ABSTRACT

YOUNG, NIKKISHA DANTINA. Using Sensory Analysis Techniques to Evaluate Peanut and Cheddar Cheese Products. (Under the direction of Dr. MaryAnne Drake and Dr. Timothy H. Sanders.)

Preference mapping techniques are useful for identifying which consumer attributes drive consumer acceptance. However, minimal research has been conducted in using preference mapping to understand the flavor characteristics of specific American commodities: peanuts and Cheddar cheese. The objectives of this study were to evaluate distinctive peanut and cheese flavor characteristics using descriptive analysis and to determine the overall acceptability of peanuts and cheese using consumer preference mapping techniques.

Sixty peanut samples from the United States, China, and Argentina were evaluated. Descriptive analysis of the peanuts was conducted using a trained panel and an established peanut flavor lexicon. A total of eighteen peanut samples (six from each country) were selected for consumer evaluation. Consumers (n=605) evaluated peanuts for overall liking and strength/intensity and liking of other consumer attributes. Data analysis was conducted using principal component analysis and internal preference mapping.

Seven Cheddar cheeses ranging in age from one month to 19 months were selected. Descriptive sensory profiles of cheeses were determined using a trained panel (n=14) and an established cheese flavor sensory language. For consumer acceptability, cheeses were evaluated in two locations: North Carolina and Oregon. Consumers (n=200 at each location) evaluated the cheeses for overall liking and other consumer attributes. Data analysis was conducted using principal component analysis, internal preference mapping, and external preference mapping.

Descriptive analysis of both peanut and Cheddar cheese results indicated distinctive flavor differences. Preference mapping identified consumer preferences for peanuts and consumer segments for Cheddar cheese.

USING SENSORY ANALYSIS TECHNIQUES TO EVALUATE PEANUT AND CHEDDAR CHEESE PRODUCTS

by

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A thesis submitted to the Graduate Faculty of
North Carolina State University in partial fulfillment of
the requirements for the Degree of Master of Science

DEPARTMENT OF FOOD SCIENCE

Raleigh

2003

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BIOGRAPHY

Nikkisha "Nikki" Dantina Young was born on January 25, 1975 in San Francisco, California, to Anita Jenkins-Helton and Caesar Young II. Nikki has two younger half-brothers, Caesar Jr. and Dante, along with a half-sister, Jasmine.

Nikki graduated from Holy Names High School in 1993 and completed her Associate of Arts degree in General Curriculum at Laney Community College in 1995. Nikki completed her Bachelor of Science degree in Food Science at the University of California at Davis in 2001. During her undergraduate study at UC Davis, Nikki became heavily involved in Food Science-related extracurricular activities and completed product development internships with Néstle USA and the Taco Bell Corporation. Upon completion of her Bachelor of Science degree, Nikki took a one-year hiatus to complete two sensory science internships at M&M/Mars, Inc. and Sensory Spectrum, Inc. As a result, these industry experiences influenced Nikki's decision to pursue Sensory Science at a respectable graduate program.

Nikki began her graduate program in August 2001 at North Carolina State University. Nikki pursued a Master's of Science degree in Food Science, Sensory Science option, with a minor in Business Management. She participated extensively in numerous extracurricular activities such as: Vice President of the Food Science Club (2002-2003); 2002 Product Development Team; Institute of Food Technologists student member (2001-present); and Minorities in Agriculture, Natural Resources, and Related Sciences student member (2001-present). Nikki has also presented at many national conferences.

ACKNOWLEDGEMENTS

The author wishes to express her deepest gratitude to her mother, Anita Jenkins-Helton, for her unwavering support, guidance, and endearing love. Ms. Jenkins-Helton's daughter is forever grateful for the encouragement and direction provided by her mother. Ms. Young also would like to thank her father, Mr. Caesar Young II, for his support and advice. Ms. Young finally wishes to thank her entire family for their determination, courage, and additional support throughout the college years and beyond.

The author especially thanks Dr. MaryAnne Drake and Dr. Timothy Sanders for their guidance, mentorship, enthusiasm for graduate research, and dedication in developing Ms. Young's research skills. The author is extremely confident that she has received superior training in enhancing her sensory/analytical skills. Many thanks to Lisa Dean, Keith Hendrix, Elaine Lowell, the Sanders lab, the Drake lab, Michele Keziah, Dr. John McCreery, Gail Civille, Barbara Pirmann, and Clare Dus for helping the author through her graduate journey. A very special thanks to Dr. Annie J. King at UC Davis, for the author is extremely grateful for Ms. King's confidence in the author's potential to attend graduate school. The author wishes to express her sincere appreciation to Wendy Campbell, Shay Penny, Trivette Vaughan, Lynette Kleman, Kelly Stevens, Mary Whetstine, Janine Beucler, Tara Kurtz, Stephenie Drake, Carol Anderson, Janell Hampton, Alicia Lockett, and David Santos for their words of encouragement, humor, and advice. They have all contributed to the author's personal and professional maturity.

Finally, the author wishes to thank her partner, Mr. John Jones, for his love, support, and confidence in the author.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

Introduction

CHAPTER 1. INTRODUCTION

Preference mapping techniques are useful in the food industry. They are instrumental in assessing consumer liking, product preference, and product positioning. Preference mapping assists in probing the numerous sensory attributes of a product and in gaining insight into improving product acceptability (McEwan, 1996). Numerous companies conduct reformulation procedures on new and existing products; and preference mapping aids in the product optimization process. Preference mapping techniques also involve placing market products, which may enable companies to identify potential opportunities through product gaps (McEwan, 1996). The two areas of preference mapping are *internal preference mapping* and *external preference mapping*.

Internal preference mapping is a principal component analysis (PCA) of the matrix of hedonic scores across the products (the observations) and the consumer (the variables) which is carried out on a covariance matrix to allow for differences in the strength of the consumer preferences to be expressed (Guinard, 1998). The results are presented in a biplot format, in which consumers or product samples are illustrated. Internal preference mapping identifies preference trends and allows for the visual identification of the consumer groups pointing in the same direction, thus preferring the same products (Schlich, 1995).

External preference mapping regresses individual consumer preferences onto the first two principal components of the covariance matrix of descriptive or other analytical ratings across products (Schlich, 1995; Guinard, 1998). The profile space is typically external to the acceptability data (McEwan, 1996). In external preference mapping, the dimensions of the profile space are the explanatory (or predictor) variables, while acceptability is the response (or dependent) variable (Schlich, 1995). The two common types of preference behavior models are the *vector* model (fits a linear regression) and the *ideal point/circular* model (fits a quadratic regression) (McEwan, 1996).

Minimal research has been conducted in using preference mapping techniques to understand the flavor and textural characteristics of specific American commodities. For instance, peanuts and cheese are two of America's most popular food items. They are consumed in such forms as snack items, food ingredients, and as dietary food selections. However, minimal preference mapping techniques have been investigated in relation to these two commodities. The objectives of this research study are: (1) To evaluate the distinctive peanut and cheese flavor characteristics using descriptive analysis methods; (2) to determine the overall acceptability of peanuts and cheese using consumer/affective testing efforts; and (3) to interpret both the descriptive analysis and consumer evaluation data results independently and together using univariate statistics and multivariate statistics for both peanut and cheese commodities.

CHAPTER 2

Literature Review

CHAPTER 2. LITERATURE REVIEW

2.1 Sensory Analysis

Sensory analysis is defined as a scientific application used to evoke, measure, analyze, and interpret responses to food attributes or characteristics as they are perceived through a person's sense of sight, smell, hearing, touch, and taste in forming a food perception (Stone and Sidel, 1993). Sensory analysis methods are used in quality control, product development, and research and development applications. The primary goal of sensory analysis is to conduct valid and reliable tests in producing data for which important and sound decisions can be made (Meilgaard et al., 1999). The two primary areas of sensory analysis are *analytical* and *affective* tests (Lawless and Heymann, 1999).

Analytical tests are comprised of discrimination tests (paired-comparison, triangle, and duo-trio), threshold determinations, and descriptive analysis (Chambers and Wolf, 1996; Meilgaard et al., 1999; Lawless and Heymann, 1999). These tests usually require a trained panel to assess the sensory attributes related to a food or beverage product. *Affective* tests are classified under two categories: *qualitative* tests (focus groups, focus panels, and one-on-one interviews) and *quantitative* tests (preference tests and acceptance tests) (Meilgaard et al., 1999). Affective tests typically use untrained consumers for product evaluation and determining product preferences. Both groups of tests have wide applications and can be powerful tools when used appropriately.

2.2 Analytical Tests

2.2a. Discrimination Tests

Discrimination tests are a class of tests based on the perceived difference between two products. Descriptive sensory evaluation may be subsequently conducted in identifying the basis for difference (Sidel and Stone, 1993; Meilgaard et al., 1999). The respondent is forced to choose one sample, and the choice can be either designated as correct or incorrect (Sidel and Stone, 1993; Chambers and Wolf, 1996). Discrimination tests are best applied when there is a slight or minimal difference between samples (Chambers and Wolf, 1996). They are used in determining product reformulation procedures, product positioning, ingredient and/or processing changes, and cost reduction (Chambers and Wolf, 1996). Many discrimination testing methods are available; the most commonly used tests are *paired comparison*, *triangle*, and *duo trio tests* (Sidel and Stone, 1993; Meilgaard et al., 1999).

2.2b. Paired-Comparison Test

The *paired-comparison* (or paired difference) test is a two sample test in which a subject indicates that one sample has a higher desired characteristic (such as sweetness, flavor, texture, appearance, etc.) by circling or selecting their choice using a scorecard or ballot (Sidel and Stone, 1993). Since the paired-comparison test is directional (the attribute is indicated), it is unique from other discrimination tests. The subjects are forced to make a decision by selecting either one or the other of the two samples, but not "neither" (Sidel and Stone, 1993; Lawless and Heymann, 1999). The key advantage of using the paired-comparison test is its simple testing methodology; the test is easy to implement and organize, for the samples are served simultaneously and the subject can make a quick decision (Sidel and Stone, 1993; Chambers and Wolf, 1996). However, a distinct drawback to using the paired-comparison test is the difficulty of specifying the difference or having the confidence in the subjects' understanding of the characteristic being evaluated (Sidel and Stone, 1993).

2.2c. Triangle Test

A *triangle* test is used when the testing objective is to determine if a sensory difference exists between two products (Sidel and Stone, 1993; Meilgaard et al., 1999). The testing design is comprised of three samples total, with one sample being different or the "odd" sample (Chambers and Wolf, 1996). The merits of using the triangle test are related to the simplicity of the testing design and its statistical significance over both the paired comparison and duo trio tests when small differences are observed (respondents are able to identify the correct sample 33% of the time in comparison to 50% of the time with paired comparison or duo-trio tests) (Chambers and Wolf, 1996). However, the triangle test is limited in use to products that involve sensory fatigue, carry-over, or adaptation, along with subjects who find the testing design confusing (Meilgaard et al., 1999).

2.2d. Duo-Trio Test

In a *duo-trio* test, the set of samples are similar to the triangle test but one of the matched samples is the reference sample, which is always considered first (Chambers and Wolf, 1996; Meilgaard et al., 1999). Respondents are directed to determine which of the two samples is the same as the reference sample (Chambers and Wolf, 1996). Samples are usually presented simultaneously but can be presented successively (Chambers and Wolf, 1996). The primary advantages of using the duo-trio test are the simplicity of the test (it is easily implemented and understood) and its use of a reference sample (Meilgaard et al., 1999). The main disadvantage of using the duo-trio test is that it is statistically inefficient in comparison with the triangle test because of the higher chance of obtaining a correct result by guessing (Meilgaard et al., 1999).

2.2e. Threshold Methods

Threshold methods are specifically designed for such purposes as determining the strength or concentration of a stimulus required to product effects on four different levels (Chambers and Wolf, 1996). The four different levels are: (1) *absolute* or *detection* threshold (the lowest stimulus detected); (2) *recognition* threshold (the level of a stimulus at which the specific stimulus is recognized and identified); (3) *difference* threshold (the extent of change in the stimulus necessary to produce a noticeable difference; and (4) *terminal* threshold (the magnitude of a stimulus above which there is no increase in the perceived intensity of the appropriate stimulus quality) (Chambers and Wolf, 1996; Meilgaard et al., 1999). In a typical threshold determination for an individual respondent, a series of samples (between 5-8 sets) representing increasing concentrations (of a chosen stimulus in the selected diluent) are prepared (Chambers and Wolf, 1996). Samples are presented in either odorless jars or soufflé cups and are analyzed by either sniffing the sample headspace (aroma) or by taste. For each set of samples, the individual respondent then indicates their perceived sample choice (if it is noticed) and records the information on their given ballot. Threshold methods are used for determining product acceptability, detecting product contaminants, and product formulation procedures (Sidel and Stone, 1993; Chambers and Wolf, 1996). However, threshold methods are time-consuming, labor intensive, and the quantity measured (the lowest intensity a person can detect) might be elusive and vague (Chambers and Wolf, 1996; Meilgaard et al., 1999).

2.2f. Descriptive Analysis

Descriptive analysis is the detection (discrimination) and the description of both the qualitative and quantitative sensory aspects of a product by highly trained panelists (Meilgaard et al., 1999). Human subjects/panelists are used as instruments (usually 5-15 panelists), and prospective panelists are screened and selected before a tasting project begins. The panelists have the expertise in assessing the qualitative and quantitative aspects of a food product. Qualitative aspects (Figure 1) involve selecting the characteristics in a food sample (such as appearance, flavor, texture, and color), while the quantitative aspect utilizes the intensity ratings of these characteristics for a given food sample. Descriptive panels usually require 50-100 hours of training before acceptable panel data is collected and measured accurately, which makes them a significant time investment (Meilgaard et al., 1999). The most commonly used descriptive analysis methods are *Flavor Profile®*, *Quantitative Descriptive Analysis (QDA®)* method, and *Spectrum™* method.

2.2g Flavor Profile® Method

The *Flavor Profile* method was developed by Arthur D. Little, Inc. in the late 1940s and in the early 1950s and is used primarily to perceive the aroma and flavor profiles of a product, the product intensities, product aftertaste, and the order of appearance (Meilgaard et. al, 1999; Lawless and Heymann, 1999). It is the only qualitative descriptive method known (Stone and Sidel, 1993). The method uses a total of four to six judges, and the samples are evaluated using a consensus technique. The terminology used to describe and rate the product category are determined by the judges based on consensus agreement; and the judges are trained over a 2-3 week period to accurately define the flavors of the respective product category (Lawless and Heymann, 1999). The panelists, usually seated at a round or hexagonal table, individually evaluate one sample at a time for both flavor and aroma attributes, but the samples are not tasted back and forth; that is, you cannot return back to a previous sample for evaluation due to potential bias concerns.

Results are reported to the panel leader, who then conducts a general discussion of the panel and derives a consensus profile based on the panel responses (Stone and Sidel, 1993). The Flavor Profile method is represented by a 7-point numerical type category scale anchored with words to interpret the attribute intensities (Meilgaard et al., 1999). Interestingly, the primary advantage (but also a limitation) of the Flavor Profile method is the panel size, which employs five to eight panelists and can render inconsistent data if the panelists are not sufficiently trained and if a panel member continually dominates the evaluation sessions (Meilgaard et al., 1999). In addition, another disadvantage is the extreme limitation in using the data results for statistical interpretation, since the scale has a very limited numerical range (Lawless and Heymann, 1999).

2.2h Quantitative Descriptive Analysis® (QDA) Method

The *Quantitative Descriptive Analysis (QDA)* method was developed by the Tragon Corporation in partial collaboration with the Department of Food Science at the University of California at Davis in 1974 as a result of the growth of new food products and competition in the food industry for products with distinctive sensory properties as well as addressing the lack of statistical treatment of data obtained with the Flavor Profile and/or other methods (Stone and Sidel, 1993; Meilgaard et al., 1999). The QDA method uses ten to twelve panelists who are qualified users/acceptors of products being tested, and the respondents develop a sensory language (or modify an existing one) to describe all of the products' sensory attributes under the direction of a panel leader (Chambers and Wolf, 1996). The panelists group the attributes by modality (appearance, flavor, texture, etc.) and develop definitions for each attribute category. Then the panelists also develop a standardized evaluation procedure and practice the scoring of the products evaluated (Chambers and Wolf, 1996; Stone and Sidel, 1993). After completing the training session, the panel evaluates all products using a repeated trials design (Chambers and Wolf, 1996).

The merits of the QDA method include individual panelist judgments, the short training time (only 6-10 hours), and the freedom of panel language development without the panel leader's influence (Lawless and Heymann, 1999). Another advantage to using the QDA method is related to the substantial amount of statistical analysis, where the data is represented in the graphical form of a "spider web" plot with a branch or spoke from a central point for each attribute to identify specific attributes that define a product (Meilgaard et al., 1999; Lawless and Heymann, 1999). However, the limitations are that the panel must be trained for a specific product category (which can be quite expensive), the lack of indicating the order of sensation perceptions, and that the results are relative and not absolute (Lawless and Heymann, 1999; Meilgaard et al., 1999).

2.2i Spectrum™ Descriptive Analysis Method

The Spectrum method was developed by Gail Civille from Sensory Spectrum in 1987 and is a procedure that consists of complete, detailed, and descriptive characterization of a product's sensory attributes (Meilgaard et al., 1999; Muñoz and Civille, 1992). The characterization provides information on the perceived sensory attributes and the intensity levels of each; perceived intensities are recorded in relation to universal or absolute scales, which are constant across all products and attributes (Muñoz and Civille, 1992; Chambers and Wolf, 1996). A Spectrum panel is trained in a variety of attribute modalities; and the panel is capable of evaluating an array of product categories that include foods, beverages, home care, personal care, paper, skinfeel/cosmetics, and other products (Muñoz and Civille, 1992; Chambers and Wolf, 1996). The panelists are selected based on several criteria: perceptual acuity, rating ability, availability, interest, health, positive attitude, and the capacity of abstract reading (Muñoz and Civille, 1992). The panelists' training is conducted in two phases: the *orientation* phase, in which physiological principles for the sensory modalities of procedures and interest are used; and the *practice* phase, where physical demonstrations are performed to allow the respondents to practice and apply the principles learned during the orientation sessions (Chambers and Wolf, 1996). The panelists use numerical 15-point intensity scales, and their scales have been created to have equi-intensity across scales (for instance, a 5 on the sweetness scale is a 5 on the salty scale) (Lawless and Heymann, 1999).

The major advantages of using the Spectrum method are that it gives specific emphasis to both the qualitative and quantitative aspects of descriptive measurement; one panel can be used to evaluate and compare a wide range of products since the language and scale are not particular to one product; and includes the wide use of statistical analysis methods (Muñoz and Civille, 1992). On the other hand, the major disadvantages of using the Spectrum method are panel development (the panel requires a significant amount of training time, which can be very expensive), panel maintenance, and panel leadership (Lawless and Heymann, 1999). The Spectrum method requires a highly trained panel leader.

2.2j. Other Descriptive Analysis Methods

Other descriptive analysis methods are used to a lesser extent. The *Texture Profile* method was originally developed at the General Foods Corporation to define the textural characteristics of foods and was later modified to include specific attribute lexicons for products such as semisolid foods, beverages, skinfeel products, and paper and fabric items (Civille and Szczesniak, 1973; Civille and Liska, 1975; ASTM, 1997; Civille and Dus, 1990). The terminology is specific for each product type but is based on the defined rheological principles expressed in the early Texture Profile publications (Szczesniak, 1963; Szczesniak et al., 1963; Brandt et al.; 1963). Panelists are carefully screened and selected based on their ability to discriminate between specific product textural differences, and panelists define all terms and procedures used in the evaluation in reducing experimental variation (Stone and Sidel, 1993). In addition, there are several descriptive panel techniques that are actually an amalgam of two or more descriptive approaches.

Time–Intensity (TI) is a special application of descriptive analysis in which all sensations perceived in food and beverage systems are examined over time as the food or beverage system is exposed to chemical, thermal, dilution, and physical changes in the mouth and nasal passages (Chambers and Wolf, 1996). The sensory responses are monitored at multiple time points during the entire mastication period; and the responses are recorded using pen and paper, a scrolling chart recorder (Larson-Powers and Pangborn, 1978), or a computer system (Guinard et al., 1985). Data analysis is handled usually by selecting selected parameters such as maximum intensity, duration, and the area under the curve, and applying traditional descriptive data statistical analysis procedures (Chambers and Wolf, 1996; Lawless and Heymann, 1999).

The *Free-Choice Profile* method is a distinctive procedure developed by Williams and Arnold in 1984 at the Agricultural and Food Council in the United Kingdom as a solution to the problems of consumers using difference terms for a particular attribute (Meilgaard et al., 1999). This method allows the panelist to invent and use as many terms as he or she needs to describe the sensory properties of a sample set; the samples are all from the same product category, and the panelist develops their own ballot (Meilgaard et al., 1999; Lawless and Heymann, 1999). Data analysis is conducted using the generalized Procrustes analysis (Gower, 1975), a procedure that provides a consensus picture of the data from each individual panelist using a two or three-dimensional space (Lawless and Heymann, 1999).

2.3 Affective Tests

The primary goal of a consumer (or affective) test is to measure the personal responses (preference, degree of liking, and/or acceptance) by potential or existing customers of a product, a product idea, or specific product attributes (Guinard, 1998). Consumer tests have proven very effective as a principal tool in designing products or services that will sell in larger quantity and/or attract a higher market price (Meilgaard et al., 1999). Consumer tests are excellent in predicting product success in the market and product functionality based on consumer feedback. Consumer tests use untrained panelists and require a large sample size (50 to 500 consumers) for acceptable data results. The most commonly used consumer/affective tests are classified under two categories: *qualitative* tests (focus groups, focus panels, and one-on-one interviews) and *quantitative* tests (preference tests and acceptance tests).

2.3a Qualitative Affective Tests

Focus groups are a small group of 10 to 12 consumers selected on the basis of specific criteria (consumer demographics, purchasing habits, product usage, etc.) that meet for one to two hours with a focus group moderator (Meilgaard et al., 1999). The moderator discusses the subject of interest and gathers as much subjective product information as possible using group dynamic techniques; the moderator collects the information using tapes, audio or visual aids; and traditionally two to three total sessions are held to determine the overall trends and attitudes of the consumers towards a specific concept or product prototype (Lawless and Heymann, 1999; Meilgaard et al., 1999).

Focus panels are a variation of the focus group in which the interviewer uses the same groups of consumers an additional two to three times for expanded discussion. The objective is to make preliminary contact with the group, have a discussion on the product topic, send the group home to use the product, and then have the group return to discuss its experiences and consumer attitudes towards the product (Meilgaard et al., 1999).

One-on one interviews occur when a researcher desires to understand and investigate a great deal from each consumer or in which a topic is too sensitive for a focus group (Meilgaard et al., 1999). The interviewer conducts successive interviews with up to 50 consumers in assessing their distinctive consumer behavior traits; this method is unique in that the consumer at times might prepare a product in either a central interviewing site or in their own home (Meilgaard et al., 1999). Personal notes or a video regarding the process are used, which is then discussed with the consumer for more information into their own experiences with preparation and usage; this information provides the researcher insight into consumer behavior and underlying consumer needs and wants, in which this information can lead to innovative products and services to meet and address such consumer needs (Meilgaard et al., 1999).

2.3b Quantitative Affective Tests

Preference tests are designed to determine the consumers' subjective responses to product samples and their reasons for selecting their choice (Amerine et al., 1965). This method requires the panelist to indicate which of the two coded samples is preferred (Stone and Sidel, 1993). The major rule associated with preference tests is that the order of presentation must be balanced in minimizing positioning biases and the rule must never be violated (Chambers and Wolf, 1996). This method is fairly simple to use and allows for statistical analysis methods. However, the major limitation of the preference test is that the panelists do not indicate the likes and dislikes of each of the products tested; thus, the researcher should have existing knowledge of the “affective status” of the current product or competitive product against the tested product (Meilgaard et al., 1999). Another limitation is that unintentional outside variables (such as different serving temperatures, different sample amounts in the testing container, product sizes, and other variables) might affect the overall sample appeal and consequently the overall test (Chambers and Wolf, 1996). The most common preference tests are paired preference, rank preference, multiple paired preference (all pairs), and multiple paired preference (selected pairs).

Acceptance or hedonic tests measure the degree of acceptance and specifics of what is liked and disliked about the product being tested (Amerine et al., 1965). Samples are presented either monadically, sequentially, or in groups (Chambers and Wolf, 1996); and the consumers measure specific consumer responses to particular sensory attributes (appearance, color, flavor, texture, etc.) of a product. The use of intensity, hedonic, or “just right” scales can generate data which can be related to hedonic ratings and to descriptive analysis data (Meilgaard et al., 1999). The major advantage of acceptance tests is that they provide significant insight into a consumer’s likes and dislikes of a particular food product or sample and provides the researcher with numerical values to conduct sophisticated statistical analysis methods (both univariate and multivariate statistics are used in interpreting acceptance testing results) in understanding consumer preferences. On the other hand, the major criticisms of acceptance tests are the use of parametric analysis methods using a bipolar scale, the lack of evidence of interval equality, and neutral category avoidance (Stone and Sidel, 1993).

2.4 Relationship between Descriptive Analysis and Consumer Responses

There is significant interest in understanding which sensory characteristics drive consumer acceptance of food and beverage products. These responses influence product development guidance and business decisions. There are several experimental methods used for examining the relationship between descriptive measurements and consumer responses. The most common methods are *Response Surface Methodology (RSM), factor analysis, multiple regression, partial least squares regression,* and *preference mapping* (Guinard et al., 2001).

Response Surface Methodology is a designed regression analysis that predicts the value of the response variable (dependent variable) based on the controlled values of the experimental factors (independent variables) using quantitative measurements (Meilgaard et al., 1999). *Factor analysis* is a statistical approach used to analyze interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors) (Hair et al., 1992). The statistical approach involves finding a way of condensing the information contained in a number of original variables into a smaller set of dimensions (factors) with minimum information loss (Hair et al., 1992). The two main types of factor analysis are *principal component analysis* (reviews the total variance among the variables, with the generated solution including as many factors as there are variables) and common factor analysis (uses an estimate of common variance among the original variables to generate the factor solution; the number of factors will always be less than the number of original variables) (Thaplia, 2002). *Multiple regression* is a multivariate method that allows multiple independent variables to be included in the regression equation for *y*; and an integral part of the analysis involves the assessment of the value of each term considered for inclusion in the model (Meilgaard et al., 1999). *Partial least squares regression* derives factors (linear combinations of the x-variables) that (1) explain large portions of the variability in the x-variables and simultaneously (2) correlates with the dependent predictor variable *y* as much as possible (Meilgaard et al., 1999). Partial least squares regression ensures that each factor known has maximum predictive power over *y* (Meilgaard et al., 1999).

Preference mapping techniques are commonly used to examine the relationship between descriptive sensory/analytical data and consumer responses. Preference mapping assists scientists in understanding the sensory attributes that influence consumer preferences (Schlich, 1995; McEwan, 1996; Murray and Delahunty, 2000). It also offers the opportunity to use information generated from the best source in each data set; the consumer only provides hedonic data, while a trained sensory descriptive panel provides reliable descriptive data (McEwan, 1996). Preference mapping techniques are influential in evaluating consumer liking, product preference, and product positioning. Preference mapping techniques are very useful in the food industry as well as others. The two areas of preference mapping are *internal preference mapping* and *external preference mapping*.

Internal preference mapping is a principal component analysis (PCA) of the matrix of hedonic scores across the products (the observations) and the consumer (the variables) which is carried out on a covariance matrix to allow for differences in the strength of the consumer preferences to be expressed (Guinard, 1998). The results are presented in a biplot format, in which consumers or product samples are illustrated. Internal preference mapping identifies preference trends and allows for the visual identification of the consumer groups pointing in the same direction, thus preferring the same products (Schlich, 1995). Internal preference mapping's advantages are related to its relative ease of use (in comparison to external preference mapping), allows actual preference dimensions to be determined (since only consumer acceptability data is used), and can be used as a screening procedure without sensory descriptive profiling methods (McEwan, 1996). However, the disadvantages include limited dimensions examined (only two are acceptable) and very low percentage of variability explained by the data set (McEwan, 1996; Guinard, 1998).

External preference mapping regresses individual consumer preferences onto the first two principal components of the covariance matrix of descriptive or other analytical ratings across products (Schlich, 1995; Guinard, 1998). The profile space is typically external to the acceptability data (McEwan, 1996). In external preference mapping, the dimensions of the profile space are the explanatory (or predictor) variables, while acceptability is the response (or dependent) variable (Schlich, 1995). The two common types of preference behavior models are the *vector* model (fits a linear regression) and the *ideal point/circular* model (fits a quadratic regression) (McEwan, 1996). The merits of using external preference mapping are that it offers a "relatively" straight forward procedure for relating sensory and consumer information for product optimization, helps identify new markets, provides future product development direction, and provides market segmentation information in relation to sensory preferences (McEwan, 1996). The limitations to using external preference mapping include a fairly large sample size set is required (usually 12-20 samples), the complexity of programming the experimental procedure, cost, consumers not completely well represented by the models, and the preference data is not always directly related to the sensory profile map (McEwan, 1996; Guinard, 1998).

Both internal and external preference mapping techniques have been implemented in numerous research studies. Research studies conducted using only internal preference mapping techniques include mozzarella cheese (Pagliarini et al., 1997), ranch salad dressing (Yackinous et al., 1999), retail fat spreads (Bower and Saadat, 1998), apples (Daillant-Spinnler et al., 1996; Jaeger et al., 1998), starchy food cuisines (Monteleone et al., 1998), sheep meat (Prescott et al., 2001), and liquid dairy products (Richardson-Harman et al., 2000). Research studies conducted using only external preference mapping practices include rice products (Meullenet et al., 2001), muesli oat flakes (Kälviäinen et al., 2002), powdered chocolate milk (Hough and Sánchez, 1998) and coffee (Heyd and Danzart, 1998). Research studies that performed both internal and external preference mapping techniques include dry fermented sausages (Helgesen et al., 1997), Cheddar cheese (Murray and Delahunty, 2000), lager beers (Guinard et al., 2001), and tortilla chips (Meullenet et al., 2002).

2.5 Peanuts: Current Industry Information

Peanuts consumption is quite extensive, with 2.4 billions pounds consumed in the United States alone, 50% of it consumed as peanut butter (Peanuts and Health, 2001). Peanuts are consumed as an individual raw ingredient or incorporated in other products such as peanut butter, confectioneries, ice cream, trail/nut mixes, baked goods (cookies, cakes, muffins, etc.), or in dinner foods. Peanuts are also used as cooking agents (such as peanut oil and peanut flour). In the United States, peanuts are grown in the following states: Alabama, Florida, Georgia, North Carolina, Oklahoma, South Carolina, Texas and Virginia. Peanuts grow underground in the soil and are classified as a legume (Peanuts and Health, 2001). The four types of peanuts grown in the United States are Runner variety, Virginia, Spanish, and Valencia.

2.6 History of Peanuts

Peanuts, a legume from the plant *Arachis hypogaea*, are native to South America and have been found in Peruvian settlements as early as 900 B.C. (McGee, 1984). Peanut seeds were spread by Portuguese explorers to East Africa and by the Spanish to the Philippines; it appeared in North America via Africa and the slave trade and was primarily used as a livestock feed for a long period (McGee, 1984). The peanut became a very important oil and food source during World War II and is currently consumed in massive amounts (Peanuts and Health, 2001). George Washington Carver, a gifted botanist at the Tuskegee Institute in Alabama, in 1896 conducted fundamental research on peanuts and recommended that peanuts be planted as a rotation crop in the southeastern cotton-growing areas (American Peanut Council, 2002a). Dr. Carver not only changed peanut farming techniques, but also developed more than 300 uses for peanuts, generally for industrial purposes. Currently, the major peanut world market exporters are the United States, China and Argentina (American Peanut Council, 2002b). United States peanuts represent approximately 10% of the world's peanut production; the United States has become one of the principal world exporters, accounting for about one-fourth of world peanut trade (American Peanut Council, 2002b).

2.7 Peanut Composition and Health Significance

Peanuts are comprised of 26% protein, 48% fat, 19% carbohydrates, and 6% water (McGee, 1984). Peanuts also provide significant health benefits. Peanuts are rich fiber and vitamin E sources, and are relatively high in folic acid, copper, thiamin, manganese, phosphorus, magnesium, niacin and zinc. Peanut fat content is primarily monounsaturated and polyunsaturated (The Peanut Institute, 2001). In addition, the United States Department of Agriculture (USDA) indicates that resveratrol, a plant compound, might help reduce the risks of heart disease and cancer (Sanders and McMichael, 1998). Furthermore, peanuts are also cholesterol-free and a naturally low-sodium food product.

2.8 Peanut Growing and Harvesting

Peanut growing and harvesting involves several crucial steps. All steps have been provided by the American Peanut Council (2002c). Peanuts are planted after the last frost in April or May when soil temperatures reach 65–70° F (20° C) and preplanting the tillage ensures a rich, well-prepared seedbed. The row spacing is determined to a large extent by the type of planting and harvesting equipment utilized. Peanuts may be cultivated up to three times per year, depending on the region, to control weeds and grasses. A climate with approximately 200 frost free days (175 days for Spanish peanuts) is ideal for a good crop. Warm weather conditions, coupled with rich, sandy soil, will result in the appearance of peanut leaves 10-14 days after the first planting. In addition, many farmers are utilizing irrigation in an effort to reduce crop stress and thereby enhance opportunities for the production of high quality peanuts.

Peanut harvesting occurs in two stages. The first stage, digging, begins when about 70% of the peanut pods have reached maturity; and at the optimum soil moisture, the digger loosens the plant and cuts the tap root. A shaker lifts the plant from the soil, gently shakes the soil from the peanuts and inverts the plant, exposing the pods to the sun in a windrow. The second phase of the harvest, curing, occurs for two to three days in the field; and a combine separates the pods from the vines, placing the peanut pods into a hopper on the top of the machine. The vine is returned to the field to improve the soil fertility or baled into hay for livestock feed; and the freshly dug peanuts are then placed into drying wagons for further curing with forced hot air slowly circulating through the wagons. In this final curing stage, moisture content is reduced to 8-10% for safe storage.

2.9 Peanut Flavor

Peanut flavor is very complex in nature and is comprised of numerous volatile and non-volatile compounds. Volatile compounds are responsible for the aroma and flavor of roasted peanuts, with over 300 compounds present (Ahmed and Young, 1982). Peanut aroma and flavor are highly influenced by oil stability, since peanuts are comprised of 50% oil (Braddock et al., 1995). Both How (1984) and Oupadissakoon and Young (1984) used descriptive analysis terminology in defining attributes that corresponded to the effects of peanut variety, handling, roasting, and storage. Johnsen et al. (1988) created a descriptive flavor lexicon of terms to describe the desirable and undesirable flavors in peanuts and this lexicon was later expanded by Sanders et al. (1989) in describing the effects of maturity and curing temperatures on same size peanuts of different maturity. The lexicon (Johnsen et al., 1988) consisted of three categories: aromatics, tastes, and chemical feeling factors. The aromatic attributes included roasted peanutty, raw/beany, dark roast, sweet aromatic, and woody/hulls/skins as well as the off-flavors cardboard, painty, burnt, green, earthy/musty, grainy, and plastic chemical. The off-flavor fruity-fermented was later added to the aromatic category (Sanders et al., 1989). The tastes attributes included the four basic tastes: sweet, sour, salty, and bitter; and the chemical feeling factor attributes were astringent and metallic.

Gas chromatography (GC) analysis methods have exposed specific flavor compounds associated with roasted peanuts. Mason et al. (1969) and Johnson et al. (1971a, b) first reported that pyrazine and carbonyl compounds were responsible for roasted peanut flavor. Mason et al. (1969) stated that the roasted nutty character of peanuts was caused by the reaction of reducing sugars liberated from sucrose with free amino acids. Mason et al. (1969) also reported that the pyrazines found in roasted peanuts can arise from the glucose, fructose, and free amino acids found in raw peanuts. Interestingly, monosaccharides, which participate in Maillard browning reactions, are extremely important in the formation of pyrazine compounds in roasted peanuts (Newell et al., 1967). In regards to amino acids prevalent in peanuts, Newell et al. (1967) reported that aspartic acid, glutamine, asparagine, histidine, and phenylalanine were associated with typical or desired peanut flavor; while threonine, tyrosine, lysine, and an unknown amino acid were considered precursors of atypical or undesirable peanut flavor. In addition, Newell et al. (1967) mentioned that the amino acids associated with typical peanut flavor were comprised of 50% of the total free amino acids in fully mature peanuts.

Pyrazines greatly influence peanut flavor and overall product acceptability (Bett and Boylston, 1992; Braddock et al., 1995; Warner et al., 1996). In a study conducted by Buckholz et al. (1980) using GC analysis, 2-ethyl-6-methyl pyrazine was identified as contributing a roasted nutty flavor in peanuts and was positively correlated with overall product acceptance. A later study performed by Bett and Boylston (1992) showed that alkylpyrazines were primarily responsible for the roasted peanut attribute. Ironically, when the concentration of pyrazine compounds increased in peanuts, the flavor became increasingly bitter (Leunissen et al., 1996). The compounds phenylacetaldehyde and benzeneacetaldehyde are associated with contributing a sweet and caramel note to peanuts (Mason et al., 1969; Braddock et al., 1995).

Substantial research has also been conducted in understanding the off-flavor volatile compounds in peanuts. Off-flavor levels in peanuts are a function of curing temperature, exposure time to the temperature, moisture content, peanut size, and maturity stage of the peanut kernels (Pattee et al., 1965). It is also known that immature kernels have higher off-flavor levels than mature kernels for a given curing temperature and the level of aldehydes increase during storage as pyrazine levels decrease (Pattee et al., 1965; Sanders et al., 1990; Warner et. al, 1996). In addition, storage time greatly affects peanut flavor and quality characteristics, for peanuts stored over time increase in off-flavor development and greatly decrease in roasted peanutty flavor (Bett and Boylston, 1992; McNeill and Sanders, 1998; Pattee et al., 1999). Finally, peanuts contain a high amount of polyunsaturated fatty acids, which make peanuts more susceptible to lipid oxidation (Braddock et al., 1995).

In regards to specific peanut off-flavor attributes, cardboardy is detected when light-induced lipid oxidation occurs in peanuts (Pattee et al., 1995). As lipid oxidation progresses, the peanut characteristics intensify and change and are associated with the sensory attribute "painty," which is described as having a aromatic note reminiscent of old paint or linseed oil (Pattee et al., 1995). The compounds most associated with cardboardy, rancid, and painty flavors are hexanal, heptanal, 2-decenal, 2, 4 decadienal, and octanal (Bett and Boylston, 1992). All of these compounds are lipid oxidation compounds. Pentenal, a typical carbonyl compound, contributed green, solventy notes in peanuts and was negatively correlated with overall product acceptance; it also contributed chemical burn notes (Buckholz et al.1980; Braddock et al, 1995; Basha and Young, 1996). Both Basha and Young (1996) and Young and Hovis (1990) reported that n-methylpyrrole imparted a musty flavor in peanuts. There is no evidence concerning how musty flavor develops in peanut flavor, but it is believed to be related to peanut handling procedures. Basha and Young (1996) also noted that 2-methylpropanal is associated with fruity fermented flavors in peanuts. The fruity fermented attribute develops from abusive environmental and handling exposures during peanut development, harvesting, and curing (Pattee et al., 1999). Basha and Young (1996) also reported that hexenal, a secondary oxidation product, contributed the raw/beany note in peanuts.

2.10 Cheese: Current Industry Information

Cheese is a very popular dairy product in the United States. According to the United States Department of Agriculture's Economic Research Service (1970-95), the average consumption of cheese increased an impressive 146% between 1970 and 1997 from 11 pounds per person to 28 pounds. In particular, Cheddar cheese, America's most popular cheese, increased in consumption 65% to 9.6 pounds per capita from 1970 to 1997 (USDA Economic Research Service, 1970-97). The main reason why cheese consumption has increased in the United States corresponds to the consumer market's demand for foods that are convenient, on the go, nutritious in content, and appealing to children (Gorski, 1998). In fact, consumers recognize cheese's natural nutritional and functional qualities (Gorski, 1998). Clever promotional campaigns such as "I Love Cheese" found in magazines, radio and television commercials, and on billboard displays have contributed to the increase in cheese consumption. Cheese is consumed in a variety of food products such as pizza, enchiladas, tacos, bagel spreads, pasta dishes, nachos, fast-food sandwiches, sauces for baked potatoes, packaged snack foods, and other related food items.

2.11 History of Cheese

Cheese has an extensive and slightly conflicting history. McGee (1984) reported that the earliest evidence of cheese dates back to 2300 B.C. from a residue found in an Egyptian pot. On the contrary, MSN Encarta (2002) states that cheese history dates back to the ancient Sumerians, who are known to have made and consumed cheese as early as 3500 B.C. The Greek poet Homer in his 9th century BC epic, the *Odyssey*, describes the

Cyclops Polyphemus making cheese and pressing it into wicker baskets (MSN Encarta, 2002). However, numerous food historians credit cheese discovery to an Arabic nomad who poured milk into a leather bottle made from a sheep's stomach before journeying across the desert more than five thousand years ago; when he stopped to drink, he discovered the milk had been transformed into curds and whey by the heat of the sun and the rennet in the sheep's stomach (MSN Encarta, 2002). The first cheese was most likely a result of prolonged bacteria action beyond the point at which a homogeneous, yogurt-like texture was reached (McGee, 1984). By the time Daniel Defoe completed his *Tour Through England and Wales* early in the 18th century, both Cheddar and Stilton brand cheeses were well established (McGee, 1984).

Until the 19th century, cheese making was a local farm industry that used many techniques established by monks in the Middle Ages. In 1851 a farmer in upstate New York named Jesse Williams recognized cheese's potential economic value and created the first Cheddar cheese factory in the United States (MSN Encarta, 2002). About 1900, significant processing developments were made in cheese technology, and the amount and variety of cheese and cheese products consumed and manufactured in the United States have increased tremendously over the last century and in recent years (National Dairy Council, 2000a).

2.12 Cheese Composition and Health Significance

Milk is comprised of 87.4% water and 12.6% milk solids (3.7% fat, 8.9% milk solids-not-fat); the milk solids-not-fat contain protein (3.4%), lactose (4.8%), and minerals (0.7%) (National Dairy Council, 2000c). Milk is a complex colloidal dispersion of proteins (casein and whey) and fat globules in an aqueous solution of lactose, minerals, and other minor constituents (Chandan, 1997). The two prominent proteins, casein and whey, have distinctive roles in milk. Caseins constitute over 80% of the total protein of milk and are subdivided into four main classes: alpha-, beta-, gamma-, and kappa-casein (National Dairy Council, 2000c; Varman and Sutherland, 1994). Whey proteins, which are more heterogeneous than casein, consist mainly of two gene products: beta-lactoglobulin and alpha-lactalbumin (National Dairy Council, 2000c; Varman and Sutherland, 1994).

The fat globules are primarily represented by milkfat, saturated fatty acids, and unsaturated fatty acids. Milkfat, the most complex of the lipids, is comprised mainly of triacylglycerols or esters of fatty acids with glycerol, phospholipids, free sterols (cholesterol, waxes, and squalene), traces of free fatty acids, and varying amounts of fat-soluble vitamins A, D, E, and K (National Dairy Council, 2002c). Saturated fatty acids in milk are largely represented by myristic (14:0), palmitic (16:0), and stearic (18:0) acids (National Dairy Council, 2002c; Varman and Sutherland, 1994). Finally, the major unsaturated fatty acids in milk are oleic (18:1), linoleic (18:2), and linolenic (18:3) acids (National Dairy Council, 2002c). Milk is the base ingredient for the cheese making process.

Cheese is comprised of 25% protein, 30% fat, and 30-40% water (McGee, 1984). The National Dairy Council in 2000 (d) reported that Cheddar cheese, a ripened cheese, is comprised of 32% fat, 23% protein, and 45% other components (carbohydrates, dissolved salts, and other proteins). Cheese also possesses important health benefits.

According to the National Dairy Council (2000e), cheese provides many essential nutrients and vitamins. Cheddar cheese, for example, contains 1059 International Units (UI) of vitamin A per 100g and contributes only 7.3% of sodium. Cheese is also a great source of calcium. For Cheddar cheese, because it is a cheese made with whole milk and is made with a coagulating enzyme, the calcium and phosphorus levels remain largely in the curd (National Dairy Council, 2000e). Cheese is a good source of essential fatty acids linoleic (18:2) and linolenic (18:3) and is low in trans fatty acids (National Dairy Council, 2000e). In regards to health implications, cheese might reduce the risk of cancer and heart disease, and may reduce the risk of dental decay (National Dairy Council, 2000e). Cheese also contains a significant amount of conjugated linoleic acid (CLA), which reduces the risk of certain cancers and heart disease, enhances the immune system function, and regulates body weight/body fat distribution (National Dairy Council, 2000d).

2.13 Cheese and Cheddar Cheese Processing

A Cheddar cheese flow diagram is provided in Figure 2. The first step in cheese processing is the formation of a casein gel. Lactic acid-producing bacteria are infused into pasteurized warm milk to obtain an acceptable acidity for the action of rennet (Green and Manning, 1982). In raw milk cheeses, the lactic acid bacteria also serve to outgrow or out-compete the potentially pathogenic organisms. Rennet anacid protease is then added, which causes the casein micelles to aggregate and trap fat globules and water in a casein gel matrix (McGee, 1984). Rennet, an enzyme found in the stomach of young ruminants, is the enzyme responsible for curdling the milk during the cheese making process (Varnam and Sutherland, 1994). The second stage, the concentration of the curds, occurs when the free whey is drained off and the curds are cut, pressed, cooked, and finally salted (McGee, 1984). The final stage, the "ripening" or "aging" of the cheese curds, transforms the initially bland and rubbery curds into a smooth substance with a distinctive and complex flavor profile (McGee, 1984; National Dairy Council, 2000b). Ripening and associated flavor development is mainly associated with the molecular breakdown of cheese caused by microbial enzymatic activity, including lipase and protease activity (Varnam and Sutherland, 1994). The average aging period of Cheddar cheese is two months to two years.

2.14 Cheddar Cheese Flavor

Cheddar cheese flavor is a complex system that features several key volatile and non-volatile compounds. Green and Manning (1982) reported that there are over 200 volatile components in Cheddar cheese. McGugan et al. (1979) discovered that water-soluble fraction made the greatest contribution to the intensity of cheese flavor. Drake et al. (2001) developed a Cheddar cheese flavor lexicon in which specific terms associated with Cheddar flavor were identified. Lactic acid bacteria are the primary starter cultures in Cheddar cheese flavor production. The main functions of lactic acid bacteria are: the breakdown of lactose to lactic acid, flavor generation, and the modification of the cheese body (Urbach, 1995).

In young Cheddar cheese, the key flavor attributes are cooked, whey, diacetyl, and milkfat/lactone (Drake et al., 2001). Interestingly enough, Christensen and Reineccius (1995) identified methional as the compound that imparted a cooked milk note in aged sharp Cheddar cheese. Milo and Reineccius (1997) identified the following compounds with their respective aromas in mild, young Cheddar cheese: 5-Ethyl-4-hydroxy-2-methyl-2-*H*-furan-3-one and 4-hydroxy-2,5-dimethyl-2-*H*-furan-3-one were associated with caramelized, cooked flavor; δ-Decalactone with a coconut-like milk flavor; methional with a boiled potato, brothy note; and diacetyl possessing a butter-like aroma. It is important to note, however, that no sensory studies were conducted in their study.

Diacetyl has been described as having a "butter-like" aromatic or flavor, and its presence has been documented substantially in Cheddar cheese flavor research. Diacetyl, an a-dicarbonyl, is formed from the citrate present in milk by the microbes *Str. Diacetylactis*, *Leuconostoc citrovorum* and other organisms that utilize citrate (Collins, 1986). For example, Grazier et. al. (1991) conducted a study examining temperature effects on Cheddar cheese flavor and aroma. In particular, they observed that the "buttery" or diacetyl flavor was perceived in the earlier months but declined over time and increasing temperature. Urbach (1997) stated that diacetyl is not prevalent in cheeses matured over six months because the "good full Cheddar flavor" has emerged and the diacetyl aromatic has disappeared. However, diacetyl, in conjunction with glutathione, in some way is essential to Cheddar cheese flavor production (Urbach, 1995).

Milkfat/lactone is an attribute characterized as having a milkfat, coconut milk-like flavor and imparts desirable flavor and texture qualities in Cheddar cheese. In regards to chemical formation, milkfat contains small amounts of d–hydroxyacids which in certain situations lactonize spontaneously to form the corresponding d-lactones (Adda, 1986). Wong et al. (1975) found that lactones contribute to Cheddar cheese flavor in two ways:

(1) they contribute their own distinct flavor and (2) they create a smoother flavor profile with the addition of delta lactones, which could produce mellowing effects in cheese flavor. Wong et al. (1975) also noted that the longer chain lactones might contribute to rancidity in Cheddar cheese. On the other hand, Urbach (1997) noted that lactones contributed a marginal flavor contribution in all cheeses.

In aged Cheddar cheese, the key sensory attributes are fruity, free fatty acid (FFA), sulfur, brothy, nutty, and catty (Drake et al., 2001). The fruity attribute is characterized by a pineapple-like aromatic. Christensen and Reineccius (1995) identified the compounds ethyl butyrate and ethyl caproate for contributing the fruity characteristic and methional for imparting a mushroom, brothy note in aged Cheddar cheese. Bills et al. (1965) identified the esters ethyl butyrate and ethyl hexanoate as the compounds responsible for imparting fruity flavors in Cheddar cheese. Fruity notes in Cheddar cheese are caused by esters, which are common components of cheese volatiles and are regarded as a defect flavor by professional graders, although reportedly consumers are willing to pay for premium fruity cheddar (Urbach, 1997). The "fruity" attribute can also be a microbial induced flavor defect, in which *Psedomonas fragi* hydrolyzes milk fat and esterifies certain lower fatty acids with ethanol, producing fruity flavors (Urbach, 1995).

Free fatty acids (FFA) impart a "baby-burp," rancid type flavor in Cheddar cheese. FFAs are derived from two major sources: (1) the breakdown of the fat by lipolysis and (2) the metabolism of amino acids and carbohydrates by bacteria (Aston and Dulley, 1982). FFAs are formed mainly as a result of lipolytic enzyme action on glycerides (de Jong and Badings, 1990). Law et al. (1976) identified two findings related to free fatty acid development: (1) psychotropic bacteria that possess heat stable lipases are also potential contributors to free fatty acid production during cheese ripening; and (2) when free fatty levels are excessive in Cheddar cheese, rancidity flavor develops. FFAs are important to the flavor of Romano and Parmesan cheeses but are less apparent in Cheddar cheese flavor (Aston and Dulley, 1982).

Sulfur compounds in Cheddar cheese are widely recognized as significant contributors to Cheddar cheese flavor (Aston and Dulley, 1982; Green and Manning, 1982; Urbach, 1995). Sulfur imparts a boiled egg/match-like aromatic, and numerous studies have been conducted in understanding its impact on Cheddar cheese flavor. Earlier research conducted by Kristofferson and Nelson (1955) demonstrated that –SH groups and free hydrogen sulfide levels both increased with Cheddar cheese age. In fact, hydrogen sulfide was considered important in cheese flavor with the cheeses having the highest relative concentration of the free hydrogen sulfide receiving the highest Cheddar flavor intensity score. Later research conducted by Urbach (1995) indicated that such compounds as hydrogen sulfide, dimethyl sulfide, methional, dimethyl trisulfide, dimethyl tetrasulfide, dimethyl sulfone, and sulfur dioxide were isolated from Cheddar cheese. It was also suggested that the production of hydrogen sulfide is dependent on milk enzymes (Urbach, 1995).

The “brothy” attribute in Cheddar cheese is classified as having either a meaty (beef stew) or vegetable (mushroom or potato) aromatic or flavor and is widely regarded as the attribute that most defines Cheddar cheese flavor (Aston and Dulley, 1982). The brothy attribute is primarily associated with amino acids, primarily glutamic acid and methionine. In fact, the Strecker degradation has been regarded as the most likely pathway in methanethiol production since Cheddar cheese contains the necessary dicarbonyl compounds (such as diacetyl) for this reaction to occur (Green and Manning, 1982). The Strecker reaction occurs when the reaction between an amino acid and a diketone results in the formation of an aldehyde of one carbon atom less than the original amino acid. When methionine undergoes the Strecker degradation, the main product is methional (Aston and Dulley, 1982). Methanethiol is also viewed as a precursor to other sulfur compounds such as hydrogen sulfide carbonyl sulfide, and dimethyl sulfide, which can be produced either by cheese microflora and their enzymes or non-enzymatically (Adda, 1986). Interestingly, it has been reported by Green and Manning (1982) that the concentration of methionethiol in Cheddar cheese closely correlates with flavor intensity and its absence might be associated with reduced Cheddar flavor. A study conducted by Dimos et al. (1996) in a comparison of volatiles from full-fat and reduced-fat cheeses confirmed a significant correlation between Cheddar cheese flavor intensity and methanethiol concentration in the cheeses, which indicated that a lack methanethiol in the reduced-fat cheeses contributed to a lack of flavor.

The nutty attribute is characterized by nut-like aromatics or flavor (roasted peanuts, cashews, etc). However, there is limited research suggesting its impact in Cheddar cheese flavor. Lin (1976) identified 2, 5-dimethylpyrazine and 2, 3, 5-trimethylpyrazine among volatiles in American processed cheese and considered that the volatiles imparted a “nuttiness” to the background flavor. In addition, McGugan (1975) stated that 2-acetylpyrazine and 2-methoxy-3-ethylpyrazine were present in distillates from old Cheddar cheese and, though the pyrazines were present in low concentrations, might collectively contribute to Cheddar cheese flavor.

The catty attribute is characterized by a cat-like urine aromatic or flavor (Steinsholt and Svensen, 1979). Like the nutty attribute, there is limited research suggesting the catty attribute's impact on Cheddar cheese flavor. Both Polak et al. (1988) and Drake (2002, personal communication) have indicated that mercaptan compounds are responsible for the catty attribute in cheese. Steinsholt and Svensen (1979) demonstrated that mesityl oxide contributes the catty aromatic in Cheddar cheese over time, with the greatest amount found on the outer regions of the cheese. In fact, mesityl oxide might be introduced to the cheese by varnish used on cheese racks (Steinsholt and Svensen, 1979). Furthermore, Drake et al. (2001) identified specific Cheddar cheeses with the catty aromatic using sensory descriptive analysis.

The basic tastes, sour, bitter, salty, sweet, and umami, are also present in both young and aged Cheddar cheeses. Urbach (1995) claimed that the acidic fraction from Cheddar cheese volatiles was shown to play a crucial role in Cheddar flavor. Acid taste is caused by hydrogen ions and substances which yield hydrogen ions on hydrolysis (McSweeney, 1997). Grazier et al. (1991) found that bitterness in Cheddar cheese was attributed to the proteolytic breakdown of casein to peptides that exhibit a bitter taste. Dunn and Lindsay (1985) stated that phenylacetaldehyde contributed an astringent bitterness. Salt primarily acts as a preservative and provides flavor characteristics to Cheddar cheese. In fact, salty taste is stimulated by small inorganic ions which are the taste of chlorides from Group I elements and increases with cheese maturity

(McSweeney, 1997). Sweet and umami attributes provide flavor qualities to Cheddar cheese. Both Murray and Delahunty (2000) and Drake et al. (2001) found both sweet and umami flavor attributes in Cheddar cheese using sensory analysis.

In conclusion, minimal research has been conducted in understanding the flavor and texture characteristics of food products using preference mapping techniques. In fact, there is nominal research for preference mapping techniques concerning peanut and cheddar cheese flavor product commodities. The objectives of this research study are:
(1) To evaluate the distinctive peanut and cheese flavor characteristics using descriptive analysis methods; (2) to determine the overall acceptability of peanuts and cheese using consumer/affective testing efforts; and (3) to apply statistical analysis to interpret both the descriptive analysis and consumer evaluation data results independently and together using univariate statistics and multivariate statistics for both peanut and cheese commodities.

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CHAPTER 3

Descriptive Analysis and U.S. Consumer Acceptability Of Peanuts from Different Origins

ABSTRACT

The objective of this study was to evaluate descriptive and consumer flavor responses to peanuts (*Arachis hypogaea*, runner type) from different production origins: United States, China, and Argentina. Twenty, 25-lb. lots from each country (Total = 60) were randomly selected by manufacturers, and the samples were then shipped to the United States. After roasting, peanuts were evaluated using descriptive analysis. Based on roast peanut intensity, overall off-flavors, descriptive sensory profiles, and principal component analysis, six samples which covered the range of attributes and intensities from each origin were selected for consumer testing. Consumers (n=100) evaluated peanuts for overall liking, overall flavor liking, and the strength/intensity for liking of: color, roasted peanut flavor, sweet taste, bitter taste, fresh peanut flavor, and crisp texture using a nine-point hedonic scale. The sixty samples demonstrated differences in the descriptive sensory profiles specific for the different origins ($p<0.05$). Consumer scores from the 18 samples for overall liking were 5.36, 4.97, and 4.45 for the United States, China, and Argentina respectively; while scores for overall flavor liking were 5.27, 4.89, and 4.26 for the United States, China, and Argentina respectively. Observed overall and flavor liking differences were correlated to significant differences in the strength/intensity for liking characteristics of the different attributes ($p<0.05$). This study demonstrated the production origin's impact on the descriptive properties and consumer preference of roasted peanuts.

Key Words: Peanut flavor, sensory analysis, descriptive analysis, consumer evaluation

INTRODUCTION

Peanut flavor is a significant factor for determining product quality and consumer acceptability. Volatile compounds are responsible for the aroma and flavor of roasted peanuts, with over 300 compounds present (Ahmed and Young, 1982). Extensive research has been conducted in understanding peanut flavor through instrumental and sensory analysis methods. Sensory methods have been performed in assessing peanut flavor characteristics primarily using descriptive analysis methods. Both How (1984) and Oupadissakoon and Young (1984) used descriptive analysis terminology in defining attributes that corresponded to the affects of peanut variety, handling, roasting, and storage. Syrarief et al. (1985) used both descriptive analysis terms and principal component analysis in evaluating peanut flavor characteristics. However, these studies did not feature an expansive lexicon for characterizing specific flavors in peanuts. Johnsen et al. (1988) created a descriptive flavor lexicon to better describe the desirable and undesirable flavors in peanuts. This defined sensory language was later expanded by Sanders et al. (1989) to describe the effects of maturity and curing temperatures on same size peanuts of different maturity. Minimal research has been conducted in using consumer research methods and internal preference mapping techniques to understand the flavor and textural characteristics of roasted peanuts.

Differences in variety, environment, and handling result in a range of flavor profiles in peanuts from various origins. Undesirable peanut flavors are a function of curing temperature, exposure time to excessive temperature, moisture content, peanut size, and maturity stage of the peanut kernels (Pattee et al., 1965). Storage time also greatly affects peanut flavor and quality characteristics, for peanuts stored over time increase in off-flavor development and greatly decrease in roasted peanutty flavor (Bett and Boylston, 1992; Pattee et al., 1999).

Currently, the major peanut world market exporters are the United States, China and Argentina (American Peanut Council, 2002). Determination of the flavor profile of peanuts from specific origins will be helpful to manufacturers of peanut products throughout the world. The objectives of the study were to (1) evaluate the flavor characteristics of peanuts from different origins using descriptive analysis and (2) to determine consumer acceptability of the peanuts from three different origins (United States, China, and Argentina).

MATERIALS AND METHODS

Selection of Samples

Twenty 25-lb. sample lots of raw shelled peanuts (*Arachis hypogaea,* runner type) from the United States, China, and Argentina, randomly collected by manufacturers in the Netherlands and the United Kingdom, were shipped to the Department of Food Science, North Carolina State University where the peanuts were prepared for sensory analysis. For each peanut sample, three pounds were dry roasted on a conveyor belt in a gas fired, thermostat controlled Aeroglide roaster (Aeroglide Corporation, Raleigh, NC) at 177°C. The peanuts were roasted to a target Hunter L value of 49.0 measured by a Hunter DP-9000 (Hunter Associates Laboratory, Reston, VA). Temperature was held constant in the roaster, and the speed of the belt was varied until the target peanut color was obtained. The roasted peanuts were cooled and outer skins were removed from the seed manually. Peanuts were then stored at -22°C for 20 days before descriptive analysis work was conducted.

Descriptive Sensory Analysis

Roasted peanuts (n=60) were converted into paste form with a Cuisinart Little Pro Plus food processor (Cuisinart®, East Windsor, NJ) for descriptive sensory analysis. A grind-cool procedure was used to minimize paste temperature (Sanders et al., 1989b). The pasting of the roasted peanut samples consisted of two 2-minute grinds separated by 30 second cooling intervals until the desired paste consistency was acquired. The paste form was used for descriptive analysis to reduce within sample variability (Sanders et al., 1989a). Pastes (approximately two teaspoons) were placed into 2-oz. soufflé cups with three-digit codes for descriptive analysis.

Descriptive analysis employed the Spectrum® method and the peanut lexicon (Johnsen et al, 1988). A trained descriptive sensory panel (five panelists with over 1000 hours of experience each with descriptive analysis of products and more than 100 hours of experience each with descriptive analysis of peanut flavor) evaluated the intensity of roasted peanut, sweet aromatic, dark roast, raw/beany, woody/hulls/skins, phenol, green twig, musty, other nut, sweet, sour, bitter, astringency, and chemical burn attributes using a 10-pt Spectrum intensity scale (Meilgaard et al., 1999). Definitions for each attribute are provided in Table 1. Based on descriptive sensory data including composite off-flavor ranking, roasted peanut ranking, and principal component analysis, a total of six samples which represented the entire sensory space of flavors and intensities within each country were selected for consumer evaluation.

Consumer Evaluation

Chopped peanuts were presented for consumer analysis. Roasted peanuts (n=18, six from each country) were converted into chopped form with a Cuisinart Little Pro Plus food processor. Peanuts were ground for thirty seconds and sifted through an American Society of Testing Materials Sieve #4 (the size of the hull) with a diameter between 4.75mm to 2.00mm (Bowen, personal communication). Samples that failed to meet the grind size were reground for an additional 15 seconds and were sifted accordingly. Chopped peanut samples were stored in one-quart Ball mason jars at -22°C for 24 hours until consumer evaluation.

For the consumer evaluation, the eighteen peanut samples were tested across six days with a constant peanut control sample. The control sample was presented across all six testing days to evaluate consumer response across days. Three samples (one from each country) plus the control were evaluated each day. Chopped peanuts were dispensed into 2 oz. soufflé cups with lids numbered with three digit codes. Consumers were provided with consent forms consistent with North Carolina State University Human Subjects approval, screener forms, and a scoring ballot. The screener form and scoring ballot are featured in Appendices 1 and 2 respectively. A screener form was designed for obtaining general demographic information and examining consumer purchasing decisions for peanuts and/or peanut products. A ballot was used to assess consumer evaluations of peanuts for overall liking, overall flavor liking, and the strength/intensity for liking of: color, roasted peanut flavor, sweet taste, bitter taste, fresh peanut flavor, and crunchy texture using a nine-point hedonic scale. Approximately 100 consumers evaluated peanuts each day of testing.

Statistical Analysis

Both univariate and multivariate statistics were applied for analysis of descriptive and consumer data. Frequency histograms of consumer results were first constructed and examined for each attribute to determine if bimodal distributions occurred. Analysis of variance (ANOVA) with means separation was conducted using the PROC GLM procedure of the SAS program (Version 8.0, SAS Institute, Cary, NC). Principal Component Analysis (PROC PRINCOMP) was performed to model the relationship between the peanut descriptive data and the sensory attributes that most defined the country of origin. Univariate statistics and internal preference mapping (PROC PRINQUAL) were used in analyzing the consumer evaluation results. Possible relationships between consumer attributes and peanut attribute intensities were visually assessed using scatterplots. Linear relationships among consumer attributes and between consumer and descriptive attributes were determined using correlation analysis (PROC CORR) with Bonferroni's adjustment.

RESULTS AND DISCUSSION

Descriptive Analysis

Descriptive analysis results indicated distinctive flavor characteristics according to country origin (Figure 1). The United States peanuts were characterized by sweet aromatic, roasted peanut and dark roast. Chinese peanuts were characterized by woody/hulls/skins, bitter, and sour. Argentine peanuts were a diverse sample group primarily characterized by musty and sweet notes. A more frequent occurrence of the off-flavor “musty” in Argentine peanuts and higher bitter taste in Chinese peanuts compared to U.S. peanuts was documented.

Consumer Evaluation Results

Both screener forms and ballots were collected for data analysis. There was a similar balance of males and females (42% and 58% respectively), and 78% of the consumers were between the ages of 19-45 years. The ethnicity breakdown consisted of primarily White/Caucasian (77%) and African Americans (10%), with a total of 82% consumers being U.S. citizens. In regards to peanut products consumption, most consumers indicated that they primarily consumed peanuts either occasionally (26%) or once per week (20%). The primary factors that influenced peanut choice and consumption were price (63%) and flavor (89%).

There were no differences in overall liking for the control peanuts across the six days of consumer testing ($p>0.05$). Since consumer results across all attributes were consistent for the constant control across the six days of testing ($p>0.05$), consumer data across the six days were pooled. The consumer mean scores across all attributes are featured in Table 2. The U.S. peanuts received the highest consumer scores for overall liking, overall flavor liking, and for both strength/intensity and liking for the following attributes: roast peanut, sweet taste, fresh peanut, and texture ($p<0.05$).

Several linear relationships among consumer and consumer/descriptive results were determined. Many attributes were positively associated with the overall liking and overall flavor liking attributes (Table 3). Overall liking and overall flavor liking scores were significantly different among the three peanut origins and were correlated to significant differences in the strength/intensity for liking of the color and flavor attributes evaluated ($p<0.05$). Overall liking was positively correlated across all attributes except "color intensity," "sweet taste intensity," "bitter intensity," and "texture intensity." Overall flavor liking was positively correlated with "roasted peanut intensity," "fresh peanut intensity," and most of the liking attributes (color, roasted peanut, sweet taste, bitter, and fresh peanut). "Roasted peanut intensity" was positively correlated with "fresh peanut intensity" and with all of the liking attributes. "Bitter intensity" was negatively correlated among all attributes except "color intensity," "roasted peanut intensity," "sweet taste intensity," and "texture intensity."

Many of the consumer and descriptive analysis correlations (Table 4) were anticipated. The descriptive term roasted peanut was positively correlated with "roasted peanut intensity," "texture intensity," and "texture liking." Unpleasant descriptive flavor attributes "woody/hull/skins" and "bitter" were negatively correlated with many desirable consumer attributes, including "roasted peanut intensity," "texture liking," and "texture intensity" (bitter attribute only). Scatterplot matrices were created to visually assess any non-linear relationships between the consumer and descriptive/consumer attributes. No non-linear relationships were observed (data not shown).

Internal preference mapping was used to model the peanut consumer responses. Internal preference mapping is a principal component analysis (PCA) of the matrix of hedonic scores across the products (the observations) and the consumer (the variables) which is carried out on a covariance matrix to allow for differences in the strength of the consumer preferences to be expressed (Guinard, 1998). An internal preference map (Figure 2) of the consumer acceptability results explained 95% of the total variation. The internal preference map revealed distinctive consumer flavor profiles among the peanuts according to their respective origins. The Argentine peanuts were associated with bitter intensity, while the Chinese peanuts were associated with color liking. Both the Argentine and Chinese peanuts were negatively associated with overall liking. In contrast, the United States peanuts were mainly associated with positive attributes such as overall flavor liking, roast peanut intensity, sweet taste liking, and overall liking.

It is important to note that this study was conducted in the United States to understand American consumer preferences and these scores may reflect cultural preference. Therefore, additional studies should be performed to address non-United States consumer markets and their consumer preferences.

CONCLUSIONS

Production origin impacted peanut flavor characteristics. Descriptive analysis and consumer testing demonstrated distinctive flavor profiles for the United States, China, and Argentina peanuts. Based on U.S. consumer acceptability, roasted peanut intensity and fresh peanut intensity were the desired attributes while bitterness was an undesirable attribute.

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Table 3.1. Lexicon of Peanut flavor descriptors.

Flavor Attribute	Definition
Roasted peanut	*The aromatic associated with medium-roast peanuts (about 3-4 on USDA color chips) and having fragrant character such as methyl pyrazine.*
Sweet aromatic	*The aromatics associated with sweet material such as caramel, vanilla, molasses, fruit.*
Dark Roast	*The aromatic associated with dark-roasted peanuts (4+on USDA color chips) and having very browned or toasted character.*
Raw/beany	*The aromatic associated with light-roast peanuts (about 1-2 on USDA color chips) and having a legume-like character.*
Woody/hulls/skins	*The aromatics associated with base peanut character (absent of fragrant top notes) and related to dry wood, peanut hulls, and skins.*
Phenol/plastic chemical	*The aromatic associated with plastic and burnt plastics.*
Green Twig	*The aromatic associated with uncooked vegetables/grass/twigs, cis-3-hexenal.*
Musty/Earthy	*The aromatic associated with wet dirt and mulch.*
Sweet	*The taste on the tongue associated with sugars.*
Sour	*The taste on the tongue associated with acids.*
Bitter	*The taste on the tongue associated with bitter agents such as caffeine or quinine.*
Astringent	*The chemical feeling factor on the tongue, described as flat, metallic and associated with iron and copper.*
Chemical Burn	*The chemical feeling factor on the tongue, described as hot, such as capsaicin.*

Referenced from Johnsen et al., 1988.

Table 3.2. Consumer attribute means (n=100) for the three peanut world origins.

	USA	China	Argentina
Overall Liking	5.36a	4.97b	4.45c
Overall Flavor Liking	5.27a	4.89b	4.26c
Color Intensity	6.61b	4.16c	7.00a
Roasted Peanut Intensity	5.85a	4.98b	4.99b
Sweet Taste Intensity	4.10a	3.74b	4.02a
Bitter Intensity	4.14ab	3.97b	4.32a
Fresh Peanut Intensity	5.43a	5.14b	4.49c
Texture Intensity	6.27a	5.54c	6.07b
Color Liking	5.40b	6.01a	5.11c
Roasted Peanut Liking	5.43a	4.96b	4.52c
Sweet Taste Liking	5.14a	4.84b	4.72c
Bitter Liking	4.91a	4.95a	4.66b
Fresh Peanut Liking	5.31a	4.93b	4.21c
Texture Liking	6.21a	5.57c	5.91b

-*Means in a row followed by different letters represent significant differences ($p<0.05$).*

Table 3.3. Correlations between consumer attributes.

	Overall Flavor Liking	Color Intensity	Roasted Peanut Intensity	Sweet Taste Intensity	Bitter Intensity	Fresh Peanut Intensity	Texture Intensity	Color Liking	Roasted Peanut Liking	Sweet Taste Liking	Bitter Liking	Fresh Peanut Liking	Texture Liking
Overall Liking	**0.99**	-0.27	**0.93**	0.56	**-0.84**	**0.98**	0.44	**0.70**	**0.98**	**0.97**	**0.89**	**0.98**	**0.68**
Overall Flavor Liking		-0.27	**0.92**	0.56	**-0.84**	**0.98**	0.44	**0.71**	**0.98**	**0.97**	**0.90**	**0.98**	0.68
Color Intensity			0.04	0.20	0.45	-0.33	0.61	-0.77	-0.23	-0.16	-0.35	-0.31	0.37
Roasted Peanut Intensity				0.57	-0.66	**0.90**	0.66	0.50	**0.95**	**0.94**	**0.76**	**0.91**	**0.83**
Sweet Taste Intensity					-0.37	0.47	0.61	0.15	0.52	0.64	0.59	0.48	0.61
Bitter Intensity						**-0.85**	-0.17	**-0.72**	**-0.78**	**-0.77**	**-0.89**	**-0.84**	-0.41
Fresh Peanut Intensity							0.40	**0.74**	**0.98**	**0.94**	**0.89**	**0.99**	0.66
Texture Intensity								-0.19	0.47	0.54	0.35	0.42	**0.93**
Color Liking									**0.68**	0.63	0.67	**0.72**	0.11
Roasted Peanut Liking										**0.97**	**0.85**	**0.98**	**0.70**
Sweet Taste Liking											**0.89**	**0.94**	**0.74**
Bitter Liking												**0.90**	0.57
Fresh Peanut Liking													0.67

Numbers in **bold** represent significant correlations ($P \leq 0.0002$)

Table 3.4. Correlations between descriptive and consumer attributes.

	Overall Liking	Overall Flavor Liking	Color Intensity	Roasted Peanut Intensity	Sweet Taste Intensity	Bitter Intensity	Fresh Peanut Intensity	Texture Intensity	Color Liking	Roasted Peanut Liking	Sweet Taste Liking	Bitter Liking	Fresh Peanut Liking	Texture Liking
Roasted Peanut	0.62	0.62	0.44	**0.86**	0.41	-0.20	0.60	**0.72**	-0.15	0.68	0.75	0.28	0.60	**0.83**
Beany	-0.18	-0.12	-0.35	-0.28	-0.29	-0.23	-0.10	-0.25	0.05	-0.14	-0.27	0.11	-0.08	-0.36
Dark Roast	0.12	0.07	0.22	0.24	0.18	-0.11	0.08	0.24	-0.03	0.14	0.12	-0.24	0.07	0.25
Woody/hulls/skins	-0.54	-0.55	-0.50	**-0.79**	-0.43	0.02	-0.47	-0.70	0.18	-0.61	-0.69	-0.29	-0.50	**-0.84**
Sweet Aromatic	0.47	0.48	0.51	0.71	0.40	-0.15	0.46	0.64	-0.25	0.51	0.62	0.29	0.46	0.76
Phenol	-0.66	-0.61	0.06	-0.57	-0.17	0.43	-0.58	-0.21	-0.24	-0.65	-0.69	-0.51	-0.61	-0.31
Green Twig	0.33	0.38	-0.03	0.25	-0.03	-0.36	0.29	-0.02	0.01	0.32	0.20	0.29	0.30	0.02
Musty	-0.48	-0.49	0.08	-0.46	-0.09	0.51	-0.53	-0.17	-0.27	-0.48	-0.50	-0.46	-0.52	-0.33
Other Nut	-0.18	-0.10	-0.13	-0.21	-0.39	0.04	-0.03	-0.21	0.25	-0.12	-0.14	-0.06	-0.05	-0.19
Sweet	-0.37	-0.36	0.55	-0.19	0.39	0.29	-0.43	0.33	-0.69	-0.37	-0.22	-0.13	-0.44	0.22
Sour	-0.01	-0.02	-0.47	-0.31	-0.17	-0.39	-0.06	-0.45	0.27	-0.16	-0.24	0.21	-0.02	-0.43
Bitter	-0.51	-0.51	-0.59	**-0.79**	-0.63	-0.02	-0.45	**-0.83**	0.39	-0.56	-0.71	-0.41	-0.50	**-0.88**
Astringent	-0.35	-0.36	-0.44	-0.55	-0.39	-0.25	-0.35	-0.43	0.22	-0.45	-0.56	-0.08	-0.35	-0.46
Chemical Burn	-0.57	-0.53	0.20	-0.45	-0.10	0.33	-0.51	-0.03	-0.43	-0.55	-0.59	-0.44	-0.52	-0.13

Numbers in **bold** represent significant correlations ($P \leq 0.0002$)

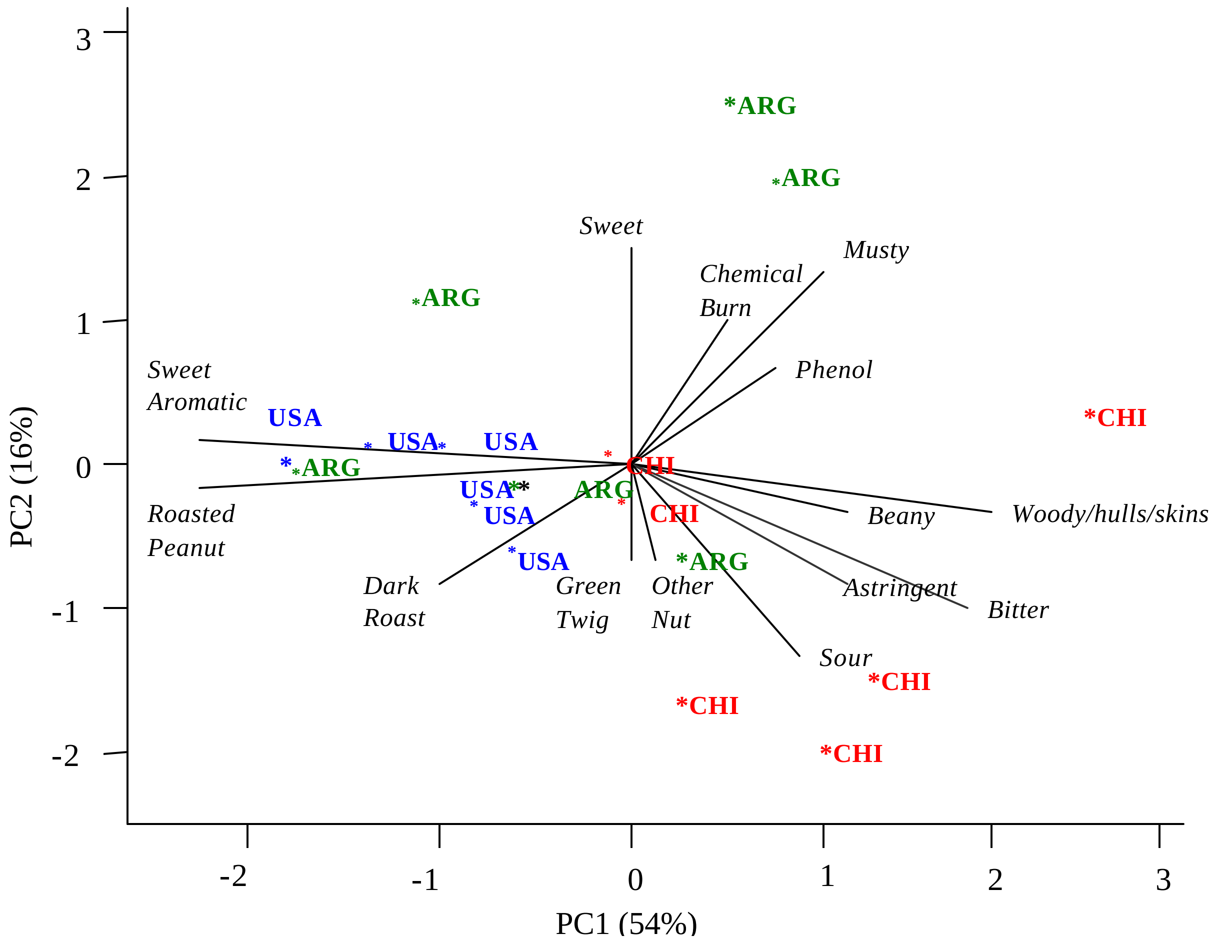

Figure 3.1. Principle Component Analysis Biplot of the Peanut Samples from the three Different Origins: United States, China, and Argentina by Descriptive Analysis.

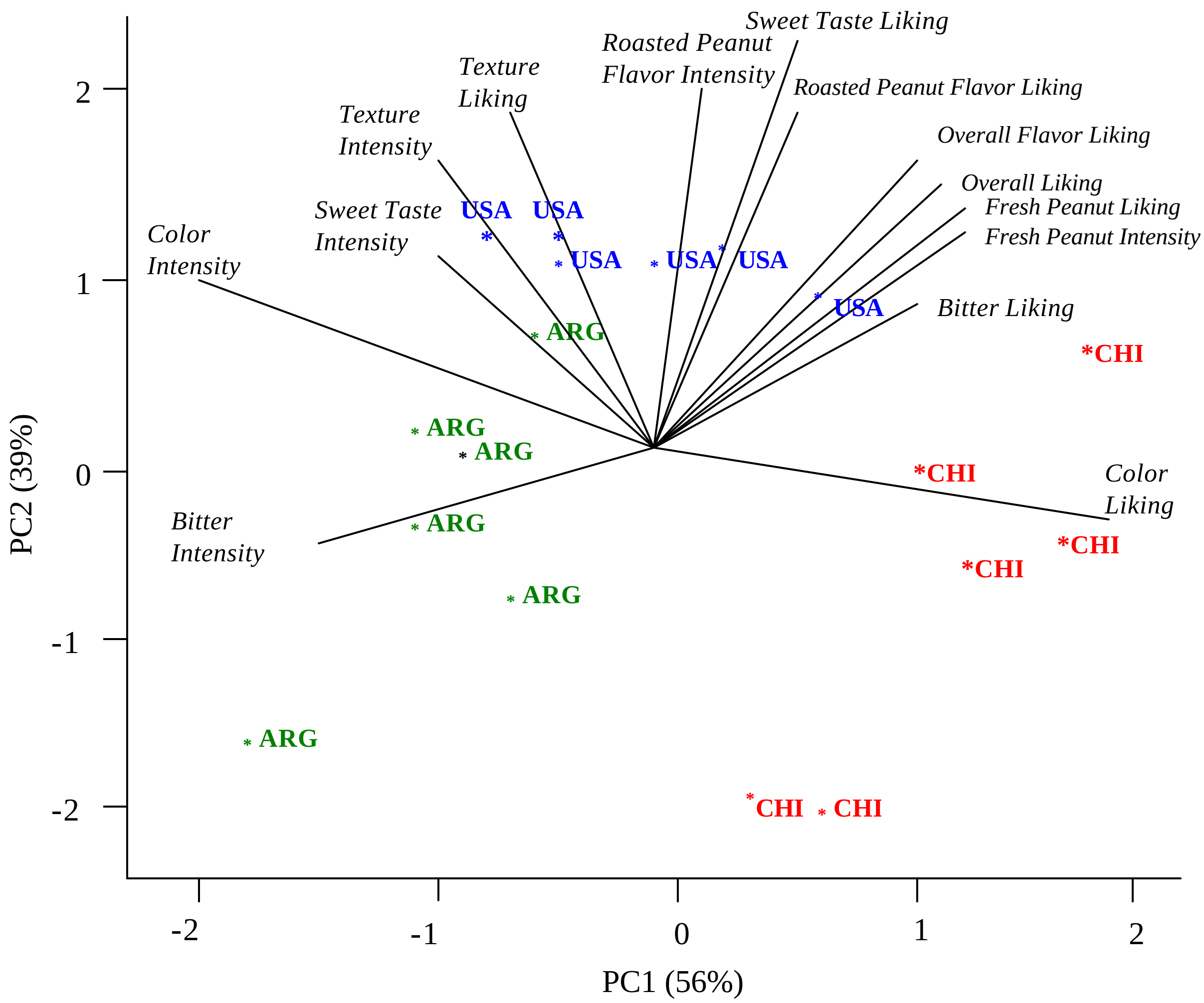

Figure 3.2. Consumer Internal Preference Map of the Peanut Samples from the three Different Origins: United States, China, and Argentina.

CHAPTER 4

PREFERENCE MAPPING OF CHEDDAR CHEESE WITH VARYING MATURITY LEVELS

ABSTRACT

The objective of this study was to evaluate the flavor profile and acceptability of seven Cheddar cheeses of varying maturity using descriptive analysis and consumer acceptance tests. Cheddar cheeses (n=7) ranging in age from one month to 19 months were selected based on age, geographic region, and flavor profile. Descriptive sensory profiles of selected cheeses were determined using a trained panel (n=14) and an established cheese flavor sensory language. Cheeses were evaluated for consumer acceptability in two demographic locations: North Carolina and Oregon. Consumers (N=200 at each location) assessed the cheeses for overall liking and other consumer attributes. Cheddar cheeses demonstrated distinct differences in descriptive sensory profiles ($p<0.05$). Average consumer responses between the two locations were not different ($p>0.05$). Six distinct consumer clusters were identified and the number of consumers in these clusters differed between the two locations ($p<0.05$). Consumers differentiated “young” and “aged” cheese flavor, but both young and mature cheeses were perceived by consumers as exhibiting intense Cheddar cheese flavors. Cheddar cheese acceptance was related to maturity level, flavor, and texture characteristics.

Key Words: Cheese flavor, sensory analysis, descriptive analysis, consumer evaluation

INTRODUCTION

Flavor is widely recognized as a significant factor of cheese acceptance and quality. Extensive research has been conducted in understanding Cheddar cheese flavor through analytical and sensory analysis methods. Sensory methods have been used to determine Cheddar cheese flavor attributes using descriptive analysis and consumer evaluation methods (McEwan et al., 1989; Muir et al., 1997; Fenelon et al., 2000; Guldfeldt et al., 2001). In 2001, Drake et al. (2001) published a Cheddar cheese flavor lexicon for describing Cheddar cheese flavor attributes. The language was subsequently validated using independently trained sensory panels at three sites *(*Drake et al., 2002*)*. The development of a standardized flavor lexicon for Cheddar flavor provides a platform to link perceived flavors to volatile components and to consumer perception (Drake and Civille, 2003).

Preference mapping assists scientists in understanding the descriptive sensory attributes that influence consumer preferences (Schlich, 1995; McEwan, 1996; Murray and Delahunty, 2000). Preference mapping techniques are commonly used to examine the relationship between descriptive sensory data and consumer responses (McEwan, 1996). The two main areas of preference mapping are *internal preference mapping* and *external preference mapping*. *Internal preference mapping* is a principal component analysis (PCA) of the matrix of hedonic scores across the products (the observations) and the consumer (the variables) which is carried out on a covariance matrix to allow for differences in the strength of the consumer preferences to be expressed (Guinard, 1998). *External preference mapping* regresses individual consumer preferences onto the first two principal components of the covariance matrix of descriptive or other analytical ratings across products (Schlich, 1995; Guinard, 1998). In external preference mapping, the dimensions of the descriptive analysis space are the predictor variables while consumer acceptability is the response variable (Schlich, 1995). Both internal and external preference mapping techniques have been implemented in an increasing number of dairy research studies (Pagliarini et al., 1997; Hough and Sánchez, 1998; Yackinous et al., 1999; Murray and Delahunty, 2000; Richardson-Harman et al., 2000).

Limited research has been performed using preference mapping techniques to understand the flavor profile of Cheddar cheese. Cheddar cheese flavor is characterized by complex flavors associated with age and processing procedures; cheeses with varying maturity levels have distinctive flavor profiles (Drake et al., 2001). Moreover, diverse demographics might have different attitudes relating to the consumer acceptability of Cheddar cheese. The objective of this study was to evaluate the flavor profile and acceptability of seven Cheddar cheeses of varying maturity using descriptive analysis and consumer acceptance tests.

MATERIALS AND METHODS

Selection of Samples

Cheddar cheeses (n=7) ranging in age from one month to 19 months were selected based on age and flavor profile from a diverse set (n=20) of commercial Cheddar cheese blocks. Cheeses were received as 20 kg vacuum-sealed blocks. Cheeses were stored at 7°C in the dark until analysis. All cheeses were full fat commercial U.S. Cheddar cheeses, made from pasteurized milk with less than 39 % moisture (w/w) (Table 1).

Descriptive Sensory Analysis

Cheddar cheese samples were cut into one-inch cubes for descriptive sensory analysis. The cheeses were placed into 4-oz. soufflé cups with three-digit codes. The cheeses were tempered at 10°C for one hour and were served at this temperature with spring water and unsalted crackers for palate cleansing. Descriptive analysis used the Spectrum® method (Meilgaard et al., 1999) and the Cheddar cheese lexicon (Drake et al., 2001) (Table 2). A trained descriptive sensory panel (n=14) with over 150 hours of experience each with descriptive analysis of cheese flavor evaluated each of the cheeses in triplicate in a balanced block design.

Consumer Evaluation

Consumer evaluation was conducted within two weeks of the descriptive analysis of the cheeses. Cheeses were evaluated in two demographic locations: North Carolina and Oregon. Cheeses were sliced into 5 kg blocks, vacuum-sealed and mailed by overnight carrier on ice gel packs to Oregon State University. Consumer testing was conducted at the Oregon State University Sensory Center and at the North Carolina State University Sensory Center. Testing at both sites was coordinated and conducted simultaneously. Testing procedure was also identical at each site.

The Cheddar cheeses (n=7) were tested across two days at each site using a constant control cheese presented each day. A constant control cheese was presented along with three cheeses each day (4 cheeses evaluated each day) to reduce the sample testing bias that could be associated with testing across two days. The constant control cheese that was presented both days was selected from descriptive analysis results based on its moderate flavor intensities. Cheeses were cut into one-inch cubes and dispensed into 4 oz. soufflé cups with lids numbered with three digit codes. The cheeses were served at 10°C. Consumers (N=200 at each location) were provided with consent forms consistent with North Carolina State University Subjects approval, screener forms, and a scoring ballot. A screener form was designed for collecting demographic information and evaluating consumer decisions for cheese and/or cheese products. The ballot was used to evaluate consumer evaluations of cheese for: overall acceptance, overall color liking, overall flavor liking, overall texture liking; and the intensity of overall cheddar cheese flavor and overall aged cheese flavor using a nine-point hedonic scale. Consumers were provided with gift certificates (Oregon) or food treats (North Carolina) for their participation.

Statistical Analysis

Univariate and multivariate statistical methods were used in analyzing the sensory results. Descriptive and consumer data were analyzed individually and then together. Analysis of variance with means separation and principal component analysis was used to analyze the descriptive data (SAS, version 8.2, Cary, NC). Chi-squared tests (PROC FREQ) were conducted to compare consumer demographic data from each location (SAS, version 8.2, Cary, NC). Frequency histograms of consumer results were created and investigated for each attribute to determine if bimodal distributions occurred. Analysis of variance with means separation was then conducted. Correlation analysis was conducted on descriptive and consumer data individually and together to determine linear relationships. Possible nonlinear relationships between consumer attributes and cheese attribute intensities were visually assessed using scatterplots.

Internal preference mapping was conducted on consumer means using SAS (version 8.2, Cary, NC) (PROC PRINQUAL) and treatment mean scores were plotted on the resulting principal component eigenvectors. External preference mapping was conducted on the descriptive data and the consumer acceptance scores using SPSS (v 10, Chicago, IL) and *Sensetools* (OP&P Product Research, Utrecht, Netherlands). Briefly, consumer acceptability scores were segmented using principal component analysis followed by cluster analysis. Clusters were confirmed using discriminant analysis. Generalized Procrustes Analysis (GPA) was then used to relate consumer clusters and descriptive data.

RESULTS AND DISCUSSION

Descriptive Analysis

Descriptive analysis results showed distinguishing flavor differences between the Cheddar cheeses (Table 3) (Fig. 1). Some Cheddar cheeses (treatments 6, 7, and 1) were characterized by the attributes “cooked,” “whey,” “diacetyl,” and “milkfat/lactone.” These cheeses were less than 1 year old. The Cheddar cheeses that were older than 1 year were primarily characterized by the attributes “sulfur,” “brothy,” and “nutty” (treatments 2, 3, 4, and 5). “Free fatty acid” and “catty” flavors were also detected in many of these more aged Cheddar cheeses. As previously reported (Drake et al., 2001), with increased cheese maturity, aged/developed flavors become more prevalent as does the variety of Cheddar cheese flavors. Correlation analysis (Table 4) revealed positive correlations between the aged Cheddar cheese flavor attributes ("fruity," "free fatty acid," "sulfur," "brothy," "nutty," and "catty") and the basic tastes ("sweet," "sour," "bitter," "salty," and "umami"). Young Cheddar cheese flavor attributes ("cooked," "whey," "diacetyl," and "milkfat/lactone") were negatively correlated with the mature Cheddar cheese flavor attributes. These relationships have been previously noted with Cheddar cheeses (Drake et al., 2001; 2003).

Consumer Evaluation

There were similarities and differences in the demographics of the cheese consumers polled (Table 5). Gender profiles, age groups and cheese types consumed were different between the two locations (Table 5). In contrast, cheese consumption habits and factors that influenced cheese choice/purchase were not different ($p>0.05$). Consumer responses between the two locations were not different by analysis of variance ($p>0.05$). There were no differences in overall acceptance for the control cheese across the two days of testing for both locations ($p>0.05$). Since consumer results across all attributes were consistent for the constant control cheese across the two days of testing for both locations ($p>0.05$), consumer data across the two days was pooled. The consumer mean scores across both locations are featured in Table 6. The constant control cheese received the highest consumer scores across all liking attributes ($p<0.05$). This Cheddar cheese was initially chosen as the control in the consumer experimental design due to its mild or bland flavor. Treatments 2, 3, 4, and 5 were characterized by descriptive analysis as exhibiting aged, mature cheese flavors, and these cheeses had the highest consumer scores for overall aged cheese intensity ($p<0.05$). Interestingly, both young and mature cheeses were perceived by consumers as exhibiting intense Cheddar cheese flavors. Treatments 2 and 6 received the highest scores for Cheddar cheese flavor intensity. These cheeses were quite diverse in flavor character by descriptive analysis (Table 3). Cheese 6 was characterized by young flavors while cheese 2 exhibited sulfur, nutty and brothy flavors. Figures 2 and 3 are internal preference maps of the NCSU and OSU consumer data, respectively. The similarity between the two figures confirms the overall lack of differences noted between the two sites for the univariate analysis results.

Several linear relationships among consumer, and consumer/descriptive results were determined. Strong relationships were observed between “overall acceptance” and “overall flavor liking” ($r = 0.99$), “overall acceptance” and “overall texture liking” ($r = 0.93$), “overall flavor liking” and “overall texture liking” ($r = 0.92$), and “overall aged cheese intensity” and “overall cheddar cheese intensity” ($r = 0.90$) (Table 7). The consumer/descriptive correlations (data not shown) showed minimal linear relationships. Negative relationships were observed between “whey” flavor and “overall aged cheese intensity” ($r = -0.92$) and “diacetyl” and “overall aged cheese intensity” ($r = -0.94$) suggesting that consumers do associate these flavors with young cheeses. Scatterplot matrices were created to visually determine any non-linear relationships existing between the consumer and descriptive/consumer attributes. No non-linear relationships were observed (data not shown).

Since consumers results indicated that both young flavored and aged flavored Cheddar cheese were associated with high Cheddar cheese flavor intensity (Table 6) this suggests, not surprisingly, that the Cheddar cheese flavor concept varies among consumers. Cheese 1, which was 1 month old, was characterized by descriptive analysis with high intensities of young flavors (cooked, whey, milkfat, diacetyl) and low sour and salty tastes received the lowest consumer scores for Cheddar cheese flavor intensity which also suggests that while the Cheddar flavor concept may vary among consumers it does not encompass Cheddar cheeses with extremely young and mild flavors.

Dacremont and Vickers (1994a) used the R-index method to evaluate the Cheddar cheese concept with 17 consumers and Cheddar and non-Cheddar cheeses. In general, consumers distinguished between Cheddar and non-Cheddar cheeses. Both aged and young Cheddar cheeses were used in their study also although descriptive analysis was not conducted. Dacremont and Vickers (1994b) used analysis of variance and the R-index method to evaluate the impact of individual volatile compounds on the Cheddar cheese aroma concept using 16 subjects who consumed Cheddar cheese regularly. Several Cheddar cheese extract mixtures were compared to several Cheddar and non-Cheddar cheeses. There were some relationships observed between the mixtures and the Cheddar cheese concept. Again, traditional descriptive analysis techniques were not used.

Subtle differences in consumer likes and dislikes may be missed by analysis of variance where overall means from a number of consumers are generated and compared. For this reason, external preference mapping was conducted to determine if there were distinct segments of Cheddar cheese consumers within the populations polled. GPA and cluster analysis revealed six distinct clusters or segments of consumers (Figs. 4, 5). Segment 1 was comprised of individuals that prefer young flavored cheeses (cooked, diacetyl, milkfat, whey). Consumers in segment 2 preferred aged flavored cheeses and did not like young flavored cheeses while those in segment 3 preferred young and brothy flavored cheeses. Consumers in segment 4 preferred young cheese but did not like brothy flavors. Consumers in segment 5 were characterized by their dislike of young flavored cheese with whey and sour flavor/taste. Consumers in segment 6 did not like brothy cheeses but did like other aged flavors including nutty and fruity flavors and sweet tastes. There were differences in the numbers of consumers within each segment at the two locations (Fig. 6). These differences were primarily located in segments 2 and 6. Both of these segments were consumers that prefer aged cheese, but they differed in specific likes/dislikes of aged cheese flavor. North Carolina consumers preferred sharp cheeses alone, while Oregon consumers were more specific in terms of aged flavors they liked and these segments also liked mild cheese. According to their different preferences for cheese flavor, there were differences in how each segment scored acceptability of the Cheddar cheeses (Fig. 7). These differences in preferences among the different consumer segments indicate that Cheddar cheeses with specific flavor profiles could be marketed to specific target market segments.

Previous research has discussed cheese flavor and consumer testing methods, particularly Cheddar cheese. However, early Cheddar cheese sensory analysis has been traditionally evaluated by trained panelists or individual cheese graders (Piggott and Mowat, 1991). Piggott and Mowat (1991) evaluated Cheddar cheeses using descriptive analysis techniques, in which the cheeses varied in age/maturity. Descriptive analysis identified the differences in the cheeses according to age and showed that maturation (age) dictated cheese flavor strength, aftertaste, and mouthfeel characteristics (Piggott and Mowat, 1991). McEwan et al. (1989) used Free-Choice profiling and conventional methods to evaluate seven Cheddar cheese varieties. Their results indicated differences in matured cheese profiles, with results varying in flavor and texture profiles. Drake et al. (2001) confirmed these observations in their development of a referenced descriptive language for Cheddar cheese flavor.

Lawlor and Delahunty (2000) determined consumer preferences for ten specialty Irish cheeses using external preference mapping and cluster analysis. The results indicated diverse flavor differences among the different cheese varieties. Seven distinct consumer clusters were identified and related to their respective cheese sensory profiles. Wide consumer preferences would be expected among different types of cheeses. Murray and Delahunty (2000) conducted preference mapping with factory and farmstead Cheddar-type cheeses. Again, a wide variety was observed in descriptive flavor profiles of cheeses and in distinct consumer preference clusters. Consumer perception of "age" and "Cheddar flavor" were not evaluated. Our study indicates a wide variability in cheese preferences within one specific type of cheese: Cheddar cheese.

CONCLUSIONS

Descriptive analysis and consumer evaluation showed distinctive flavor profiles for all Cheddar cheeses and their relationship with acceptability. The concept of “Cheddar cheese” flavor varied widely among consumers, but consumers distinguished aged cheeses from young cheeses. These significant relationships illustrate that Cheddar cheese acceptance is related to maturity level, flavor, and texture characteristics and varies widely among consumers with specific segments preferring specific Cheddar flavor profiles.

ACKNOWLEDGEMENTS

This study was funded in part by Dairy Management, Inc., the California Dairy Research Foundation, and the North Carolina Agriculture Experiment Station.

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Table 4.1. Cheddar Cheese Samples Used In the Study.

Cheese	Location	Age
Treatment 1	Mid-west, stirred curd, location 1	1 month
Treatment 2	Northeast, milled curd, location 5	19 months
Treatment 3	Mid-west, milled curd, location 4	19 months
Treatment 4	Mid-west, milled curd, location 4	12 months
Treatment 5	Northeast, milled curd, location 3	19 months
Treatment 6	Mid-west, milled curd, location 2	8 months
Treatment 7	Mid-west, milled curd, location 2	4 months

Table 4.2. Lexicon of Cheddar Cheese Flavor Descriptors.

Flavor Attribute	Definition	Reference
Cooked	*Aromatics associated with cooked milk.*	Skim milk or 2% heated milk for 30 minutes.
Whey	*Aromatics associated with cheese whey.*	Fresh Cheddar whey
Diacetyl	*Aromatics associated with diacetyl or artificial butter flavor.*	Diacetyl
Milkfat/Lactone	*Aromatics associated with milk fat.*	
Fruity	*Aromatics associated with different fruits.*	Fresh pineapple; ethyl hexonate
Sulfur	*Aromatics associated with sulfurous compounds.*	Boiled mashed egg; struck match
Free Fatty Acid	*Aromatics associated with short chain fatty acids.*	Butyric acid
Brothy	*Aromatics associated with boiled meat or vegetable soup stock.*	Canned potatoes; Wylers low sodium beef broth cubes; methional
Nutty	*The nut-like aromatic associated with different nuts.*	Roasted peanut extract; 2-methoxy-pyrazine
Catty	*Aromatics associated with tom-cat urine.*	2 mercapto-2-methyl-pentan-4-one, 20 ppm
Sour	*The taste on the tongue associated with acids.*	Citric acid
Bitter	*The taste on the tongue associated with bitter agents such as caffeine or quinine.*	Caffeine, quinine sulfate
Salty	*The taste stimulated by sodium salts, such as sodium chloride and sodium glutamate, and in part by other salts, such as potassium chloride.*	Sodium Chloride
Sweet	*The taste on the tongue associated with sugars.*	Sucrose
Umami	*The taste stimulated by monosodium glutamate (MSG).*	Monosodium Glutamate

Referenced from Drake et al.,2001.

Table 4.3. Descriptive attribute means (n=14) for the seven Cheddar cheeses.

Cheese	Trt 1	Trt 2	Trt 3	Trt 4	Trt 5	Trt 6	Trt 7
Cooked	2.7a	0.8bc	0.8c	1.2b	0.6c	2.5a	2.5a
Whey	2.9a	0.2c	0.2c	0.6b	0.2c	3.0a	3.0a
Diacetyl	2.4a	0.1c	0.2c	0.4c	0.0c	1.5b	1.5b
Milkfat/ Lactone	2.8a	0.7c	0.5c	0.8c	0.4d	2.1b	2.4ab
Fruity	0.0c	0.4a	0.3b	0.4a	0.2c	0.0c	0.0c
Sulfur	0.1d	2.7b	2.6b	3.1ab	3.4a	0.5c	0.4c
Free Fatty Acid	0.0c	0.7a	0.3b	0.5a	0.4b	0.0c	0.0c
Brothy	0.2c	2.4b	4.0a	2.6b	2.7b	0.7c	0.5c
Nutty	0.0d	2.4a	1.3c	1.5bc	1.9b	0.1d	0.2d
Catty	0.0c	0.5b	0.5b	1.0a	1.1a	0.0c	0.0c
Sweet	1.7ab	1.8a	1.6b	2.0a	1.3b	1.5b	1.6b
Sour	2.2c	3.5a	2.9b	3.0b	3.3ab	3.3ab	3.2ab
Salty	2.7c	3.6a	3.1bc	3.2bc	3.2b	3.1bc	2.9c
Bitter	0.1d	0.5c	0.9b	0.4c	1.6a	0.2d	0.1d
Umami	0.1b	1.0a	0.9a	0.8a	0.8a	0.2b	0.2b

-*Means in a row followed by different letters represent significant differences ($p<0.05$).*

-*Intensities scored on a 15-point Universal Spectrum™ intensity scale where 0=none and 15=very.*

Table 4.4. Correlations between descriptive attributes.

Sample	Cooked	Whey	Diacetyl	Milkfat	Fruity	Sulfur	Free Fatty Acid	Brothy	Nutty	Catty	Sour	Bitter	Salty	Sweet	Umami
Cooked	1.00	**0.99**	**0.97**	**0.99**	**-0.89**	**-0.99**	**-0.87**	**-0.94**	**-0.93**	**-0.91**	-0.40	**-0.75**	-0.68	-0.05	**-0.97**
Whey		1.00	**0.94**	**0.97**	**-0.91**	**-0.98**	**-0.90**	**-0.93**	**-0.94**	**-0.89**	-0.34	-0.71	-0.69	-0.14	**-0.98**
Diacetyl			1.00	**0.98**	**-0.85**	**-0.95**	**-0.84**	**-0.91**	**-0.91**	**-0.84**	-0.60	-0.70	**-0.76**	0.02	**-0.96**
Milkfat				1.00	**-0.86**	**-0.97**	**-0.84**	**-0.95**	**-0.91**	**-0.87**	-0.49	**-0.75**	-0.71	0.01	**-0.96**
Fruity					1.00	**0.88**	**0.94**	**0.83**	**0.89**	0.73	0.33	0.36	**0.76**	0.49	**0.94**
Sulfur						1.00	**0.87**	**0.90**	**0.92**	**0.95**	0.42	0.73	0.67	0.04	**0.94**
Free Fatty Acid							1.00	0.72	**0.97**	**0.75**	0.46	0.44	**0.87**	0.39	**0.93**
Brothy								1.00	**0.78**	**0.78**	0.28	0.68	0.53	0.06	**0.92**
Nutty									1.00	**0.81**	0.52	0.63	**0.86**	0.17	**0.95**
Catty										1.00	0.31	**0.76**	0.49	-0.10	**0.80**
Sour											1.00	0.30	**0.75**	-0.26	0.45
Bitter												1.00	0.32	-0.56	0.62
Salty													1.00	0.27	**0.79**
Sweet														1.00	0.21
Umami															1.00

Numbers in bold represent significant correlations ($p<0.01$)

Table 4.5. Demographic information and consumption characteristics of participants in the study.

	Location 1 (NCSU) N = 201	Location 2 (OSU) N = 210
Gender* (% males/females)	43/57	37/63
Age group*	0 % $\leq$ 18 y 38 % 19-25 y 30 % 26-35 y 18 % 36-45 y 10 % 46-55 y 4 % > 56 y	1 % $\leq$ 18 y 20 % 19-25 y 30 % 26-35 y 18 % 36-45 y 24 % 46-55 y 7 % > 56 y
Shop for household* (% yes/no)	93/7	100/0
Cheese consumption	0 % never 5 % once per mo 18 % 2-4 times per mo 77% > once per wk	0 % never 4 % once per mo 15 % 2-4 times per mo 81 % > once per wk
Cheese types consumed*[a]	67 % Processed cheeses 89 % Mild cheeses 75 % Aged/strong flavored cheeses	23 % Processed cheeses 92 % Mild cheeses 89 % Aged/strong flavored cheeses
Factors influencing choice of cheese	67 % Price 97 % Flavor 46 % Texture 28 % Health 40 % Availability	68 % Price 99 % Flavor 49 % Texture 31 % Health 38 % Availability

*Indicates differences between the 2 locations ($p<0.05$)
[a] Consumers were allowed to choose more than one category so category percentages do not add up to 100

Table 4.6. Combined NCSU and OSU consumer attribute means (N=204) for the Cheddar cheeses.

Cheese	Trt 1	Trt 2	Trt 3	Trt 4	Trt 5	Trt 6	Trt 7
Overall Acceptance	5.7cde	6.3bc	5.7de	5.6e	6.5b	7.2a	6.1bcd
Overall Color Liking	6.4d	7.1ab	7.1b	6.7cd	6.6d	7.5a	7.0bc
Overall Flavor Liking	5.5cd	6.3b	5.5d	5.3d	6.0bc	7.2a	6.1b
Overall Texture Liking	6.5bc	6.6bc	6.7b	6.3c	6.5bc	7.2a	6.5bc
Overall Cheddar Cheese Intensity	4.1d	6.9a	6.2b	6.3b	6.3b	7.0a	5.5c
Overall Aged Cheese Intensity	4.1c	6.5ab	6.5ab	7.2a	6.7a	5.9b	4.6c

-*Means in a row followed by different letters represent significant differences ($p<0.05$).*

Table 4.7. Correlations between consumer attributes.

	Overall Acceptance	Overall Color Liking	Overall Flavor Liking	Overall Texture Liking	Overall Cheddar Cheese Intensity	Overall Aged Cheese Intensity
Overall Acceptance	1.00	0.67	**0.99**	**0.93**	0.49	0.18
Overall Color Liking		1.00	0.62	0.73	0.69	0.38
Overall Flavor Liking			1.00	**0.92**	0.38	0.05
Overall Texture Liking				1.00	0.34	0.01
Overall Cheddar Cheese Intensity					1.00	**0.90**
Overall Aged Cheese Intensity						1.00

Numbers in bold represent significant correlations ($p<0.01$)

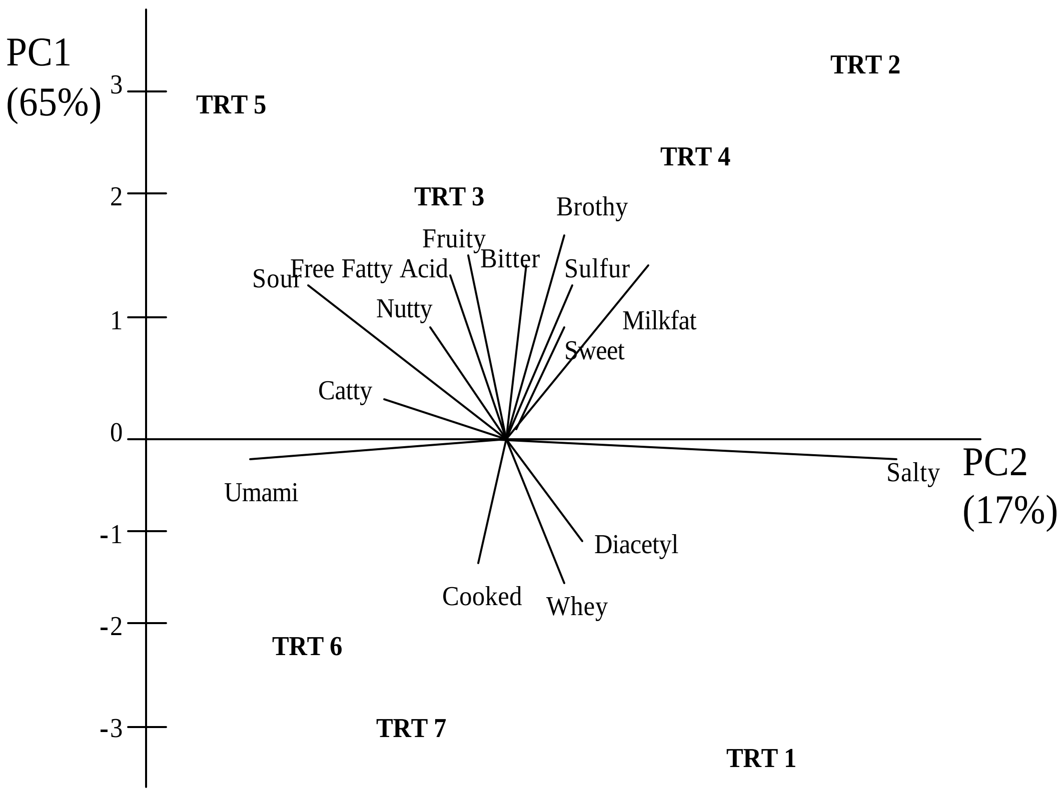

Figure 4.1. Principal Component Analysis of the Descriptive Analysis Results.

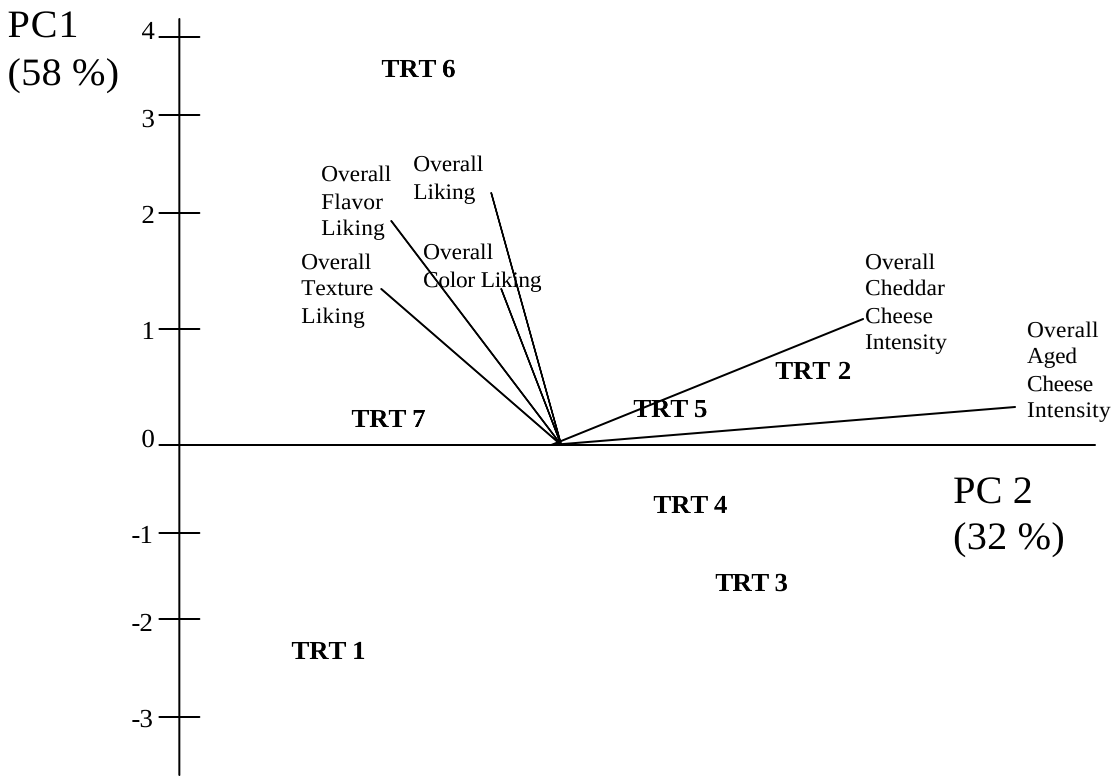

Figure 4.2. Internal Preference Map of the Oregon State University Results.

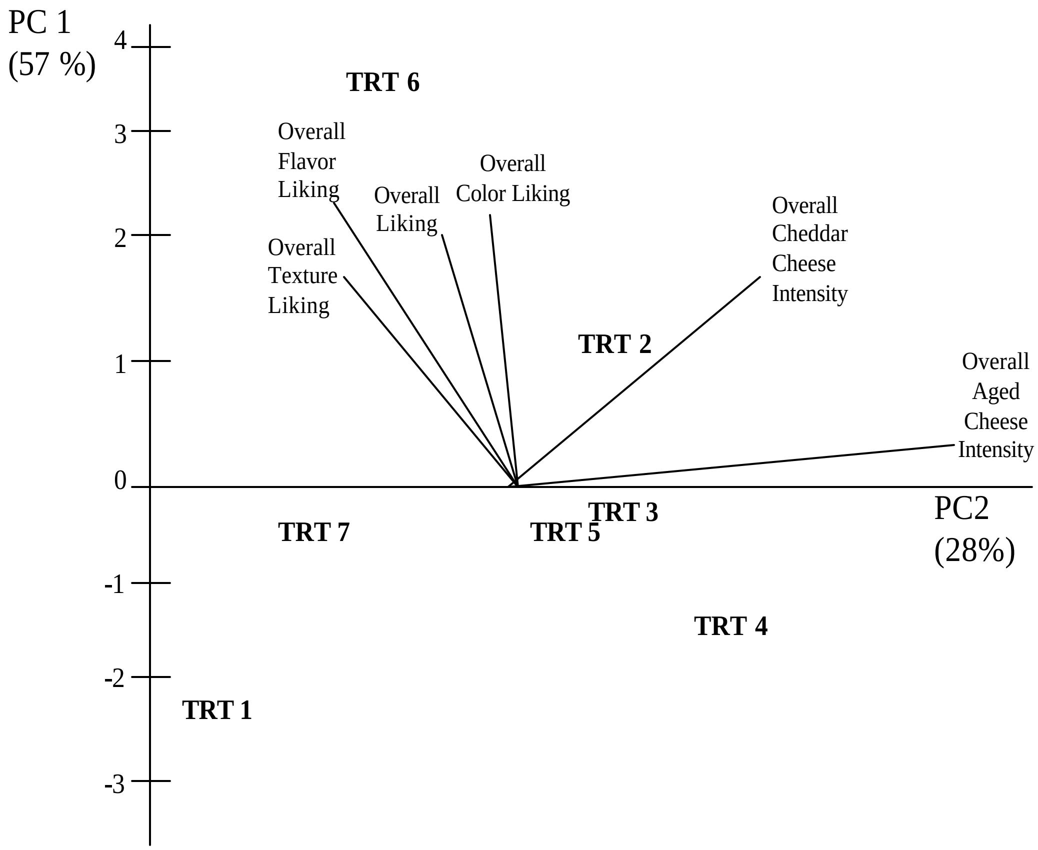

Figure 4.3. Internal Preference Map of the North Carolina State University Results.

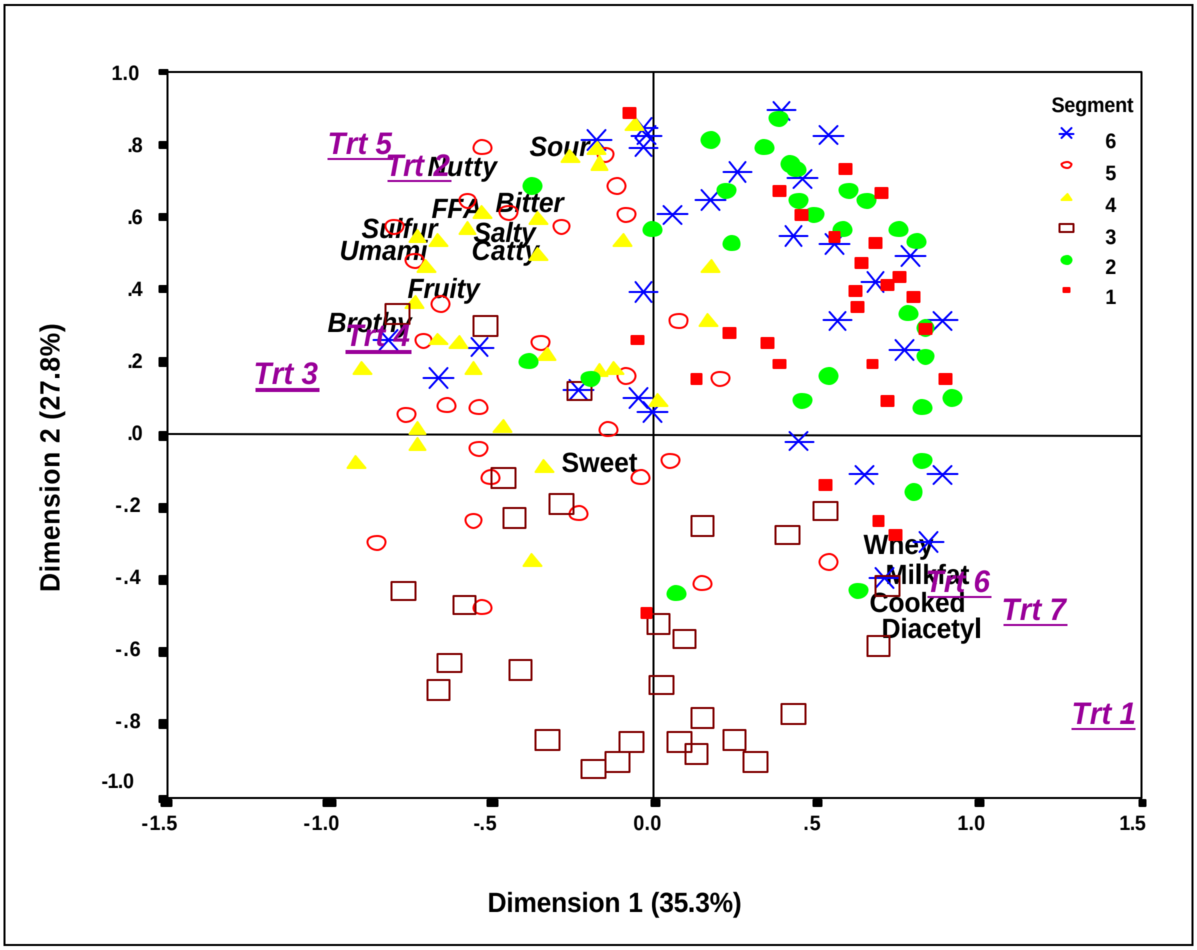

Figure 4.4. Generalized Procrustes Analysis with cluster analysis of combined consumer data with descriptive analysis data.

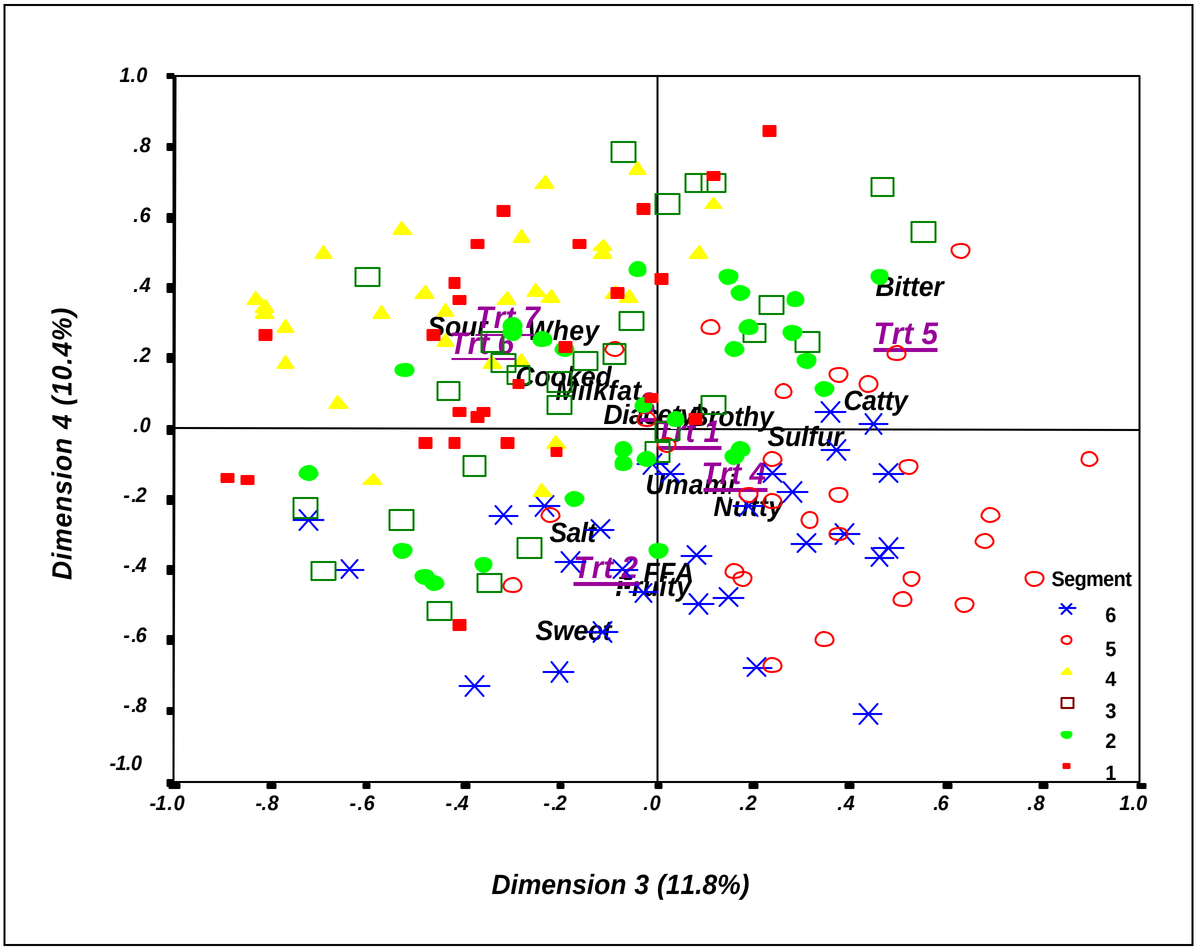

Figure 4.5. Generalized Procrustes Analysis with cluster analysis of combined consumer data with descriptive analysis data.

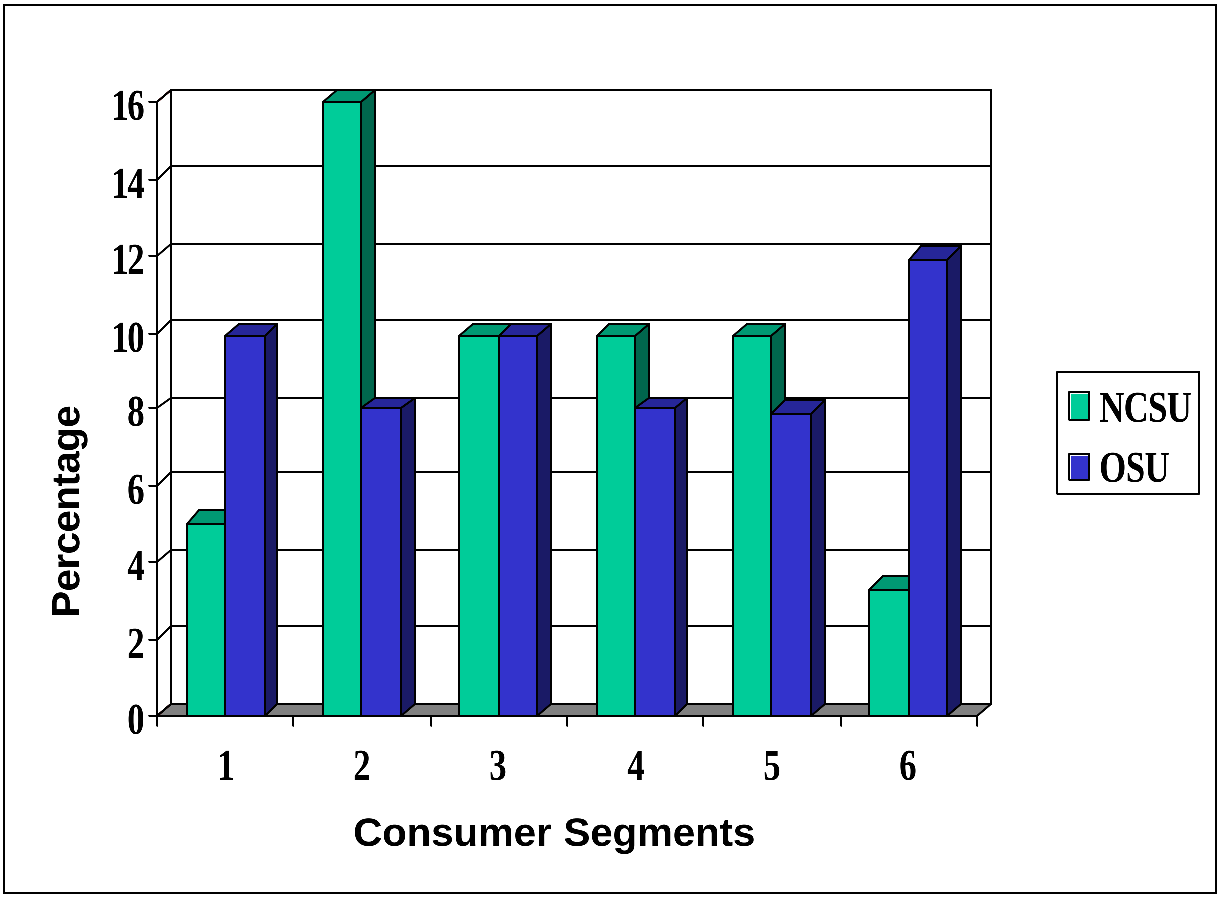

Figure 4.6. Segment Compositions as Percentages of Total Consumers (N=411) from NCSU and OSU.

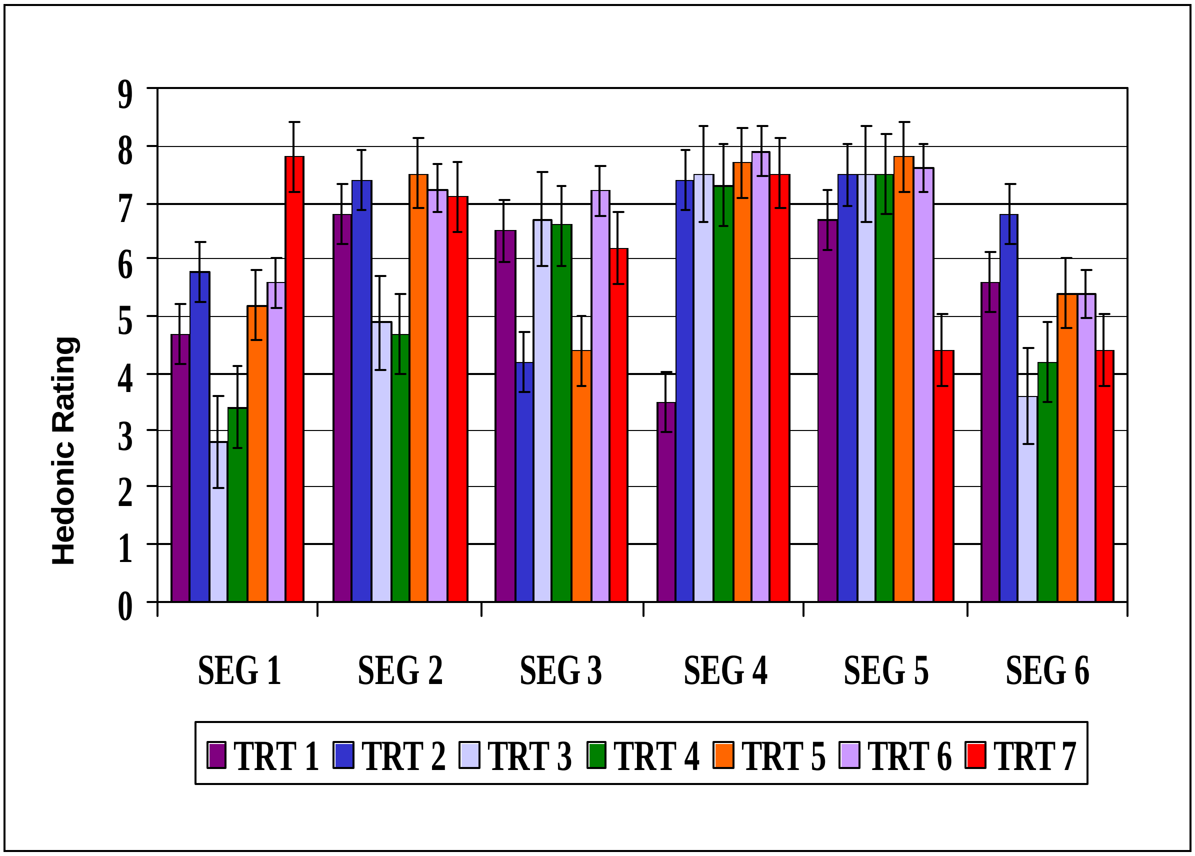

Figure 4.7. Overall Liking Scores for Cheeses Within Consumer Segments.

APPENDICES

PRODUCT PROFILE-CARAMEL FLAVOR LEXICON

Aromatics

Caramelized Sugar - A term used to describe starches and sugars which have been browned; used alone when the starch or sugar cannot be named.

Dairy Complex – Those volatiles related to milk, butter, cheese, and other cultured dairy products.

Baked Butter- The baked flavor of high-fat fresh cream or fresh butter.

Cooked Milk-The aromatics of milk which has been gently heated or boiled.

Sweet Aromatics – Those aromatics or volatiles which are derived from various sweet food products.

Vanilla – The sweet aromatic compound associated with real vanilla beans.

Vanillin - The sweet aromatic compound associated with artificial vanilla flavorings (ethyl vanillin) or marshmallows.

Diacetyl – The volatile flavor associated with artificial butter.

Scorched- A term related to overheating or burning the starches or sugars in a product.

Yeasty (dough) – The term related to natural yeast (not chemical leavening).

Other (cellophane) – Aromatics associated with cellophane-type compounds.

Basic Tastes

Sweet - The taste stimulated by sucrose and other sugars such as fructose, glucose, etc., and other sweet substances such as saccharin, Aspartame, and Acesulfan K.

Sour- The taste stimulated by acids such as citric, malic, phosphoric, etc.

Salty- The taste stimulated by sodium salts such as sodium chloride and sodium glutamate, and in part by other salts such as potassium chloride.

Chemical Feeling Factors

Heat/Tongue Burn – The burning sensation in the mouth caused by certain substances such as capsaicin from red or piperine from black peppers; mild heat or warmth is caused by some brown spices.

Appendix 1: Caramel product lexicon.
Reference: Meilgaard, 1999.

Technology

Standardize Milk

↓

Pasteurize

↓

Cool to 30ºC

↓

Add starter at 0.7%

↓

Add rennet

↓

Curd formation
(30-31ºC/45-50 min)

↓

Cut curd

↓

Scald

↓

Stir, 39-40ºC/45-60 min

↓

Drain

↓

'Cheddar'

↓

Mill

↓

Salt

↓

Hoop

↓

Press

↓

Ripen

Appendix 2. Cheddar cheese processing steps.
Reference: Varnam and Sutherland, 1994.

CONSUMER PEANUT QUESTIONNAIRE

Please check the appropriate answer for the following demographic information:

1. Sex _____male _____female

2. Age group
_____18 years or younger
_____19 – 25 years
_____26 – 35 years
_____36 – 45 years
_____46 – 55 years
_____56 – 65 years
_____65 years or older

2a. Ethnicity
a. Caucasian_____
b. African-American_____
c. Native American_____
d. Asian_____
e. Latino_____
f. Other _______

3. Do you have any **food allergies** to peanuts? ____yes _____no

4. I am a U.S. citizen ____yes ____no

5. If you are not a U.S. citizen, what country are you from? ____________________________

Please answer the following questions. There are no right or wrong answers. We want to know about you and what you think. Please ask if you have any questions!

6. Do you shop for your household, even if it is you alone? ______yes _____no

7. Do you purchase peanut products? _____yes _____no

8. How often do you consume peanuts and/or peanut products?
_____ I do not consume peanuts
_____ Occasionally
_____ At least once per month
_____ At least 2-3 times per month
_____ At least once per week
_____ Two to three times per week
_____ Four or more times per week

9. If you consume peanuts, what products do you eat? Check all that apply:
_____Freshly roasted
_____Unsalted/salted
_____Peanut Butter
_____In-Shell peanuts (Ballpark type)
_____Confectioneries (candy bars, etc.)
_____Ice cream/dairy products
_____Baked goods (cakes, cookies, etc.)
_____Snack/trail mix
_____Other (specify)_______________

10. What factors influence your choice of peanuts and/or peanut varieties? Check all that apply:
_____Price
_____Flavor
_____Texture
_____Health
_____Availability

Appendix 3. Peanut consumer screener.

Please taste the peanuts with the sample number indicated. After you have tasted the product, please circle your response for the questions below. **PLEASE ANSWER ALL QUESTIONS. We want to know what you think!!**

OVERALL, how well did you LIKE or DISLIKE this peanut sample?

Sample_____

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike			Extremely	Like

OVERALL, what did you LIKE or DISLIKE about this peanut sample?

LIKES	DISLIKES
______________________	______________________
______________________	______________________

Overall Flavor

1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

STRENGTH/INTENSITY	LIKING
Color: 1 2 3 4 5 6 7 8 9 Light Color … Dark Color	1 2 3 4 5 6 7 8 9 Dislike Extremely … Neither like nor dislike … Like Extremely
Roasted Peanut Flavor: 1 2 3 4 5 6 7 8 9 Not at all Peanutty … Extremely Peanutty	1 2 3 4 5 6 7 8 9 Dislike Extremely … Neither like nor dislike … Like Extremely
Sweet Taste: 1 2 3 4 5 6 7 8 9 Not at all Sweet … Extremely Sweet	1 2 3 4 5 6 7 8 9 Dislike Extremely … Neither like nor dislike … Like Extremely
Bitter Taste: 1 2 3 4 5 6 7 8 9 Not at all Bitter … Extremely Bitter	1 2 3 4 5 6 7 8 9 Dislike Extremely … Neither like nor dislike … Like Extremely
Fresh Peanut Flavor: 1 2 3 4 5 6 7 8 9 Spoiled … Extremely Fresh	1 2 3 4 5 6 7 8 9 Dislike Extremely … Neither like nor dislike … Like Extremely
Crunchy Texture: 1 2 3 4 5 6 7 8 9 Not Crunchy … Extremely Crunchy	1 2 3 4 5 6 7 8 9 Dislike Extremely … Neither like nor dislike … Like Extremely

Appendix 4. Peanut consumer ballot.

NAME_______________

Warm-ups

Please use your references to help you warmup up before tasting the unknowns. Do not forget to write your name on this sheet!

Salt

|______|______|______|______|______|______|______|______|______|______|

0 1 2 3 4 5 6 7 8 9 10

low **high**

0.2% sodium chloride = 2.5 **0.35 % sodium chloride = 5**

Warm-Up Cheese

Profile example:

Attribute	Intensity Rating
Brothy (beefy)	**4.5**
Sulfur	**3.0**
Catty	**trace**
Fruity	**1.5**
Bitter	**2.5**
Rosy/floral/metallic (aftertaste only)	**1.0**

Appendix 5: Cheddar cheese descriptive ballot.

Definitions

Flavors

Cooked	Aromatics associated with cooked milk	skim milk or 2 % heated To 85^{o}C for 30 min.
Whey	Aromatics associated with cheese Whey	fresh Cheddar whey
Diacetyl	Aromatic associated with diacetyl	diacetyl
Milkfat/ Lactone	Aromatics associated with milkfat	
Fruity	Aromatics associated with different fruits	fresh pineapple Ethyl hexanoate
Sulfur	Aromatics associated with sulfurous compounds	boiled mashed egg struck match
Free Fatty Acid	Aromatics associated with short chain fatty Acids	butyric acid
Catty	Aroma associated with tom-cat urine	2 mercapto-2 methyl-pentan-4-one, 20 ppm
Brothy	Aromatics associated with boiled meat or vegetable soup stock	canned potatoes Wylers low sodium beef , broth cubes, methional
Nutty	The nut-like aromatic associated with Different nuts	roasted peanut extract 2 methoxy pyrazine

Appendix 5: Cheddar cheese descriptive ballot (continued).

Aromatics:
***Fresh Curd/Undeveloped flavors**

-Milky Flavors

1. Cooked
Reference = autoclaved 2 % milk

|______|______|______|______|______|______|______|______|______|______|
0 1 2 3 4 5 6 7 8 9 10

2. Whey
Reference = Fresh cheese whey

|______|______|______|______|______|______|______|______|______|______|
0 1 2 3 4 5 6 7 8 9 10

-Buttery/fatty Flavors

1. Diacetyl
Reference = diacetyl

|______|______|______|______|______|______|______|______|______|______|
0 1 2 3 4 5 6 7 8 9 10

2. Fresh Milkfat/Lactone
Reference = cream, fresh coconut, lactone solution

|______|______|______|______|______|______|______|______|______|______|
0 1 2 3 4 5 6 7 8 9 10

Appendix 5: Cheddar cheese descriptive ballot (continued).

<u>Aged developed flavors</u>

1. **Fruity**

Reference = fresh pineapple, ethyl hexanoate

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

2. **Sulfur**

Reference = boiled mashed egg, match, H2S in water

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

3. **Free fatty acid/rancid**

Reference = butryic acid

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

4. **Brothy**

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

Reference = Wylers low sodium beef broth, knorr beef broth cubes, canned potatoes

5. **Nutty**

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

Reference = toasted hazelnuts – skin, walnuts – skin

6. **catty**

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

Reference = catty chemical reference

Appendix 5: Cheddar cheese descriptive ballot (continued).

Basic Tastes

Sour

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10
low **high**
0.05% citric acid = 2 0.08 % citric acid = 5
0.15 % citric acid = 10

Bitter

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10
0.05 % caffeine= 2
0.08% caffeine = 5 0.15 % caffeine = 10

Salty

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

0.2% NaCl= 2.5 0.35% NaCl = 5
0.5% NaCl = 8.5

Sweet

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10

2 % sucrose = 2 5 % sucrose = 5
10 % sucrose = 10

Umami

|_______|_______|_______|_______|_______|_______|_______|_______|_______|_______|
0 1 2 3 4 5 6 7 8 9 10
0.5 % MSG = 3
1 % MSG = 6

Appendix 5: Cheddar cheese descriptive ballot (continued).

CONSUMER CHEESE QUESTIONNAIRE

Please check the appropriate answer for the following demographic information:

1. Sex _____male _____female

2. Age group
   _____18 years or younger
   _____19 – 25 years
   _____26 – 35 years
   _____36 – 45 years
   _____46 – 55 years
   _____56 – 65 years
   _____65 years or older

3. I am a U.S. citizen ____yes ____no

Please answer the following questions. There are no right or wrong answers. We want to know about you and what you think. Please ask if you have any questions!

4. Do you shop for your household, even if it is you alone? ______yes _____no

5. Do you purchase cheese or cheese-based products? _____yes _____no

6. How often do you consume cheese? (circle one answer)
   a. I do not eat cheese
   b. Less than once per month
   c. 2 to 4 times per month
   d. More than once a week

7. When you consume cheese, is it as a: (circle one answer)
   a. snack
   b. meal/part of meal
   c. either

8. What types of cheese do you consume? Check all that apply:
   a. Processed (Velveeta, Kraft Singles, etc.)
   b. Mild (Mild Cheddar, Mozarella, Monterey Jack, Colby, Swiss, etc.)
   c. Aged/Strong flavored cheeses (Parmesan, Sharp Cheddar, Feta, Romano, etc.)

9. What factors influence your choice of cheese products? Check all that apply:
   _____Price _____Texture
   _____Flavor _____Health
   _____Availability

Appendix 6. Cheddar cheese consumer screener.

Please bite a piece of saltine cracker and sip some water to rinse your palette. Taste the cheese samples with the sample number indicated. After you have tasted the product, please circle your response for the questions below. **PLEASE ANSWER ALL QUESTIONS.**

Sample _____

Overall Acceptance								
1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

Overall Color Liking								
1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

Overall Flavor Liking								
1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

Overall Texture Liking								
1	2	3	4	5	6	7	8	9
Dislike Extremely				Neither like nor dislike				Like Extremely

Overall <u>Cheddar Cheese</u> Flavor Intensity								
1	2	3	4	5	6	7	8	9
Low Cheddar Flavor								High Cheddar Flavor

Overall Aged Cheese Flavor Intensity								
1	2	3	4	5	6	7	8	9
Low Aged Flavor								High Aged Flavor

Appendix 7. Cheddar cheese consumer ballot.