Innovations in Dairy

October 2005

DAIRY INDUSTRY TECHNOLOGY REVIEW

Sensory Evaluation of Dairy Products

Note: Research on sensory evaluation of dairy products is conducted worldwide. Much of the information presented in this issue of Innovations in Dairy *was extracted from research supported by Dairy Management Inc.™ (DMI), with funding from America's dairy farmers.*

Executive Summary

Sensory analysis techniques have developed into powerful tools for understanding how the appearance, flavor and texture attributes of dairy products drive consumer preferences. Modern sensory techniques can help dairy processors develop new products that are highly appealing to consumers. They also enable processors to optimize a product's flavor, texture and color to attract specific target audiences as well as accurately monitor product quality. These tools can help determine variations in sensory attributes associated with processing variables, geographic region of production, production season, etc., and help resolve numerous other issues important to dairy processors and marketers. This report emphasizes the importance of descriptive analysis as a sensory tool for dairy products and presents a few examples of how sensory analysis has been applied successfully to resolving specific challenges in the dairy industry.

Introduction

The dairy industry has come a long way since the early 1900s, when it began developing techniques for judging dairy products to stimulate interest and education in dairy science. In the traditional methods that emerged, judging and grading dairy products normally involved one or two trained "experts" assigning quality scores on the appearance, flavor and texture of the products based on the presence or absence of predetermined defects. These traditional dairy judging methods have several shortcomings: they can't predict consumer acceptance; their quality assessments are subjective; assigning quantitative scores is difficult; and they don't combine analytically oriented attribute ratings with affectively oriented quality scores (Claassen and Lawless, 1992).

Figure 1 shows descriptive sensory profiles of two Cheddar cheeses that received the same grade by traditional grading techniques. With seven of the 11 flavor attributes measured as being significantly different between the two cheeses, the flavor perception of the two samples is actually quite different. Using traditional methods of evaluation, however, these products with very different sensory characteristics but no defect will obtain the same quality score.

Sensory Input

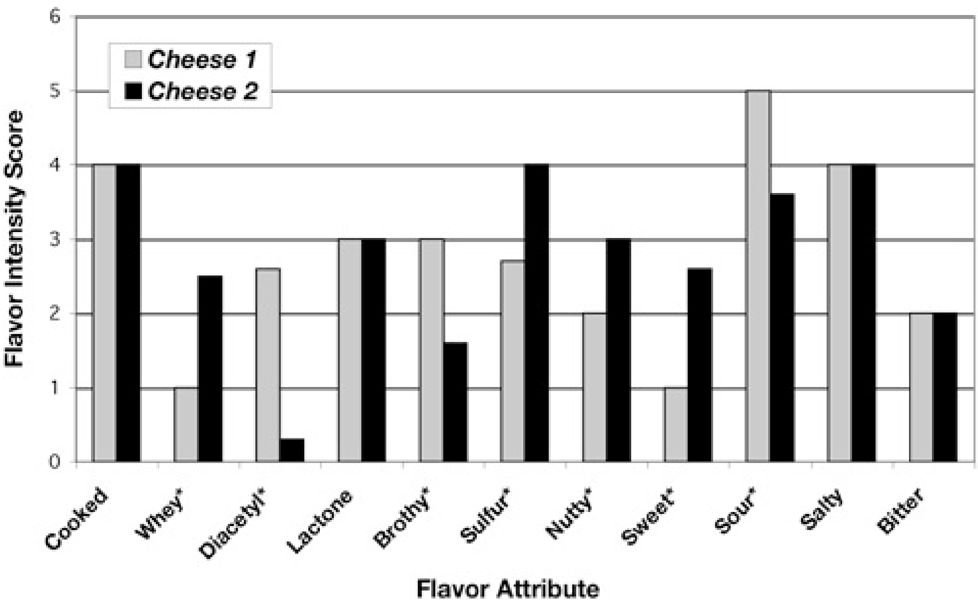
One thing in common to all sensory assessment methods is that they use humans as the measuring instrument. There are many kinds of sensory tests, the most widely used being difference tests, descriptive analysis and consumer acceptance testing. Difference tests include the triangle test, in which the panel attempts to detect which one of three samples is different from the other two, and duo-trio tests, in which the panel selects which one of two samples is different from a standard. Difference tests estimate the magnitude of sensory differences between samples, but one deficiency of these tests is that the nature of the differences is not defined. In most cases, a combination of difference tests and descriptive sensory analysis is employed for problem-solving.

Descriptive sensory analysis refers to a collection of techniques that seek to discriminate between a range of products based on their sensory characteristics and to determine a quantitative description of the sensory differences that can be identified, not just the defects. Unlike traditional quality judging methods, no judgment of "good" or "bad" is made because this is not the purpose of the evaluation. The panel operates as a powerful instrument to identify and quantify sensory properties.

Descriptive sensory analysis provides useful information for dairy research, product development and marketing.

Several assessors rating samples for a number of sensory attributes is a simple example of sensory profiling. For example, bitterness may be rated on a five-point scale, with a rating of one indicating no bitterness and a rating of five meaning very bitter. External standards (such as solutions of varying concentrations of quinine or caffeine for bitterness)

Figure 1: Descriptive Sensory Profiles of Two Cheddar Cheeses That Received the Same Grade by Traditional Dairy Judging Techniques



Note: The asterisk (*) denotes attributes that were significantly different between the two cheeses ($P < 0.05$). Source: M.A. Drake, 2004.

may help to define attributes and standardize the scale for each assessor. Developing and refining a vocabulary, or sensory lexicon, is an essential part of sensory profile work and is done in an objective manner.

Quantitative Descriptive Analysis

The first published descriptive sensory technique is the Flavor Profile Method (FPM) developed in the 1950s by Arthur D. Little Inc. Refinements and variations in FPM occurred in the 1970s with the development of Quantitative Descriptive Analysis (QDA) and the Spectrum™ method of descriptive analysis.

Today, descriptive analysis has gained wide acceptance as one of the most important tools for studying issues related to flavor, appearance and texture, as well as a way to guide product development efforts. For example, it has been used as an investigative sensory technique for studying conventionally pasteurized milk (Phillips et al., 1995; Quinones et al., 1998), ice cream (Ohmes et al., 1998; Roland et al., 1999) and cheese (Ordonez et al., 1998).

With descriptive analysis, selected panelists work together to identify key product attributes and appropriate intensity scales specific to the product under study. The panelists are then trained by the panel leader, a sensory professional rather than a member of the panel, to reliably identify and score product attributes. During training, the panel (usually eight to 12 prescreened individuals) generates the language (or lexicon) to describe the product. Descriptive analysis results are subjected to statistical analysis and are then represented in a variety of graphical formats for interpretation.

One useful statistical technique is Principal Component Analysis (PCA), a multivariate analysis method that shows groupings or clusters of similar sample types based on quantitative measurements. By applying PCA to descriptive analysis data, the set of dependent variables (i.e., attributes) is reduced to a smaller set of underlying variables (called factors) based on patterns of correlation among the original variables (Lawless and Heymann, 1998). The factors (also called principal components) are linear combinations of the independent variables.

The resulting data can then be applied in many useful ways. A few examples include profiling specific product characteristics, comparing and contrasting similar products based on attributes important to consumers, and altering product characteristics with the goal of increasing market share for a given set of products.

Flavor Lexicons for Dairy Products

M.A. Drake and G.V. Civille have reviewed lexicon history, methods and applications (2002). A flavor lexicon is a set of word descriptors that describe a product's flavor. While the panel generates its own list to describe the product array under study, a lexicon provides a source of possible terms with references and definitions for clarification.

According to Drake and Civille, development of a representative flavor lexicon requires several steps, including appropriate product frame-of-reference collection, language generation and designation of definitions and references, before a final descriptor list can be determined. Once developed, flavor lexicons can be used to record and define product flavor, compare products and determine storage stability, as well as to study correlations of sensory data with consumer liking/acceptability and chemical flavor data.

Good flavor lexicons should be both discriminating and descriptive. The language should be developed from a broad representative sample set that exhibits all the potential variability within the product. For example, Drake et al. (2001) collected 220 samples of Cheddar cheese varying in age, milk heat treatment and geographical origin to identify a descriptive language for Cheddar cheese (see Table 1.) The sample set was screened to 70 cheeses prior to language generation.

In creating a lexicon, the panel will frequently review the list, merging like terms, eliminating redundancies and organizing the list so that the attributes appear in most products being tested. It is important that multiple terms are not used to describe the same flavor; conversely, it is also important that one term doesn't represent or overlap with several other flavors. As an example of this type of lexicon problem, Drake et al. (2001) reported that use of the term "aged" in a Cheddar cheese flavor lexicon was in fact a meta term that comprised three flavors and one basic taste.

An optimized lexicon can relate consumer acceptance/rejection and instrumental or physical measurements.

Table 1: Cheddar Cheese Lexicon With Identified References

Term	Definition	Reference
Cooked	Aromatics associated with cooked milk	Nonfat milk heated to 85°C for 30 min.
Whey	Aromatics associated with Cheddar cheese whey	Fresh Cheddar whey
Diacetyl	Aromatics associated with diacetyl	Diacetyl
Milkfat/Lactone	Aromatics associated with milkfat	Fresh coconut meat, heavy cream d-dodecalactone
Fruity	Aromatics associated with different fruits	Fresh pineapple, canned pineapple juice
Sulfur	Aromatics associated with sulfurous compounds through water, struck match	Boiled mashed egg, H_2S bubbled
Free Fatty Acid	Aromatics associated with short-chain fatty acids	Butyric acid
Brothy	Aromatics associated with boiled meat or vegetable soup stock	Canned potatoes, commercial low-sodium, beef broth cubes, vegetable broth cubes
Nutty	Nutlike aromatic associated with different nuts	Lightly toasted unsalted nuts, wheat germ, unsalted wheat crackers
Catty	Aroma associated with tomcat urine	2 mercapto-2 methyl-pentan-4-one
Cowy/Phenolic	Aromas associated with barns and stock trailers	p-cresol, BandAids, phenol
Bitter	Fundamental taste sensation elicited by caffeine, quinine	Caffeine (0.08% in water)
Salty	Fundamental taste sensation elicited by salts	Sodium chloride (0.5% in water)
Sweet	Fundamental taste sensation elicited by sugars	Sucrose (5% in water)
Sour	Fundamental taste sensation elicited by acids	Citric acid (0.08% in water)
Umami	Chemical feeling factor elicited by certain peptides and nucleotides	MSG (1% in water)
Prickly	Chemical feeling factor of which the sensation of carbonation on the tongue is typical	Soda water

Source: M.A. Drake, Dairy Management Inc.™ Technology Fact Sheet, 2001.

The use of chemical components (sometimes referred to as "chemical anchors"), particularly those isolated from the product under study, can make a lexicon clearer and more grounded, establishing a link to the formulation and/or production of that product. Creating this type of link can be time-consuming and challenging. However, even without such chemical references, a lexicon can be discriminating and precise.

Several different flavor lexicons have been developed to study cheese aroma and flavor development, the effects of fat reduction and the effects of different starter or adjunct bacteria. Muir et al. (1995) described nine aroma terms for characterization of aroma profiles of hard and semihard cheeses. For studying flavor development in Cheddar cheese during maturation, Piggot and Mowat (1991) determined 23 descriptive flavor terms, and Roberts and Vickers (1994) developed a flavor lexicon. Muir et al. (1996) and Drake et al. (1996 and 1997) used descriptive sensory panels to determine the effect of starter culture and adjunct cultures on Cheddar cheese flavor. Banks et al. (1993) used descriptive analysis to determine sensory properties of lowfat Cheddar cheese.

Application of Sensory Analysis to Dairy Products

Following are specific examples of how QDA and/or other types of sensory analysis techniques have been applied to dairy research studies funded by Dairy Management Inc.™ (DMI):

"Optimization of Cheddar cheese taste in model cheese systems" (B. Yang and Z. Vickers, 2004). Cheddar cheese, the most popular natural cheese in the United States, has a very complex flavor system. While much information has accumulated during the past century, the industry is still seeking to fully understand Cheddar cheese flavor and has not been able to replicate it in model systems. The nonvolatile sensory attributes of Cheddar cheese are important for providing the character of Cheddar cheese. While much work has been published on volatile components of Cheddar, far less is known on how nonvolatiles impact Cheddar flavor. Yang, a Kraft Foods researcher, and Vickers, at the Minnesota-South Dakota Dairy Foods Research Center, used sensory analysis to better understand the importance of nonvolatile compounds to Cheddar flavor.

A descriptive panel was trained to evaluate real and model cheese for a variety of taste attributes and for Cheddar-like taste. Sodium chloride, lactic acid, citric acid and monosodium glutamate were added to the model systems using mixture designs and response surface methodology to determine optimum levels of these components. The three model systems investigated were: (1) a dairy model system (containing milk isolate, anhydrous milkfat, water, annato color and chymosin); (2) a nondairy model system (containing gelatin, gum acacia, modified starch, sunflower oil, water and annato color); and (3) a mozzarella base. While the mozzarella base did present tastes, it was used because the other two model systems were too unlike Cheddar cheese (or any cheese) texture.

Less sodium chloride and fewer acids were required to simulate the taste of mild Cheddar compared with aged Cheddar. None of the model systems mimicked the texture of real Cheddar. The researchers were able to match approximately, but not exactly, the taste of aged Cheddar using a mozzarella base. Panelists generally rated the optimized taste in the dairy model system as more Cheddar-like than the optimized tastes in the nondairy model.

Two methods were used to measure how close a sample was to the Cheddar concept. One was by measuring the similarity of the sample to either mild Cheddar cheese taste or aged Cheddar cheese taste on an unstructured scale. The left end of the line was marked with "not at all like Cheddar taste" and the right end was marked with "exactly like mild Cheddar taste" or "exactly like aged Cheddar taste." The other method was by concept matching using an R-index methodology. For the mild group, the panel evaluated whether the samples were "MC" (mild Cheddar taste and sure), "MC?" (mild Cheddar taste but not sure), "N?" (no Cheddar taste but not sure) or "N" (no Cheddar taste and sure). For the aged group, "MC" and "MC?" were changed to "AC" (aged Cheddar taste and sure) and "AC?" (aged Cheddar taste but not sure).

A model system for studying Cheddar taste should be as bland-tasting as possible, and also have a texture and composition similar to that of real Cheddar cheese. The characteristic flavor of a food depends not only on the flavor compounds present and their levels but also the rate and extent to which they are released in real time, which in turn are affected by the amounts of proteins, fat and other matrix components of the sample.

By using a trained descriptive analysis panel, Yang and Vickers were able to evaluate the flavor impact of several nonvolatile Cheddar cheese components (i.e., salt, lactic acid, citric acid and monosodium glutamate) in model systems that attempted to mimic real Cheddar cheese. They achieved the most Cheddar-like taste with the mozzarella cheese base, and panelists found the optimal concentration of salts and acids in the model to be nearly indistinguishable from real Cheddar cheese.

"Cheddar cheese and powdered milk lexicons" (M.A. Drake et al., 2001 and 2003). M.A. Drake, at the Southeast Dairy Foods Research Center, developed and validated a descriptive language for Cheddar cheese flavor. For the project, 240 representative cheese samples were collected. Fifteen individuals from industry, academia and government participated in roundtable discussions to generate descriptive flavor terms. A highly trained descriptive panel (n=11) refined the terms and identified references. Identification of chemical references was conducted with the assistance of K. Cadwallader at the University of Illinois. Instrumental analyses (gas chomatography/mass spectrometry, or GC/MS) were conducted to identify many flavor compounds that were responsible for specific flavors and off-flavors in Cheddar cheese.

Twenty-four Cheddar cheeses were then presented to the panel to validate the proposed lexicon. The panel differentiated the 24 Cheddar cheeses as determined by univariate and multivariate analysis of variance. Twenty-seven terms were identified to describe Cheddar flavor.

Seventeen descriptive terms were observed in most Cheddar cheeses. Drake's standard sensory language for Cheddar cheese today is facilitating training and communication among different research groups. The Cheddar cheese lexicon is helping cheesemakers and cheese users accurately and consistently characterize the flavor of their cheese products and improve quality issues by measuring and controlling the presence of compounds that have been associated with flavor defects.

Following development of the Cheddar cheese lexicon, Drake developed a similar language to help characterize another food industry staple: dried dairy ingredients, including whey proteins and nonfat dry milk (Drake et al., 2003).

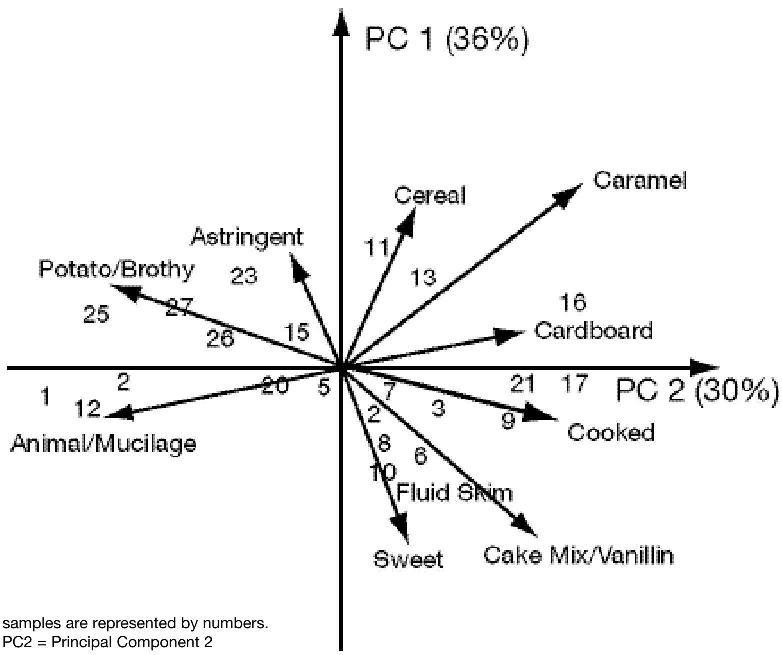
Global production of nonfat dry milk tops 3.3 million tons (USDA 2000), and whey protein demand still outstrips production, which increases annually. A sensory lexicon describing the flavor of these ingredients helps dairy processors maximize the quality of these ingredients and allows food technologists to identify the exact attributes or flavor notes these ingredients contribute to formulations.

Drake said she was surprised by the number of descriptive terms that the panel uncovered for application to the dried dairy ingredients lexicon. The panel discovered 21 flavor terms that could be applied to milk powders. Examples included cooked/milky flavor, cake mix or vanillin, sweet and sour, earth and cereal. Each of these flavors was linked to a key aroma compound, many of which were identified by Drake and Cadwallader with GC/MS. For example, lactones tend to lend a sweet, coconutlike flavor, while various free fatty acids can simulate a waxy flavor.

Many different factors contribute to flavor variability. The source of the powder, processing/packaging methods and materials, as well as storage time and conditions, are just a few. The dried dairy ingredient lexicon, linking responsible chemical factors and causal agents, provides common ground for processors and ingredient suppliers to discuss ingredient characteristics.

Figure 2 shows how descriptive analysis results based on Drake's dried dairy ingredient lexicon can be analyzed by PCA. This two-dimensional PCA plot shows the attribute variability among 27 low-heat skim milk powders less than three months old. Rehydrated milk powders are represented

Figure 2: Flavor Variability Among Low-Heat Nonfat Dry Milks Less Than Three Months Old



Note: Rehydrated milk powder samples are represented by numbers.
PC1 = Principal Component 1; PC2 = Principal Component 2
Source: M.A. Drake, 2004.

by numbers. PC1 = principal component 1; PC2 = principal component 2.

Drake has continued her sensory work and has developed a chocolate milk lexicon; work on a butter lexicon is currently under way.

"Quantitative Descriptive Analysis and Principal Component Analysis for sensory characterization of ultrapasteurized milk" (K.W. Chapman et al., 2001a). Extending the shelf life of fluid milk products will contribute to the competitiveness of the dairy industry in the beverage market. Ultra-high-temperature (UHT) processing and ultrapasteurization (UP) are two currently used approaches for extending dairy product shelf lives beyond those obtained by conventional pasteurization. One challenge is that these products, which involve higher levels of heat treatment compared with conventional high-temperature-short-time (HTST) pasteurization, have been criticized for their off-flavors. Since product flavor quality drives consumer acceptance and demand, the ability to measure sensory attributes characteristic of high-quality products is necessary for the development and production of products that meet consumer expectations.

Chapman et al. (2001a), at the Department of Food Science at Cornell University, used QDA to identify and measure UP fluid milk product attributes that are important to consumers. The researchers studied nine UP milk products of various fat levels, including two lactose-reduced products, from two dairy plants. PCA identified four significant principal components that accounted for 94.4% of the variance in the sensory attribute data for UP milk samples. PCA scores indicated that the location of each UP milk along each of four scales primarily corresponded to cooked, drying/lingering, sweet and bitter attributes. Overall product quality was modeled as a function of the principal components using multiple least square regression (R2=0.810). These findings demonstrate the utility of QDA for identifying and measuring UP fluid milk product attributes that are important to consumers.

The researchers were able to develop regression models that could be used to estimate the overall product quality rating based on measurement of its attributes. By plugging in QDA attribute scores for each sample, these regression equations could be used to calculate an overall quality rating for future samples tested. In general, perception of bitter flavor had the most dramatic effect on overall quality perception.

Table 2 lists the descriptors used for QDA and Table 3 shows the Varimax rotated PC factor loadings for UP milk attributes. Figure 3 is a sensory profile for a reduced-fat UP milk sample stored at 6°C for two days (light gray area), 29 days (black area) and 61 days (red area). Individual attributes are positioned like the spokes of a wheel around a center (zero, or not detected) point, with the spokes representing attribute intensity scales and higher (more intense) values radiating outward.

"Acceptance of reduced-fat ultrapasteurized milk by consumers, 6 to 11 years old" (K.W. Chapman and K.J. Boor, 2001b). Milk products are important dietary sources of protein, minerals and vitamins for children. To increase the appeal of their UP and UHT milk offerings, dairy processors need to understand what flavor attributes affect flavor acceptance and then devise ways to control these critical flavor attributes.

Table 2: Descriptors Used for Sensory Characterization of Ultrapasteurized Milk

Aroma	Flavor	Texture	Aftertaste
Cooked	Cooked	Viscosity	Drying
Caramelized	Sweet	Drying	Metallic
Grainy/malty	Caramelized	Chalky	Bitter
Other	Bitter	Lingering	Other
	Metallic		
	Other		

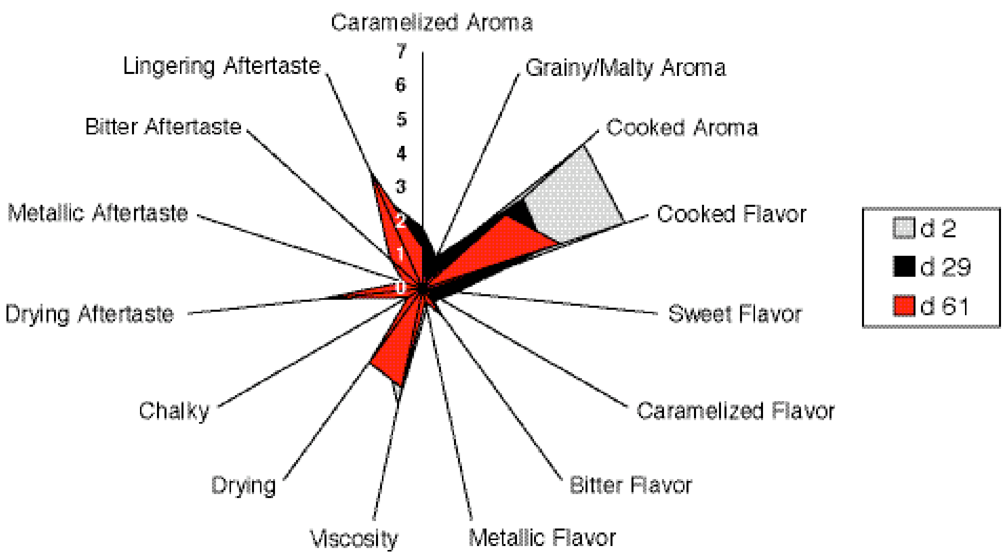
Source: K.W. Chapman et al., 2001.

Table 3: Varimax Rotated Principal Component Factor Loadings for Ultrapasteurized Milk Attributes

Attributes	PC1	PC2	PC3	PC4
Cooked aroma	0.971*	0.013	0.034	-0.208
Caramel aroma	0.497	-0.539	-0.567*	-0.252
Grainy/malty aroma	0.964*	0.021	-0.231	0.032
Cooked flavor	0.702*	-0.547	0.091	-0.350
Sweet flavor	0.038	0.082	-0.969*	-0.146
Bitter flavor	-0.186	-0.003	0.191	0.946*
Dry texture	0.004	-0.942*	-0.101	-0.092
Lingering aftertaste	-0.003	-0.758*	0.389	0.413
Proportion of total variance	33.1%	25.7%	19.0%	16.6%

*Loading with an absolute value greater than 0.560; these attributes have the greatest sensory impact. Source: K.W. Chapman et al., 2001.

Figure 3: Sensory Profiles of Reduced-Fat, Ultrapasteurized Milk Stored at 6°C for 2 Days, 29 Days and 61 Days



Source: K.W. Chapman, H.T. Lawless and K.J. Boor, J. Dairy Sci. 84:12, 2001a.

Chapman and Boor studied the degree of liking of UP milk by 6- to 11-year-old children. For comparative purposes, UP reduced-fat milks were evaluated along with conventionally pasteurized HTST reduced-fat milks and UHT reduced-fat milks. A seven-point facial hedonic scale with Peryam & Kroll verbal descriptors for affective testing with children was used with the 6-year-olds. For the older children, a seven-point hedonic scale with Peryam & Kroll verbal descriptors was used.

Figure 4 shows the distribution of ratings of milk, using a seven-point hedonic scale. (The black bar represents HTST milk, the gray bar represents UP milk and the white bar represents UHT milk.) Although UP milks had a higher percentage of "good" scores than either HTST or UHT milk, the HTST and UHT milks had higher "really good" and "super good" percentages. How children felt about milk, in general, significantly affected how much they liked the test milks, with all types of milks being influenced equally.

Children 6 to 11 rated the mean degree of liking of UP milk as slightly below "good." They liked HTST milk slightly more than the UHT milk, which they liked slightly more than the UP milk. Since UP milks are often distributed in fast-food establishments, which are commonly frequented by children in this age group, the findings may offer guidance toward making these products even more appealing to children.

This research is an excellent example of how sensory analysis can be used to understand the taste preferences of specific consumer target groups so products with appropriate sensory attributes can be developed for that group.

"Preference mapping of commercial chocolate milks" (J.L. Thompson et al., 2004). Although chocolate milk is a popular beverage with school children, limited research has been done to understand consumer preferences in chocolate milk. Chocolate milk varies considerably in flavor, color and viscosity. Thompson et al., at the Southeast Dairy Foods Research Center, identified and defined sensory characteristics of commercial chocolate milks and linked these differences to consumer preferences through the application of internal and external preference mapping.

Internal preference mapping uses only consumer data to determine consumer preference patterns, whereas external preference mapping relates consumer preference data to descriptive sensory information and/or instrumental data. Both of these techniques can guide product optimization and development.

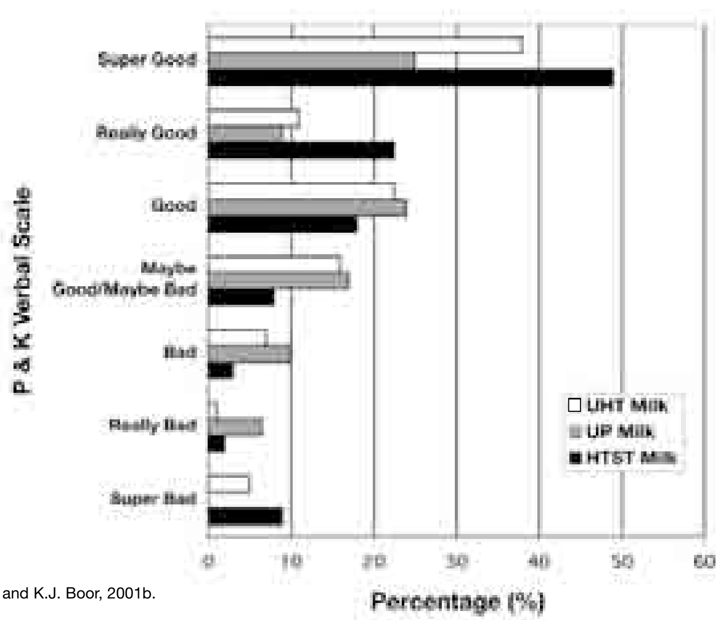
The major findings of this study were that cocoa aroma is a primary driver influencing acceptability of chocolate milks. Cooked/eggy and malty flavors also positively influence acceptability within specific market segments.

Linking Sensory and Chemical Analyses

Sensory analysis is a powerful tool in its own right. However, coupling sensory analysis with chemical analysis data can provide even more insights than using either technique alone. Two examples are illustrated below.

"Effect of antioxidant fortification on light-induced flavor of milk" (M. van Aardt et al., in press). Light-induced off-flavors can be a source of consumer complaints about processed milk. Oxidative reactions in milk reduce nutritional value and contribute to reduction in shelf life. Van Aardt et al. recently studied the effectiveness of added antioxidants against oxidation off-flavor development in light-exposed milk using both sensory and chemical analyses.

Figure 4: Distribution of Ratings of Reduced-Fat Milk Using a Seven-Point Hedonic Scale



Source: K.W. Chapman and K.J. Boor, 2001b.

Sensory testing showed no perceivable difference between milk and milk with added (a) 0.05% alpha-tocopherol (TOC) and (b) 0.025% TOC plus 0.025% ascorbic acid (AA), but did detect a perceivable difference with added (c) 0.05% AA alone. Subsequently, sensory testing for difference showed a significant difference in oxidation off-flavor development between light-exposed control milk and light-exposed milk with added TOC/AA, while milk fortified with only TOC was not different from the control. General remarks on score sheets from panelists who correctly identified the "odd" samples indicated that reduced-fat, light-exposed milk treated with a combination of TOC/AA showed more fresh milk flavor character than light-exposed milk without added antioxidants. This implies that the significant difference observed between light-exposed milk and milk treated with TOC/AA is due to a higher oxidized flavor in control milk.

Researchers also examined samples by gas chromatography-olfactometry (GC-O), a technique involving extraction of flavor volatiles from the sample, injection of the extract into a heated GC injection port, separation of chemical components as they pass through a GC column and finally sniffing of the individual chemicals as they elute from the column. It is interesting to note that, with light exposure, the addition of TOC seemed to increase the intensities of the aroma-active compounds; this could indicate a pro-oxidant effect of the antioxidant. Although GC-O data suggested the p resence of substantially more odorous flavor compounds in antioxidant-treated, light-exposed milk, these compounds could be below human detection thresholds in the sample matrix, which might indicate why sensory results did not indicate increased light-oxidation flavor.

The thiobarbituric acid reactive substances (TBARS) test verified chemically the extent of oxidation in control and antioxidant-treated milk samples. Milk that was exposed to light for 10 hours showed a significantly higher TBARS value (0.92±0.09 mg/kg) than milk that was protected from light (0.59±0.18 mg/kg) or milk that was treated with TOC/AA (0.26±0.09 mg/kg).

Both sensory and chemical analyses showed that direct addition of a combination of 0.025% TOC (1.25% TOC per g fat) and 0.025% AA to reduced-fat milk protected milk flavor over 10 hours of light exposure.

"Characterization of nutty flavor in Cheddar cheese" (Y.K. Avsar et al., 2004). Cheese flavor is one of the most important criteria for determining consumer choice and acceptance. Aged Cheddar flavor is characterized by sulfur, brothy and nutty flavors. Research that elucidates the origin of the important nutty flavor notes in cheese is scarce.

Defining the sensory term "nutty" is a difficult task, since the aroma quality in all nuts is not exactly the same. With Drake's Cheddar cheese lexicon, nutty flavor is defined as the "[nonspecific] nutlike aromatic associated with different nuts." Lightly toasted unsalted nuts, unsalted Wheat Thin® crackers and roasted peanut oil extract were used as references for nutty flavor.

Identifying specific chemical compounds associated with particular flavors requires extensive and specific instrumental and sensory analysis. A three-step process is involved. First, descriptive analysis is used to qualitatively and quantitatively identify all of the sensory-perceived flavors and tastes present in the cheese. Second, instrumental (GC) techniques can then be applied to identify volatile compounds that contribute to flavor. GC-O can assist in identification of compounds that are present in the sensory threshold range; it is often used as a way of further screening volatile compounds that play key roles in flavor. Finally, model systems, similar to the actual cheese, should then be constructed to evaluate the role of specific compounds on sensory-perceived flavor. This last step is sometimes referred to as recombination studies.

Using this process, researchers identified the key chemical components in cheese responsible for nutty flavor notes. Sensory analysis of cheese models revealed that three Strecker aldehydes–2-methylpropanal, 2-methylbutanal and 3-methylbutanal–can contribute to nutty flavors in aged (>9 months) Cheddar cheeses. Quantitative data suggested that 2-methylpropanal may be more important, because it was more prevalent in nutty cheese and present at higher concentrations than the other Strecker aldehydes.

The formation of these aldehydes requires the presence of certain amino acids: valine for 2-methylpropanal, isoleucine for 2-methylbutanal and leucine for 3-methylbutanal. In order to produce Cheddar cheese with enhanced or accelerated nutty flavor, the researchers advised one of the following three methods: (1) the use of starter bacteria capable of releasing these certain amino acids; (2) addition of certain amino acids into cheese milk or cheese slurry; and (3) accelerating the conversion rate of these amino acids into aroma compounds (Strecker aldehydes).

This study is an excellent example of how combining sensory and analytical studies can be used to formulate cheeses with specific flavor qualities for use in specific applications or to appeal to specific market segments.

Additional Applications of Sensory Analysis

Several other applications of sensory analysis to dairy products have been completed recently or are currently under investigation. A few examples include:

- Development of a flavor lexicon for chocolate milk and linkage to consumer market preferences (Thompson et al., 2004).
- Understanding sources of flavor variability in skim milk powder, whey protein concentrates and agglomerated dried dairy ingredients (M.A. Drake, ongoing research).
- Development of lexicons for cheese texture to enhance understanding of rheological and functional properties (Brown et al., 2003; Foegeding et al., 2003).
- Understanding structure/function relationships in cream cheese responsible for its performance. To date, researchers have trained a sensory panel and defined specific descriptors for the textural attributes of cream cheese, e.g., firmness, stickiness, gumminess, etc. (S. Govindasamy Lucey and J.A. Lucey, ongoing research).
- Understanding milk aftertaste and its acceptability. Includes understanding milk flavor perception by teen girls (Z.M. Vickers et al., in press).
- Flavor perceptions and preferences of Hispanic consumers (M.A. Drake, ongoing research).

These studies illustrate that sensory analysis can be used to improve understanding of (1) how textural properties affect sensory perception and consumer preference and (2) how the sensory appeal of dairy products can be optimized for specific target audiences.

Bibliography

Avsar, Y.K.; Karagul-Yuceer, Y.; Drake, M.A.; Singh, T.K.; Yoon, Y.; and Cadwallader, K.R. Characterization of nutty flavor in Cheddar cheese. 2004. *J. Dairy Sci.* 87:1999-2010.

Banks, J.M.; Hunter, E.A.; and Muir, D.D. Sensory properties of lowfat Cheddar; effect of salt content and adjunct culture. 1993. *J. Soc. Dairy Technol.* 46:119-123.

Brown, J.A.; Foegeding, E.A.; Daubert, C.R.; and Drake, M.A. Changes in rheological and sensorial properties of young cheese as related to maturation. 2003. *J. Dairy Sci.* 86:3054-3067.

Chapman, K.W.; Lawless, H.T.; and Boor, K.J. Quantitative Descriptive Analysis and Principal Component Analysis for sensory characterization of ultrapasteurized milk. 2001a. *J. Dairy Sci.* 84:12-20.

Chapman, K.W., and Boor, K.J. Acceptance of 2% ultrapasteurized milk by consumers, 6 to 11 years old. 2001b. *J. Dairy Sci.* 84:951-954.

Claassen, M.R., and Lawless, H.T. A comparison of descriptive terminology systems for the sensory analysis of flavor defects in milk. 1992. *J. Food Sci.* 57:596-621.

Drake, M.A.; Boylston, T.D.; Spence, K.D.; and Swanson, B.G. Chemical and sensory quality of reduced-fat cheese with a *Lactobacillus* adjunct. 1996. *Food Res. Int.* 29(3/4):381-387.

Drake, M.A.; Boylston, T.D.; Spence, K.D.; and Swanson, B.G. Improvement of sensory quality of reduced-fat Cheddar cheese by a *Lactobacillus* adjunct. 1997. *Food Res. Int.* 30(1):35-40.

Drake, M.A.; McIngvale, S.C.; Gerard, P.D.; Cadwallader, K.R.; and Civille, G.V. Development of a descriptive language for Cheddar cheese. 2001. *J. Food Sci.* 66:14222-1427.

Drake, M.A., and Civille, G.V. Flavor lexicons. 2002. Comprehensive Reviews in Food Science and Food Safety. 2:33-39.

Drake, M.A.; Karagul-Yuceer, Y.; Cadwallader, K.R.; Civille, G.V.; and Tong, P.S. Determination of the sensory attributes of dried milk powders and dairy ingredients. 2003. *J. Sensory Stud.* 18:199-216.

Drake, M.A. ADSA foundation scholar award: defining dairy flavors. 2004. *J. Dairy Sci.* 87:777-784.

Foegeding, E.A.; Brown, J.; Drake, M.A.; and Daubert, C.R. Sensory and mechanical aspects of cheese texture. 2003. *Int. Dairy J.* 13:585-591.

Muir, D.D.; Hunger, E.A.; Banks, J.M.; and Horne, D.S. Sensory properties of hard cheeses: identification of key attributes. 1995. *Int. Dairy J.* 5:157-177.

Muir, D.D.; Banks, J.M.; Hunter, E.A. Sensory properties of Cheddar cheese: effect of starter type and adjunction. 1996. *Int. Dairy J.* 6:407-423.

Ohmes, R.L.; Marshall, R.T.; and Heymann, H. Sensory and physical properties of ice creams containing milkfat or fat replacers. 1998. *J. Dairy Sci.* 81:1222-1228.

Ordonez, A.I.; Ibanez, F.C.; Torre, P.; Barcina, Y.; and Perez-Elortondo, F.J. Application of multivariate analysis to sensory characterization of ewes' milk cheese. 1998. *J. Sensory Stud.* 12:45-55.

Phillips, L.G.; McGiff, M.L.; Barbano, D.M.; and Lawless, H.T. The influence of nonfat dry milk on the sensory properties, viscosity and color of lowfat milks. 1995. *J. Dairy Sci.* 78:1258-1266.

Piggot, J.R., and Mowat, R.G. Sensory aspects of maturation of Cheddar cheese by descriptive analysis. 1991. *J. Sensory Stud.* 6:49-62.

Quinones, H.J.; Barbano, D.M.; and Phillips, L.G. Influence of protein standardization by ultrafiltration on the viscosity, color and sensory properties of 2% and 3.3% milk. 1998. *J. Dairy Sci.* 81:884-894.

Roberts, A.K., and Vickers, Z.M. Cheddar cheese aging: changes in sensory attributes and consumer acceptance. 1994. *J. Food Sci.* 59:328-334.

Roland, A.M.; Phillips, L.G.; and Boor, K.J. Effects of fat replacers on the sensory properties, color, melting and hardness of ice cream. 1999. *J. Food Sci.* 82:2094-2100.

Thompson, J.L.; Drake, M.A.; Lopetcharat, K.; and Yates, M.D. 2004. Preference mapping of commercial chocolate milks. In press. *J. Food Sci.* 69 (11/12):S406-S413.

Van Aardt, M.; Duncan, S.E.; Marcy, J.E.; Long, T.E.; O'Keefe, S.F.; and Nielsen-Sims, S.R. Effect of antioxidant fortification on light-induced flavor of milk. In press.

Vickers, Z.M., and Porubcan, A.R. Characterizing milk aftertaste: the effects of salivation rate, PROP taster status, or small changes in acidity, fat or sucrose on acceptability of milk to milk dislikers. *Food Quality and Preferences.* In press.

Yang, B., and Vickers, Z. Optimization of Cheddar cheese taste in model cheese systems. 2004. *J. Food Sci.* 69:S229-S236.

Innovations in Dairy
DAIRY INDUSTRY TECHNOLOGY REVIEW
October 2005

10255 West Higgins Road, Suite 900
Rosemont, IL 60018-5616

FPO

DMI DAIRY MANAGEMENT INC.