Development of a Descriptive Language for Cheddar Cheese

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ABSTRACT: A standardized descriptive language for Cheddar cheese flavor was developed and validated. Representative Cheddar cheeses (240) were collected. Fifteen individuals from industry, academia, and government participated in a 3-d roundtable discussion to generate descriptive flavor terms. A highly trained descriptive panel (n = 11) refined the terms and identified references. Cheddar cheeses (24) were presented to the panel for validation with the identified lexicon. The panel differentiated the 24 Cheddar cheeses as determined by univariate and multivariate analysis of variance ($P < 0.05$). Twenty-seven terms were identified to describe Cheddar flavor. Seventeen descriptive terms were present in most Cheddar cheeses. A standard sensory language for Cheddar cheese will facilitate training and communication between different research groups.

Keywords: cheddar, cheese, descriptive analysis, language, sensory evaluation

Introduction

QUALITY EVALUATION OF CHEESE IS AN IMPORTANT PARAMETER. Grading and judging are used extensively by the dairy industry for quality evaluation of all dairy products (Bodyfelt and others 1988). For grading and judging, a product is evaluated based on the presence or absence of specific defects and then an overall quality score is given. These quality scores are usually based on the opinions of one individual and the quality score is subjective rather than specifically defined (Bodyfelt 1981). These scores, due to nonlinearity, are not suitable for statistical analysis and previous studies have questioned their correlation with consumer acceptability (McBride and Hall 1979; Lawless and Claasen 1993). Further, they do not describe all of the attributes and intensities of flavor attributes in cheese that can be useful for market niche identification and end product application.

Academic researchers have used descriptive analysis or specific attribute analysis to study aging and various processing parameters in cheese (Piggott and Mowat 1991; Hough and others 1994; Roberts and Vickers 1994; Drake and others 1996a, 1996b; Muir and others 1996a, 1996b). The vocabulary and the scales used were different among different research groups. Definitions or references were not reported for most previous studies. Heisserer and Chambers (1993) developed a sensory language for hard cheeses with definitions that was developed from a sample set of 42 hard cheeses, but the language was not specific for Cheddar cheeses. The lack of a standard descriptive language with standard definitions and references makes comparison and/or repetition of results from different studies or across different sites difficult, as there is no uniform frame of reference.

The need for a standard descriptive language for cheese has resulted in several collaborative studies on the sensory evaluation of hard cheeses in Europe (Hirst and others 1994; Hunter and McEwan 1998; Nielson and Zannoni 1998). These studies have focused on identification of a standard consensus sensory language for 12 different varieties of hard cheeses. The sensory language was developed from descriptors previously used by the participating laboratories. Ideally, a descriptive language should be developed from a representative sample set (Meilgaard and others 1997). Standard descriptive languages have been developed for other commodities using a representative sample set and a group of panelists to generate terms (Johnson 1986; Johnson and Civille 1986; Johnson and others 1987; Janto and others 1998).

Cheddar cheese is produced across the United States and continues to be a growing commodity. Much research nationally and internationally has focused specifically on Cheddar cheese flavor. The development of a standard descriptive language with definitions and a standard scale for the sensory evaluation of Cheddar cheese would enhance communication among research groups and enable more precise profiling of flavor attributes. This information would be useful in market niche identification and end product application. The objectives of this study were to develop a standard language for Cheddar cheese using a large representative sample set and to identify the initial language using dairy researchers from industry, government, and academia.

Materials and Methods

Cheeses

Two hundred forty Cheddar cheeses were collected from companies and academic institutions nationwide and internationally. In many cases cheeses were generously donated; the remainder were purchased. Care was taken to ensure regional representation from within the United States as well as a range of cheese maturity. Cheeses were collected from the following regions/areas: Northwest, California, mid-west, Wisconsin, Minnesota, and the Northeast. Two hundred cheeses were collected from within the United States. An additional 40 cheeses were obtained from Great Britain, Scotland, Ireland, New Zealand, and Australia. Cheeses ranged in age from 2 mo to 3 y. Reduced- and low-fat Cheddar cheeses were also collected. Samples ranged from 2 to 40 pounds in size. Upon receipt, cheeses were examined to ensure that damage or temperature abuse did not occur during shipping. Cheeses were then vacuum-sealed if necessary and stored at 7 °C in the dark until evaluation. Cheeses were collected over a 2-mo period prior to evaluation.

Cheese Selection and Preparation

To narrow down the large sample set of cheeses to a more manageable number for the roundtable discussion, cheeses were screened 48 h prior to the initial roundtable sensory analysis. Cheeses were screened for flavor by 4 professional experienced experts in cheese flavor: 2 descriptive analysis experts (G.V. Civille Sensory Spectrum, Inc., Chatham, N.J., U.S.A. and M.A. Drake, Mississippi State Univ., Mississippi State, Miss., U.S.A.), a cheese grader (B. Aschebrock, Stratford, Wis., U.S.A.), and an ADSA scorecard judge (C. White, Mississippi State Univ., Mississippi State, Miss., U.S.A.). These individuals collectively had more than 2000-h experience specifically with cheese flavor evaluation. Cheeses were screened using USDA grade and ADSA scorecard criteria as well as a general dairy descriptive language. Cheeses were evaluated by tempering blocks to 12 °C followed by sampling with a cheese trier. All cheeses were screened within a 24-h period and the sensory results recorded. From the screening process, 70 cheeses were selected as representative of Cheddar cheese and were used for the roundtable discussion and language generation. These cheeses were sliced into cubes using a wire slicer within 2 h of presentation. Cheeses were tightly wrapped in foil prior to presentation.

Participants

To generate a descriptive language readily acceptable to the dairy industry and dairy research world, the flavor terms were initially identified in a 3-d roundtable discussion attended by 15 members of academia, industry, or government. These individuals represented a cross section of cheese flavor experts and a broad perspective on cheese flavor. The use of a group of individuals with different backgrounds and yet who were all experienced with cheese flavor evaluation also provided a more rapid and broad perspective of generating the initial sensory language. Participants included Bob Aschebrock (USDA review specialist, ret., Stratford, Wis., U.S.A.), Floyd Bodyfelt (Oregon State Univ., Corvallis, Oreg., U.S.A.), Bob Bradley (Univ. of Wisconsin, Madison, Wis., U.S.A.), Larry Claypool (Dairy Farmers of America, Springfield, Mo., U.S.A.), Greg Kinate (Kineva Foods, Inc., De Pere, Wis., U.S.A.), Bob Lindsay (Univ. of Wisconsin, Madison, Wis., U.S.A.), Bob Marshall (Univ. of Missouri, Columbus, Mo., U.S.A.), Johnny McGregor (Louisiana State Univ., Baton Rouge, La., U.S.A.), Jim Moran (Kraft Foods, Inc., Glenview, Ill., U.S.A.), Bill Novak (Great Lakes Cheese, La Crosse, Wis., U.S.A.), Duane Spomer (Chief USDA Standards, Washington D.C., U.S.A.), Steve Wright (Rhodia, Inc., Madison, Wis., U.S.A.), Zata Vickers (Univ. of Minnesota, St. Paul, Minn., U.S.A.), Carl Zurborg (Swiss Valley Farms, Davenport, Iowa, U.S.A.), and Charles White (Mississippi State Univ., Mississippi State, Miss., U.S.A.). The roundtable discussion was held January 25 to 27, 1999 at Mississippi State Univ.

Language Identification

The roundtable discussion was led by Gail Vance Civille (Sensory Spectrum, Inc., Chatham, N.J., U.S.A.). Panelists received a 3-h review session on descriptive analysis including techniques, scaling, basic tastes, and aroma and flavor identification. Cheeses were grouped into sets of 6 to 10 cheeses that were presented to group members followed by discussion. Once terms were generated, panel discussion identified common descriptors among word groups and initial definitions were identified (Table 1).

Table 1—Initial Cheddar lexicon from roundtable discussion

Aromatics:
Fresh Curd/Undeveloped flavors
– Milky flavors
Cooked
Whey
– Buttery flavors
Diacetyl
Milkfat/Lactone
Aging/Developing flavors
– Sulfury
– Nutty
– Brothy
– FattyAcids
– Fruity
– Animal/Unclean/Barn
Oxidized: [papery, cardboardy, painty, fatty lard-like, and so on]
Moldy/ketone
Yeasty
Tastes:
Salty
Sweet
Sour
Bitter
Chemical Feeling Factors:
Umami
Bite

Fine-tuning and Identification of References

Following the roundtable and generation of the preliminary language, a descriptive panel was trained to refine the developed language and to identify references. Twelve individuals, 7 male and 5 female, 21 to 44 y of age were selected from Univ. staff and students based on availability, interest, and a demonstrated liking for cheese. Ten panelists had prior experience with descriptive analysis. The panel received 75 h of training using the Spectrum™ method and the identified language. Panelists received food treats and monthly gift certificates at local restaurants for their participation. During training, panelists were presented with and evaluated potential references (food or chemical) for the identified descriptive terms. Additional Cheddar cheeses (approximately 60, national and international) that were not available for the roundtable discussion were presented to the panel as well as Cheddar cheeses available at the roundtable discussion. Panelists were encouraged to volunteer new descriptive terms and to address existing terms.

Validation of the Descriptive Language

Once the language was refined and references identified (Table 2), the developed language was validated by evaluation of a new set of 24 Cheddar cheeses that represented different geographical region, age, and heat treatment of milk (Table 3). Cheeses were prepared by slicing into $4 \times 2 \times 2$ cm cubes using a wire slicer within 2 h of evaluation. Cheeses were wrapped tightly in foil and tempered to 12 °C prior to evaluation. Cheeses were evaluated in a balanced block design using 3-digit codes under white lights. Order of presentation was randomized between panelists. Panelists had access to water and unsalted crackers throughout evaluation. Expectoration was encouraged but was optional. Panelists evaluated 2 cheeses per session. Tasting was conducted at the same time for each session. Tasting was conducted over a 3-wk period with panelists evaluating each cheese twice.

Table 2—Cheddar lexicon following fine-tuning and identification of references

Term	Definition	Reference
Cooked	Aromatics associated with cooked milk	skim milk heated to 85 ºC for 30 min
Whey	Aromatics associated with Cheddar cheese whey	fresh Cheddar whey
Diacetyl	Aromatic associated with diacetyl	diacetyl, 20 ppm
Milkfat/ Lactone	Aromatics associated with milkfat	fresh coconut meat, heavy cream, δ dodecalactone, 40 ppm
Fruity	Aromatics associated with different fruits	fresh pineapple Ethyl hexanoate, 20 ppm
Sulfur	Aromatics associated with sulfurous compounds	boiled mashed egg H_2S bubbled through waterstruck match
Free fatty acid	Aromatics associated with short chain fatty acids	butyric acid, 20 ppm
Brothy	Aromatics associated with boiled meat or vegetable soup stock	canned potatoes, Wylers low sodium beef broth cubes, methional, 20 ppm
Nutty	The nut-like aromatic associated with different nuts	lightly toasted unsalted nuts wheat germ, unsalted wheat thins, roasted peanut oil extract
Catty	Aroma associated with tom-cat urine	2 mercapto-2 methyl-pentan-4-one, 20 ppm
Cowy/ phenolic	Aromas associated with barns and stock trailers, indicative of animal sweat and waste	p-cresol, 160 ppm, bandaids,
Age**	Flavors indicating age in Cheddar cheese	Aged Cheddar cheese (1 y or longer)
Yeasty*	Aromatics associated with fermenting yeast	raw yeast dough, yeast in 3% warm sucrose water
Moldy/ Musty*	Aromas associated with molds and/or freshly turned soil	2-ethyl-1-hexanol potting soil
Methyl Ketone/bleu*	Aroma with associated blue-veined cheeses	2-octanone, 40 ppm
Oxidized*	Aroma associated with oxidized fat	2,4 decadienal, 20 ppm
Waxy/ Crayon*	Aromatics associated with medium chain fatty acids	Capric acid, lauric acid or decanoic acid, 100 mg/mL
Fecal*	Aroma associated with complex protein decomposition	indole, skatole, 20 ppm
Bell pepper*	Aroma associated with freshly cut green vegetables	methoxy pyrazines, 5 ppb freshly cut bell pepper
Rosy/Floral*	Aroma associated with flowers	2-phenethylamine, 20 ppm
Scorched*	Aroma associated with extreme heat treatment of milk proteins	Milk heated to 121 ºC for 25 min
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)
Prickle/bite*	chemical feeling factor of which the sensation of carbonation on the tongue is typical	soda water

*Indicates term was not frequently encountered in Cheddar cheese.
**Data analysis indicated term is redundant and is a combination of several terms.
Chemical references prepared in 95% ethanol.

Statistical Analysis

Significance was established at $p < 0.05$. Analysis of variance with means separation was conducted to evaluate panel consistency across replicates of the same cheese. Principal component analysis and factor analysis were conducted using treatment means to determine how the cheeses were differentiated and to identify redundant terms. Correlation analysis was also conducted to determine individual relationships between terms. For correlation analysis, statistical significance was adjusted using Bonferroni's adjustment (Miller 1980). Statistical analyses were conducted using SAS (Version 7.0; SAS Institute Inc., Cary, N.C., U.S.A.).

Results and Discussion

THE TERMS INITIALLY GENERATED AND AGREED UPON FROM the roundtable discussion are shown in Table 1. These terms were used as a starting basis for the descriptive analysis panel. The refined language developed by the descriptive analysis panel is provided in Table 2. Many of the identified terms have been used although not specifically defined or referenced by previous researchers thus validating the use of these descriptors (Piggot and Mowat 1991; Roberts and Vickers 1994; Muir and others 1995; Muir and others 1996a). Recently, Murray and Delahunty (2000) identified references for a Cheddar sensory language developed in Ireland. Some terms, definitions, and references were similar to those described and defined here and others are unique. Cross-cultural differences may account for these differences and is an area of potential future research (Risvik and others 1992; Hirst and others 1994).

Terms were clarified to 1 or 2 words with a specific definition by panel discussion and evaluation of cheeses. Chemical terms such as "diacetyl" and "free fatty acid" were used when possible. References were identified for all terms and chemical references were also identified for many of the terms. References for sensory terms are not necessarily identical to the described flavor, but should be sufficiently similar so panelists can be trained to identify with a specific term. Bu-

tyric acid was the selected chemical reference for the term free fatty acid (Table 2). The term "free fatty acid" was preferred by the panel since it was recognized that occasionally free fatty acid flavors reminiscent of other short chain fatty acids (such as isovaleric acid) might be encountered in Cheddar cheeses. A uniform and standardized descriptive language facilitates communication among industry and academic research and marketing groups. Standard references, food or chemical, provide the basis for common experiences tied to a common lexicon. When possible, linking sensory flavor descriptors to chemical components found in cheeses can link cheese flavor to the technology of cheese production and is an area of future research in our laboratory.

The panel also identified the potential to further separate some terms. These included free fatty acid (butyric acid and isovaleric acid), nutty (hazelnut and peanut and pecan), brothy (vegetable/mushroom and meaty), sulfur (eggy and match-like), and fruity (pineapple and apple). Berodier and others (1997) described a similar hierarchy of descriptors with a lexicon of comte cheeses. Heisserer and Chambers (1993) reported the terms fruity and pineapple as 2 distinct flavor terms in their study of hard cheese flavor. The potential to further subdivide sensory descriptors will facilitate clarification of the role between chemical components in cheese and perceived cheese flavors. The ability to use a more complex and specific language also provides a sensory tool for when such a specific need may arise.

From observation during language identification and the subsequent panel training as well as the results of the panel validation, 17 terms were frequently observed with Cheddar cheeses while 10 terms were observed rarely (Table 2). As a result, data analysis of the cheeses was conducted on the 17 frequently encountered flavors and tastes. The 10 less frequently observed terms were detected in a few of the 24 cheese sample set: oxidized (cheese 21), fecal (cheese 2), rosy/floral (cheese 2), bell pepper (cheese 23), moldy/musty (cheese 23), and prickle/bite (cheese 23). It is important to note that while these 10 terms were not observed frequently in Cheddar cheeses, this does not mean that these terms are not relevant to a sensory language for Cheddar cheese, but that they are not observed frequently in Cheddar cheeses. Thus, a basic sensory language of 17 terms could be used to train a panel and the other 10 terms not included unless specifically needed. The more terms, the more panel training required so distillation of a sensory language to its most basic or commonly observed components is a desirable thing to many users.

Cheeses were differentiated by univariate (Table 4) and multivariate analysis of variance for the 17 terms (Figure 1). Panelist performance was consistent as evidenced by the small and consistent least significant differences (LSD) across the terms. There was not a replicate effect nor was there a treatment by replicate interaction ($p < 0.05$) further indicating consistent panel performance. Principal component analysis indicated nonredundant terms that clearly differentiated cheeses (Figure 1). Factor analysis with Varimax rotation was applied to the correlation matrix of cheese means in addition to principal component analysis in order to clarify groups of attributes. Varimax rotation was applied to more clearly group individual terms. Principal component analysis, correlation analysis, and factor analysis all indicated relationships between terms (Tables 5 and 6; Figure 1). Mild flavors such as "cooked," "whey," "diacetyl," and "milkfat" were correlated to each other. These flavors are distinct from each other, but predominate in young or mild cheeses. Hence we grouped them under the heading "young undeveloped flavors." In contrast, other flavors in the lexicon were generally more associated with aging in cheeses and these terms were grouped under the heading "aged developed flavors." These terms were also correlated with each other.

Table 3—Cheeses used for validation of the language

Cheese 1	Minnesota, 3 mo, pasteurized
Cheese 2	British, 6 mo, raw
Cheese 3	British, 3 mo, pasteurized
Cheese 4	Minnesota, 1 mo, pasteurized
Cheese 5	MidWest, 6 mo, pasteurized
Cheese 6	Scottish, 9 mo, raw
Cheese 7	Northwest, 6 mo, heat treated
Cheese 8	California, 1 mo, pasteurized
Cheese 9	Northeast, 6 mo, pasteurized
Cheese 10	MidWest, 6 mo, pasteurized
Cheese 11	Northeast, 2 mo, pasteurized
Cheese 12	Northeast, 12 mo, pasteurized
Cheese 13	Northeast, 6 mo, pasteurized
Cheese 14	Irish, 6 mo, pasteurized
Cheese 15	Northeast, 6 mo, pasteurized
Cheese 16	Wisconsin, 6 mo, pasteurized
Cheese 17	Northwest, 16 mo, heat treated
Cheese 18	MidWest, 2 mo, pasteurized
Cheese 19	Northeast, 4 mo, pasteurized
Cheese 20	MidWest, 9 mo, pasteurized
Cheese 21	Minnesota, 6 mo, pasteurized
Cheese 22	Minnesota, 3 mo, pasteurized
Cheese 23	British, 24 mo, raw
Cheese 24	California, 3 mo, pasteurized

Many of the correlations were expected. The young undeveloped flavors "cooked," "whey," "diacetyl," and "milkfat" were negatively correlated with "age"; while "fruity," "sulfur," "free fatty acid," "brothy," "nutty," and "catty" were positively correlated. Mild flavors would be expected to be negatively correlated with aged flavors. Bitterness was correlated with "sulfur" and "age" flavors and was negatively correlated with sweetness. Sourness was correlated with "sulfur," "free fatty acid," and "brothy" flavors. Saltiness was correlated with "sulfur" and "brothy" flavors and the feeling factor umami. Several terms were associated with the term "age" indicating that this term is related to the perception or lack of perception of several different flavors. The flavor cowy was correlated with age and sourness, but was not correlated to any other flavors or tastes. This term was only encountered in the validation study with international Cheddar cheeses (cheeses 2, 6, 14, and 23; Table 4) and did not contribute to a lot of explained variance by factor analysis probably because it was not often encountered. Cowy/barny flavor has been linked to the chemical component p-cresol in cheese and is considered an undesirable flavor in American Cheddar cheeses (Dunn and Lindsay 1985; Suriyaphan and others 2001).

Analysis of scree plots indicated that 4 factors explained 86% of the variance among the cheeses. Removal of the term "age" did not affect the scree plots or the percent variance explained indicating that the term "age" could be removed without affecting differentiation of the flavors within the samples. Factor 1 included all of the young/undeveloped flavors inversely with many of the aged/developed flavors except for sulfur, brothy, and cowy. Cheeses with high intensities of young/undeveloped flavors (cooked, whey, diacetyl, and milkfat) are not likely to have high intensities of nutty, catty, free fatty acid, or aged flavors and explains why these terms were inversely related

Table 4–Means separation of cheeses with developed language

cheese	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	LSD
Cooked	3.3	2.8	3.0	2.5	2.9	2.9	2.9	3.3	2.5	2.5	3.3	2.3	2.8	2.3	2.9	2.9	2.5	3.1	2.7	2.9	3.3	3.4	2.5	3.3	0.3
Whey	3.0	2.1	2.3	3.3	2.6	2.1	2.3	3.3	2.0	1.7	3.1	1.7	2.2	1.9	2.1	1.9	2.1	3.0	1.9	2.3	2.7	2.6	1.8	3.0	0.4
Diacetyl	1.7	0.9	1.1	1.1	1.1	0.9	1.0	1.7	0.9	0.7	1.9	0.7	0.9	0.0	1.1	1.0	1.0	1.6	0.9	0.0	1.4	1.4	0.0	1.3	0.3
Milkfat	2.4	1.6	2.3	2.5	2.1	1.5	1.6	2.6	1.2	1.0	2.9	1.2	1.5	1.1	1.6	1.4	1.1	2.3	1.1	1.4	2.2	2.4	1.0	2.6	0.4
fruity	0.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	1.7	1.0	0.8	0.0	0.0	0.0	0.8	0.0	0.0	0.0	1.0	0.0	0.4
Sulfur	0.0	2.0	0.0	0.0	1.8	1.6	2.7	0.0	3.1	4.2	0.0	3.6	2.9	3.5	3.4	3.7	4.2	1.1	4.1	3.2	1.7	1.1	2.2	1.1	0.4
FFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.8	0.0	0.6	1.0	0.8	1.3	0.0	1.8	1.0	0.0	0.0	0.8	0.0	0.3
Brothy	1.0	2.5	1.6	0.0	1.4	2.8	2.3	1.0	3.0	1.4	0.0	2.7	2.7	2.6	2.5	2.7	2.8	1.4	2.8	2.5	1.7	1.7	2.3	2.5	0.5
Nutty	0.0	2.0	1.2	0.0	0.8	2.0	0.7	0.0	1.6	0.8	0.0	2.5	1.7	1.2	1.7	1.0	1.0	0.0	2.0	1.0	0.5	0.0	1.2	0.0	0.5
Catty	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	1.6	0.9	0.0	2.1	0.9	1.7	1.5	1.6	1.5	0.0	2.2	1.0	0.0	0.0	0.0	0.0	0.3
Cowy	0.0	2.1	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.4
Age	1.9	4.5	2.9	1.0	3.7	4.6	4.1	1.8	5.7	6.0	1.5	6.0	5.0	5.5	4.8	5.5	5.8	2.8	6.0	5.0	2.9	1.9	5.5	2.6	0.4
Sweet	1.5	2.4	1.9	1.2	1.0	1.9	1.2	1.4	2.0	1.0	2.0	1.2	2.0	1.2	1.5	1.2	1.2	1.4	1.2	1.0	1.3	1.3	1.5	1.4	0.4
Sour	2.9	2.9	3.0	2.5	3.1	2.7	3.2	3.0	3.3	3.0	2.3	3.5	3.1	3.6	3.3	3.7	3.8	3.1	3.5	3.1	3.1	2.7	3.0	3.0	0.5
Salty	2.0	2.1	1.9	2.4	2.3	0.7	2.4	2.2	2.6	2.1	1.8	2.3	2.3	2.4	2.6	2.7	2.9	2.5	2.7	2.4	2.4	2.4	2.4	2.3	0.4
Bitter	0.5	0.0	0.0	0.0	1.5	0.0	1.8	0.0	1.0	3.0	0.4	2.5	0.0	1.5	1.5	0.0	1.8	0.0	1.0	1.5	0.0	0.0	0.5	0.0	0.4
Umami	0.8	1.8	1.4	0.0	0.8	1.6	1.5	0.0	1.8	1.4	0.0	1.6	1.9	1.8	1.9	1.7	1.9	0.5	1.7	1.4	1.4	1.4	1.9	1.6	0.3

on factor 1. Sulfur and brothy tracked with salty and umami on factor 2 while sweet and bitter were inversely grouped on factor 3. Heisserer and Chambers (1993) reported an inability to differentiate sweet and sour aromatics from sweet and sour tastes. Their terminology was different from the terms in our study, however, sweet aromatic terms such as diacetyl and milkfat/lactone and sour aromatics such as whey are clearly differentiated from the basic tastes sweet and sour in the present study.

The standardized developed and referenced language was developed for Cheddar cheese using the Spectrum™ method and scales (Meilgaard and others 1997). The Spectrum™ method is based on universal intensity scales. This means that a perceived "5" intensity in bitterness is the same magnitude as a perceived "5" intensity in sourness, and so on. References for the basic taste intensities are available in Meilgaard and others (1997). The panel was trained to apply the universal intensity scales to the evaluation of cheese flavor intensities as well. Johnsen and others (1986) developed and referenced a language for peanut flavor using the same technique. The basic taste intensity references provide a starting method for training future panels on the use of the cheese language scales and improves communication between different panels. Ongoing research in our lab is focused on the application and demonstration of this identified sensory language for cheeses among different research groups (cross validation). The use of one standardized scale also lays the groundwork for the addition of new terms for the addition of other cheese types such as Italian or Dutch cheese. Texture could also be added using the same scale. A language for cheese texture has been identified and referenced (Drake and others 1999). However, this language was not specific for Cheddar cheese and used product specific scaling rather than universal scaling.

Conclusions

A DEFINED AND REFERENCED SENSORY LANGUAGE FOR Cheddar cheese flavor was identified and validated. Seventeen terms could be used to describe and differentiate the majority of flavors encountered in Cheddar cheese. The standardized language with universal intensity scales will facilitate training of similar panels at different sites and will enhance communication of cheese flavor research results.

Table 5—Factor loadings of each attribute following varimax rotation

Attribute	Factor 1	Factor 2	Factor 3	Factor 4
cooked	**–0.86**	0.09	0.33	–0.05
whey	**–0.66**	–0.52	0.22	–0.36
diacetyl	**–0.66**	–0.26	0.39	–0.42
milkfat	**–0.66**	–0.48	0.36	–0.31
fruity	**0.83**	0.30	0.21	0.16
sulfur	0.54	**0.66**	–0.43	–0.04
free fatty acid	**0.61**	0.51	–0.35	–0.03
brothy	0.32	**0.80**	0.04	0.32
nutty	**0.74**	0.34	0.09	0.32
catty	**0.62**	0.51	–0.23	–0.25
cowy	0.20	0.03	0.11	**0.91**
age	**0.64**	0.63	–0.30	0.23
salty	–0.03	**0.94**	–0.04	0.04
sweet	0.11	–0.04	**0.92**	0.13
bitter	0.37	0.11	**–0.73**	0.02
sour	0.34	**0.70**	–0.33	–0.27
umami	0.55	**0.66**	0.15	0.17
Variance Explained[a]	33%	30%	16%	7%

[a]Refers to percent variance explained following varimax rotation.
Numbers in **bold** are believed to be of primary importance.

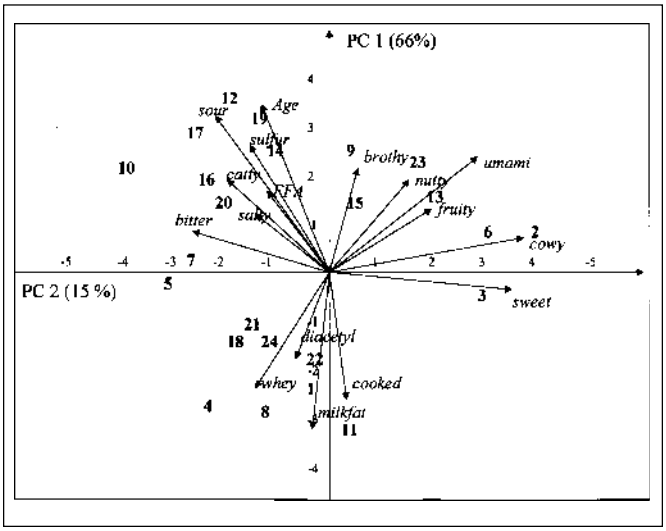

Figure 1—Principal component space plot of cheeses and descriptors. Numbers represent cheeses.

Table 6—Correlations between attributes

	whey	diacetyl	milkfat	fruity	sulfur	FFA	brothy	nutty	catty	cowy	age	sweet	sour	salty	bitter	umami
cooked	**0.60**	**0.72**	**0.70**	**–0.59**	**–0.52**	**–0.58**	–0.23	–0.51	**–0.53**	–0.20	**–0.62**	0.19	–0.38	0.07	–0.50	–0.40
whey		**0.77**	**0.89**	**–0.71**	**–0.81**	**–0.74**	**–0.72**	**–0.79**	**–0.64**	–0.42	**–0.93**	0.08	–0.50	–0.50	–0.51	**–0.75**
diacetyl			**0.85**	**–0.62**	**–0.65**	**–0.68**	**–0.58**	**–0.63**	**–0.54**	–0.47	**–0.78**	0.29	–0.46	–0.25	–0.46	**–0.61**
milkfat				**–0.64**	**–0.82**	**–0.80**	**0.70**	**–0.68**	**–0.65**	–0.40	**–0.95**	0.22	–0.50	–0.46	–0.52	**–0.68**
fruity					**0.55**	0.50	**0.59**	**0.81**	**0.52**	0.32	**0.70**	0.28	0.40	0.28	0.28	**0.70**
sulfur						**0.83**	**0.67**	**0.56**	**0.79**	0.03	**0.91**	–0.36	**0.75**	**0.60**	**0.63**	**0.68**
FFA							0.51	**0.53**	**0.77**	0.12	**0.83**	–0.26	**0.68**	0.46	0.43	**0.59**
Brothy								**0.64**	0.51	0.34	**0.77**	0.05	**0.56**	**0.72**	0.21	**0.80**
Nutty									**0.56**	0.44	**0.73**	0.15	0.34	0.31	0.34	**0.67**
Catty										–0.01	**0.73**	–0.21	**0.69**	0.45	0.41	0.50
Cowy											0.32	0.26	–0.12	0.07	–0.03	0.28
Age												–0.17	**0.69**	0.46	**0.57**	**0.75**
Sweet													–0.36	–0.04	**–0.56**	0.16
Sour														**0.63**	0.38	**0.55**
Salty															0.18	**0.54**
Bitter																0.16

Numbers in **bold** represent significant correlations ($P \leq 0.0003$)

References

Berodier F, Stevenot C, Schlich P. 1997. Descripteurs de l'arome du fromage de Comte. Lebensm Wiss Technol 30:298-304

Bodyfelt FN. 1981. Dairy product score cards: Are they consistent with principles of sensory evaluation? J Dairy Sci 64:2303-2308.

Bodyfelt FN, Tobias J, Trout GM. 1988. Sensory Evaluation of Cheese. In: Bodyfelt, FN, editor. Sensory Evaluation of Dairy Products. New York: AVI Van Nostrand Reinhold. P 300-376.

Drake MA, Boylston TD Spence KD, Swanson BG. 1996a. Chemical and Sensory Effects of a *Lactobacillus* Adjunct in Cheddar Cheese. Food Research Int 29(3/4):381-387.

Drake MA, Boylston TD, Swanson BG. 1996b. Fat mimetics in low fat cheeses. J Food Sci 61:1267-1270.

Drake MA, Gerard PD, Civille, GV. 1999. Ability of hand evaluation versus mouth evaluation to differentiate texture of cheese. J Sensory Stud 14:425-441.

Dunn HC, Lindsay RC. 1985. Evaluation of the role of microbial Strecker-derived aroma compounds in uncleaned-type flavors of Cheddar cheese. J Dairy Sci 68(11):2859-2874.

Heisserer DM, Chambers E. 1993. Determination of the sensory flavor attributes of aged natural cheese. J Sensory Stud 8:121-132.

Hirst D, Muir DD, Naes T. 1994. Definition of the sensory properties of hard cheese: A collaborative study between Scottish and Norwegian panels. Int Dairy J 4:743-761.

Hough G, Martinez E, Barbieri T, Contarini A, Vega MJ. 1994. Sensory profiling during ripening of Reggianito grating cheese, using both traditional ripening and in plastic wrapping. Food Qual and Pref 5:271-280.

Hunter EA, McEwan JA. 1998. Evaluation of an international ring trial for sensory profiling of hard cheese. Food Qual and Pref 9:343-354.

Janto M, Pipatsattayanuwong S, Kruk MW, Hou G, McDaniel MR. 1998. Developing noodles from US wheat varieties for the Far East market: sensory perspective. Food Qual Pref 9:403-412.

Johnson PB. 1986. A lexicon of peanut flavor descriptors. U.S. Dept. of Agriculture, Agriculture Research Service, ARS-52, 8 p.

Johnson PB, Civille GV. 1986. A standardized lexicon of meat WOF descriptors. J Sensory Stud 1:99-104.

Johnson PB, Civille GV, Vercellotti JR. 1987. A lexicon of pond-raised catfish flavor descriptors. J Sensory Stud 2:85-91.

Lawless HT, Claasen MR. 1993. Validity of descriptive and defect-oriented terminology systems for sensory analysis of fluid milk. J Food Sci 58:108-112, 119.

McBride RL, Hall C. 1979. Cheese grading versus consumer acceptability: an inevitable discrepancy. Aust J Dairy Technol 34:66-68.

Meilgaard M, Civille GV, Carr BT. 1997. Sensory Evaluation Techniques. 3rd ed. Boca Raton, Fla.: CRC Press, Inc. **387 p.**

Miller RG. 1980. Simultaneous Statistical Inference. 2nd ed. New York: Springer Verlag. 525 p.

Muir DD, Hunter EA, Banks JM, Horne DS. 1995. Sensory properties of hard cheese: identification of key attributes. Int Dairy J 5:157-177.

Muir DD, Hunter EA, Banks JM, Horne DS. 1996a. Sensory properties of Cheddar cheese: changes during maturation. Food Res Int 28:561-568.

Muir DD, Banks JM, Hunter EA. 1996b. Sensory properties of Cheddar cheese: Effect of starter type and adjunct. Int Dairy J 6:407-423.

Murray JM, Delahunty CM. 2000. Selection of standards to reference terms in a Cheddar-type cheese flavor language. J Sens Stud 15:179-199.

Nielson RG, Zannoni M. 1998. Progress in developing an international protocol for sensory profiling of hard cheese. Int J Dairy Technol 51:57-64.

Piggott JR, Mowat RG. 1991. Sensory aspects of maturation of Cheddar cheese by descriptive analysis. J Sens Stud 6:49-62.

Risvik E, Colwill JS, McEwan JA, Lyon DH. 1992. Multivariate analysis of conventional profiling data: a comparison of a British and a Norwegian trained panel. J Sens Stud 7:97-118.

Roberts AK, Vickers ZM. 1994. Cheddar cheese aging: Changes in sensory attributes and consumer acceptance. J Food Sci 59:328-334.

Suriyaphan O, Drake MA, Chen XQ, Cadwallader KR. 2001. Characteristic Aroma Components of British Farmhouse Cheddar cheese. J Agric Food Chem 49:1382-1387.

MS 20001541

Funding provided by Dairy Management Inc. and the Mississippi Agriculture and Forestry Experiment Station (MAFES). The authors are grateful to the companies and individuals that graciously donated cheese.

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