6.6	6.7	6.5
	5%	6.4	6.1	6.6	6.4	6.4	6.3
***P* value**	**Anticake**	0.923	0.737	0.585	0.932	0.024	0.387
	%[2]	0.0005	< 0.0001	0.002	0.002	0.007	0.009
	Anticake*%	0.009	0.001	0.827	0.689	0.476	0.546
Control[3]		7.0	7.2	6.9	6.7	6.9	7.0

Attributes were scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.
1 Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate.
2 Percent application main effects are shown in Figure 3.
3 Control was excluded from the two-way model.

Table 9. Consumer JAR scores for melted Cheddar cheese shreds with different anticake agents at 1, 3, or 5% application (n=100 through each shred).

			PCELL			**POT**			**PCOR**		
Variable	Level	**Control**	**1%**	**3%**	**5%**	**1%**	**3%**	**5%**	**1%**	**3%**	**5%**
Melt JAR	Not Melted	3%a	18%dcba	33%fedc*	38%fed*	9%ba	21%edcba*	49%f*	13%cba	29%fedcb*	46%fe*
	JAR	79%c	71%cba	60%cba	61%cba	81%c	76%cb	46%a	76%cb	67%cba	50%ba
	Too Melted	18%b	11%ba	7%ba	1%a	10%ba	3%ba	5%ba	11%ba	4%ba	4%ba
Texture JAR	Not stretchy enough	11%a	11%a	15%a	24%a*	13%a	13%a	20%a*	14%a	15%a	26%a*
	JAR	68%a	75%a	70%a	70%a	69%a	74%a	66%a	66%a	74%a	56%a
	Too Stretchy	21%a*	14%a	15%a	6%a	18%a	13%a	14%a	20%a*	11%a	18%a
Chewiness JAR	Not Chewy Enough	4%a	7%a	4%a	3%a	4%a	3%a	9%a	2%a	6%a	11%a
	JAR	72%a	72%a	71%a	78%a	77%a	81%a	64%a	68%a	75%a	63%a
	Too chewy	24%a*	21%a*	25%a*	19%a	19%a	16%a	27%a*	30%a*	19%a	26%a

JAR questions were scored on a 5-point scale where 1 or 2 = too little, 3 = just about right, and 4 or 5 = too much. Percentage of consumers that selected these options is presented. If a significant penalty ($p<0.05$) was assigned to liking for a JAR attribute, it is indicated with a *.
Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate
Percent applications are comprised of 1, 3, and 5% of anticake agents added to cheese by weight.
Different letters in rows following means signify significant differences ($p<0.05$)

Table 10. Consumer liking means for Cheddar cheese shred home usage test for shreds with three different anticake agents at 1 or 5% application (n=49 through each shred).

Anticake agent[1]	**Percent**	**Cold Appearance Liking**	**In Food Appearance Liking**	**Flavor Liking**	**Texture Liking**	**Melt Liking**	**Stretch Liking**
PCELL	**1%**	7.6	7.5	7.4	7.5	7.5	7.1
	5%	6.6	6.9	7.1	6.9	7.0	6.7
POT	**1%**	7.5	7.7	7.4	7.4	7.7	7.0
	5%	7.2	7.4	7.3	7.4	7.3	7.2
PCOR	**1%**	7.5	7.5	7.2	7.3	7.4	6.5
	5%	6.4	7.3	7.4	7.4	7.4	7.1
LSD[2]		0.51	0.51	0.54	0.53	0.59	0.61
***P* value**	**Anticake**	0.106	0.118	0.790	0.456	0.519	0.469
	%	< 0.0001	0.016	0.579	0.196	0.180	0.492
	Anticake * %	0.101	0.692	0.302	0.146	0.551	0.107
Control (No Anticake)[3]		7.8	7.5	7.3	7.3	7.5	7.1

Attributes were scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.
1 Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate
2 LSD = least significant difference.
3 Control was excluded from the two-way model.

FIGURES

Figure 1. Test cook of 40g control (no anticake) cheese baked at 204˚C for 70 s in an impinger oven

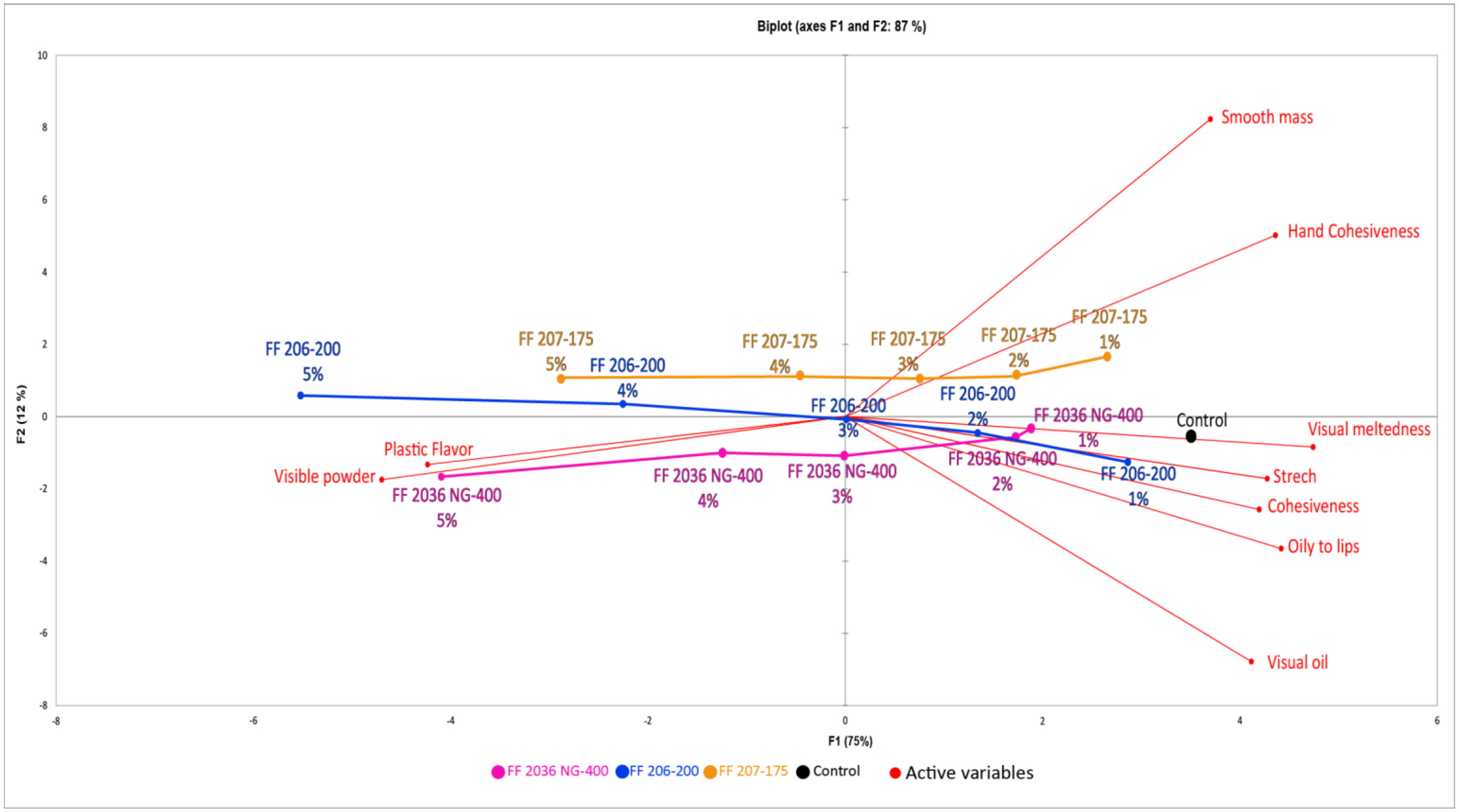

Figure 2. Principle component biplot of significant Cheddar cheese shred trained panel flavor, hot texture, cold texture, and visible powder attributes for different anticake agents at applications of 1 to 5% (w/w).
Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate.

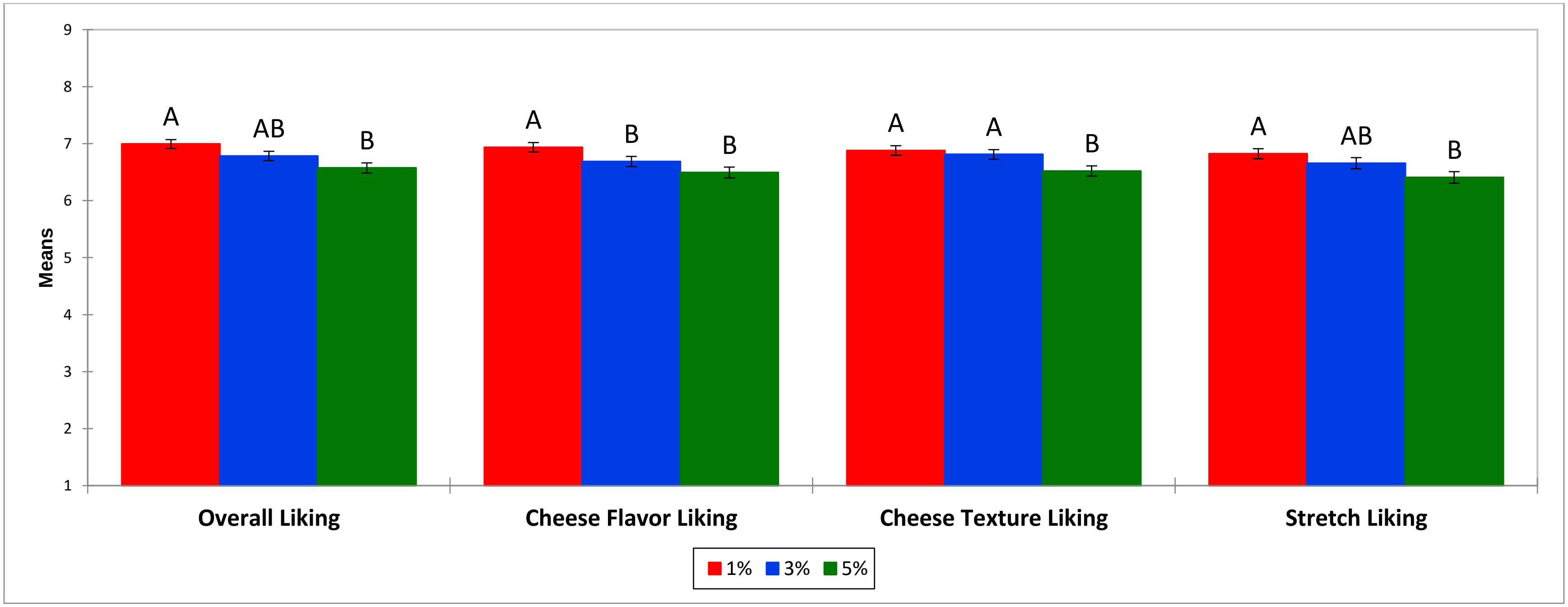

Figure 3. Consumer liking means by percent application for melted Cheddar cheese shred CLT for shreds with the anticake agents at 1, 3, and 5% application. (n=300 through each percent application)
Liking scores were averaged across the three anticake agents since interactions were not significant ($p>0.05$).
Percent applications are comprised of 1, 3, and 5% of anticake agents added to cheese by weight.
Different letters within liking questions signify significant differences between means ($p<0.05$).

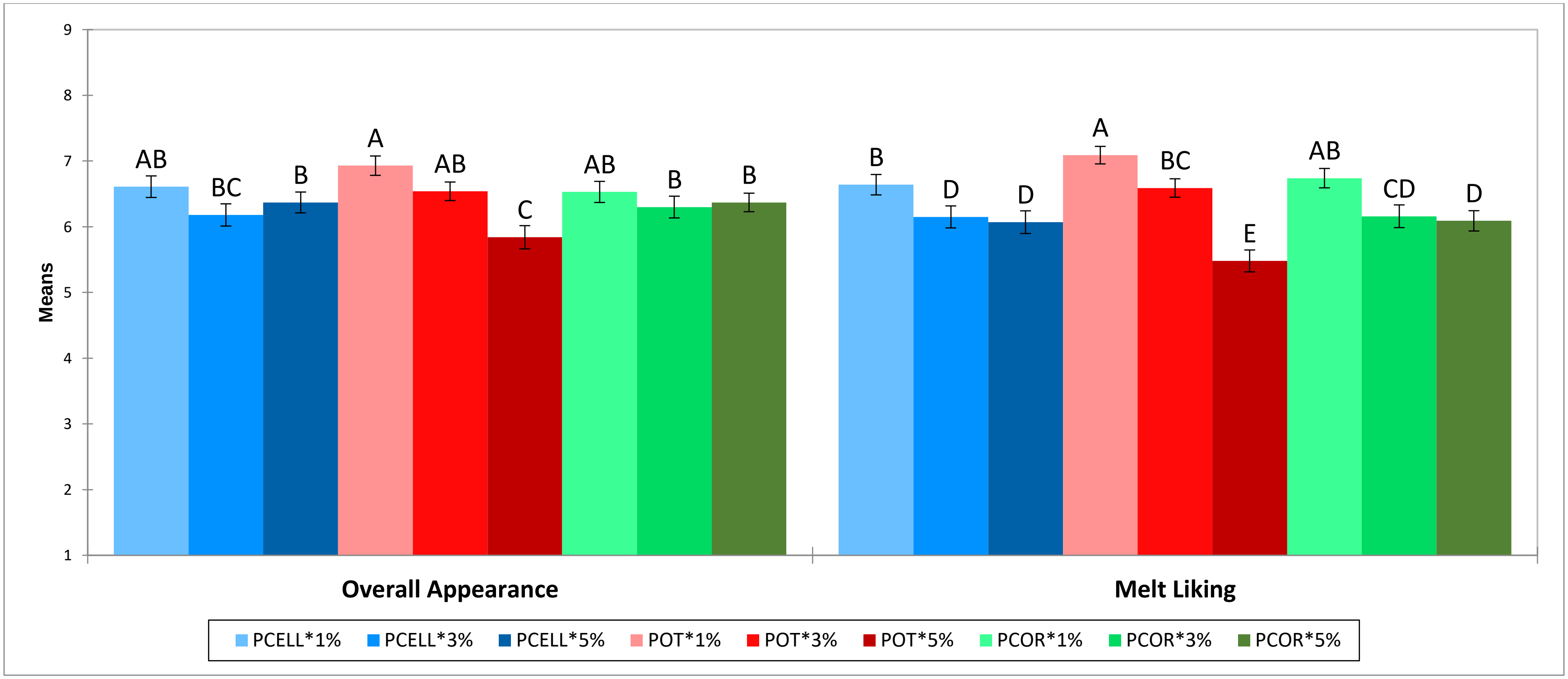

Figure 4. Consumer liking means by the interaction of percent application and the three different anticake agent for melted Cheddar cheese shred CLT (n=100 through each shred).
Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate
Percent applications are comprised of 1, 3, and 5% of anticake agents added to cheese by weight.
Different letters within liking questions signify significant differences between means ($p<0.05$).

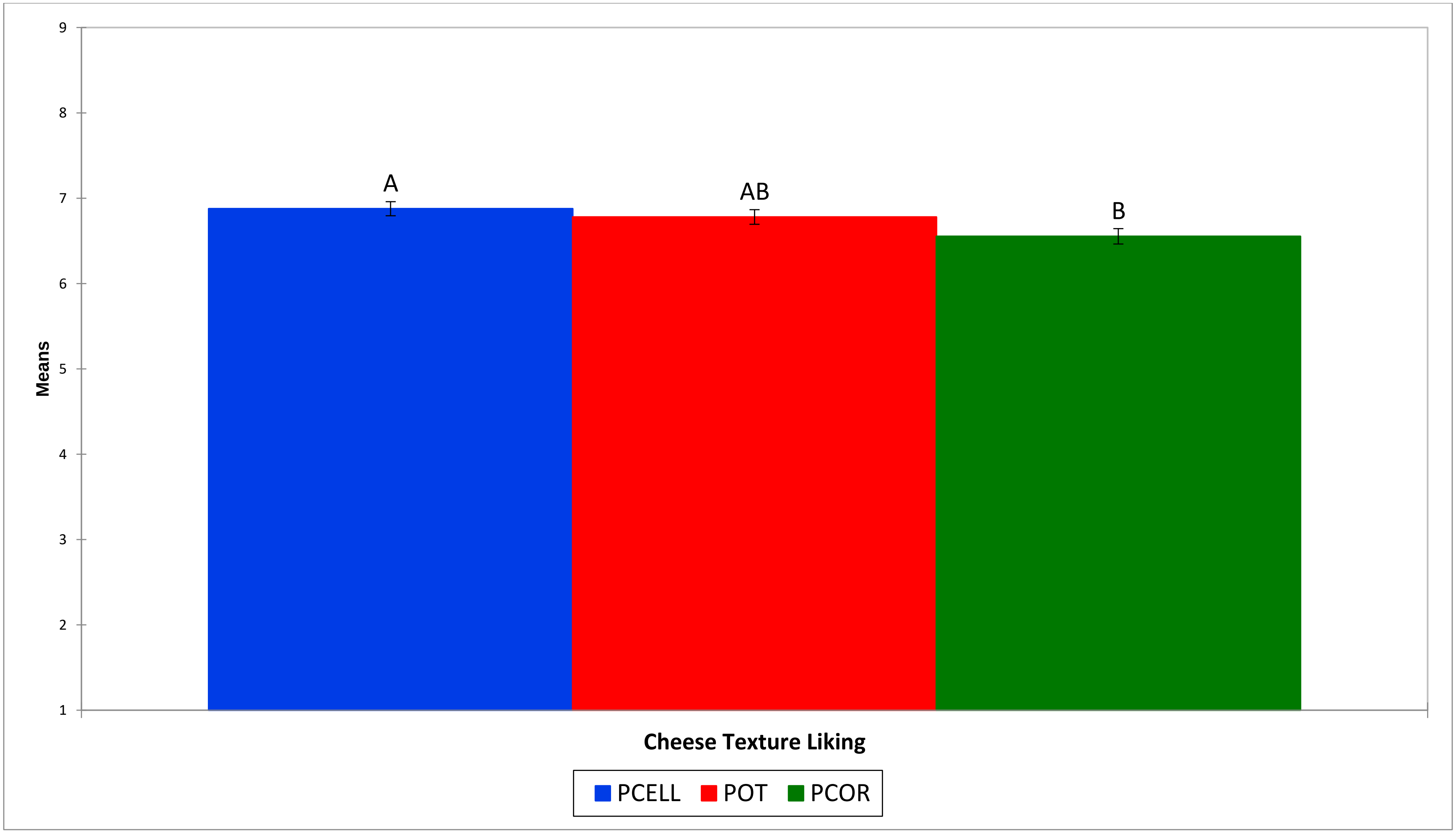

Figure 5. Consumer liking means by percent application for melted Cheddar cheese shred CLT for shreds with the three different anticake agents. (n=300 through each anticake type)
Liking scores were averaged across the three percent applications since interactions were not significant ($p>0.05$).
Anticake agents are comprised of the following: PCELL = 80/20 potato and cellulose, POT = 100% potato, PCOR = potato/corn/calcium sulfate
Different letters within liking questions signify significant differences between means ($p<0.05$).

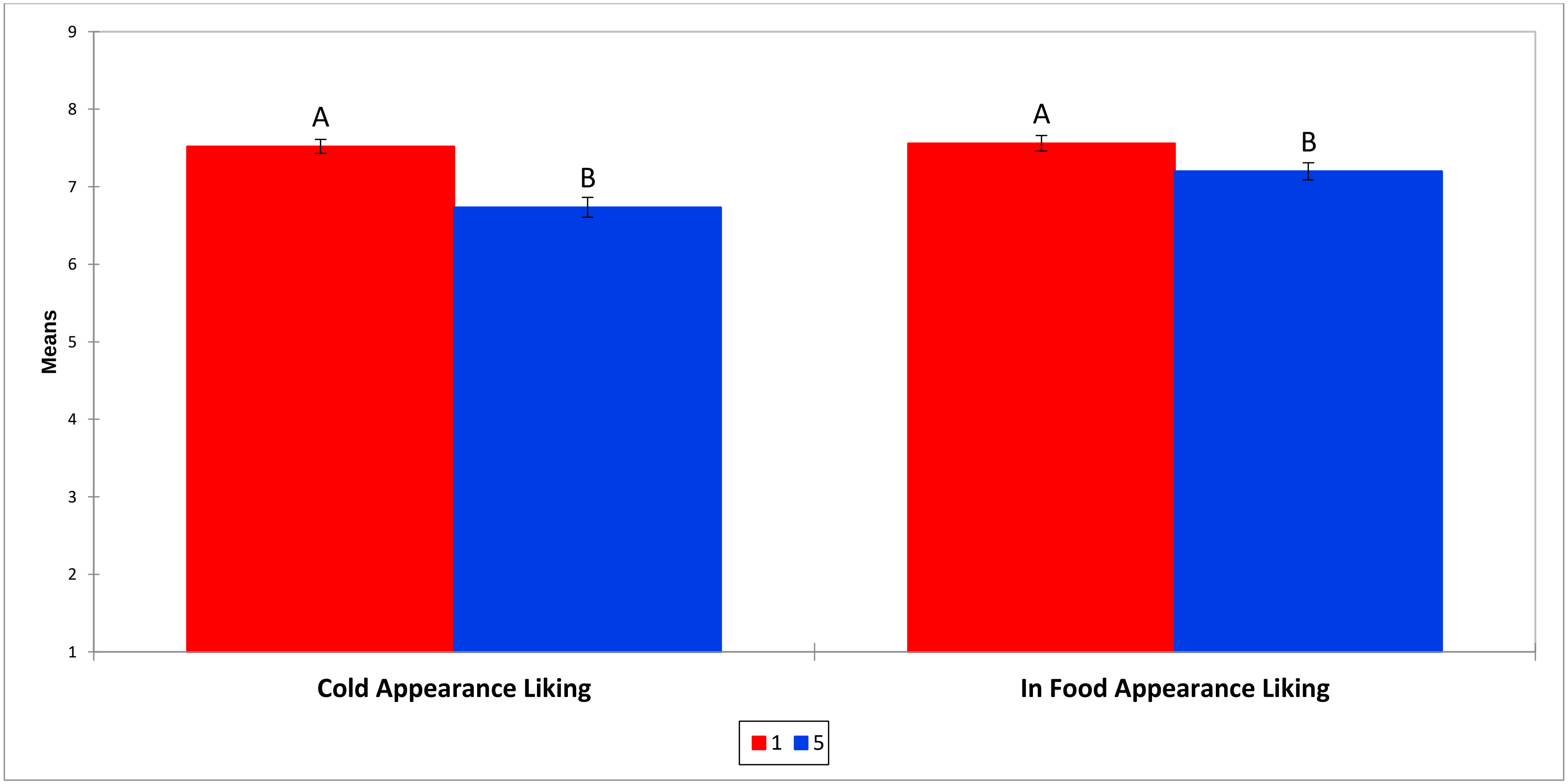

Figure 6. Consumer liking means for home usage test for Cheddar shreds with three different anticake agents at 1 or 5% application (n=49 through each shred, n=148 through 1% (w/w), n=151 through 5% (w/w))
Attributes were scored on a 9-point hedonic scale where 1 = dislike extremely and 9 = like extremely.
Different letters within liking questions signify significant differences between means ($p<0.05$).
Liking scores were averaged across the three anticake agents to show effects of percent application to liking means.
Percent applications are comprised of 1 and 5% of anticake agents added to cheese by weight.
Different letters within liking questions signify significant differences between means ($p<0.05$).