Impact of Flavor Attributes on Consumer Liking of Swiss Cheese

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ABSTRACT

Although Swiss cheese is growing in popularity, no research has examined what flavor characteristics consumers desire in Swiss cheese, which was the main objective of this study. To this end, a large group of commercially available Swiss-type cheeses (10 domestic Swiss cheeses, 4 domestic Baby Swiss cheeses, and one imported Swiss Emmenthal) were assessed both by 12 trained panelists for flavor and feeling factors and by 101 consumers for overall liking. In addition, a separate panel of 24 consumers rated the same cheeses for dissimilarity. On the basis of liking ratings, the 101 consumers were segmented by cluster analysis into 2 groups: nondistinguishers ($n = 40$) and varying responders ($n = 61$). Partial least squares regression, a statistical modeling technique that relates 2 data sets (in this case, a set of descriptive analysis data and a set of consumer liking data), was used to determine which flavor attributes assessed by the trained panel were important variables in overall liking of the cheeses for the varying responders. The model explained 93% of the liking variance on 3 normally distributed components and had 49% predictability. Diacetyl, whey, milk fat, and umami were found to be drivers of liking, whereas cabbage, cooked, and vinegar were drivers of disliking. Nutty flavor was not particularly important to liking and it was present in only 2 of the cheeses. The dissimilarity ratings were combined with the liking ratings of both segments and analyzed by probabilistic multidimensional scaling. The ideals of each segment completely overlapped, with the variance of the varying responders being smaller than the variance of the nondistinguishers. This model indicated that the Baby Swiss cheeses were closer to the consumers' ideals than were the other cheeses. Taken together, the 2 models suggest that the partial least squares regression failed to capture one or more attributes that contribute to

consumer acceptance, although the descriptive analysis of flavor and feeling factors was able to account for 93% of the variance in the liking ratings. These findings indicate the flavor characteristics Swiss cheese producers should optimize, and minimize, to create cheeses that best match consumer desires.

Key words: Swiss cheese, descriptive analysis, consumer liking, partial least squares regression

INTRODUCTION

Because the demand for Swiss cheese in the United States is growing (Sander, 2006), recent research has focused on the composition and quality of Swiss cheese (e.g., Jenkins et al., 2002; Jin and Harper, 2003; Rodriguez-Saona et al., 2006). However, the basis of this demand is not well understood and, although extensive research has been done on the flavor characteristics of Cheddar cheese (e.g., Drake et al., 2001, 2005; Young et al., 2004), relatively little research has examined the flavor characteristics of Swiss-type cheeses. No research has focused on what flavor characteristics consumers desire in Swiss cheese.

In the United States, Canada, and Australia, the term "Swiss cheese" is used to refer to several related varieties of cheese that resemble Emmenthal, a traditional cheese from Switzerland (Reinbold, 1972). Emmenthal is a medium-hard cheese, pale yellow in color, with characteristic large holes known as "eyes." Three types of bacteria (*Streptococcus thermophilus*, *Lactobacillus helveticus*, and *Propionibacterium freudenreichii*) are used in the creation of Emmenthal (Kosikowski and Mistry, 1997). American Swiss cheese is made by using the same bacteria and is similar in appearance to Emmenthal, although it often has a milder flavor (Reinbold, 1972; Kosikowski and Mistry, 1997). Baby Swiss curds are cooked to a lower temperature, using *Lactococcus lactis* and *P. freudenreichii* as the starter cultures, and are washed with water to slow bacterial action. Collectively, all these cheeses are referred to as "Swiss-type cheeses" (Kosikowski and Mistry, 1997).

Previous research has shown that changes in processing parameters used in the making of a Swiss

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Table 1. Characteristics of cheeses evaluated

Code	Cheese type	Manufacturing region	Milk treatment	Fat, %	Protein, %
B1	Baby Swiss	Midwest US	Pasteurized	32	24
B2	Baby Swiss	Midwest US	Pasteurized	30	24
B3	Baby Swiss	Midwest US	Pasteurized	30	25
B4	Baby Swiss	Midwest US	Pasteurized	34	23
E5	Emmenthal	International	Raw	31	26
S06	Swiss	Midwest US	Pasteurized	32	24
S07	Swiss	Midwest US	Thermalized	31	26
S08	Swiss	Midwest US	Pasteurized	32	24
S09	Swiss	Midwest US	Pasteurized	31	26
S10	Swiss	Midwest US	Pasteurized	30	25
S11	Swiss	Midwest US	Pasteurized	32	24
S12	Swiss	Midwest US	Thermalized	29	26
S13	Swiss	Northeast US	Thermalized	30	26
S14	Swiss	Northeast US	Thermalized	30	26
S15	Swiss	Northeast US	Thermalized	31	26

cheese can influence the flavors of the resultant cheese. Bastian et al. (1997) demonstrated that plasmin activity influenced the ripening process, which in turn altered the perceived propionic acid flavor. In addition, indigenous microflora and pasteurization were demonstrated to alter the aroma intensity and pungency of Swiss-type cheeses (Beuvier et al., 1997). Lawlor et al. (2003) found that changing the rate of acidification in the vat or changing the ripening temperature when making Swiss-type cheeses influenced their nutty and sweet flavors.

Although these studies provide insight into the flavor characteristics of Swiss cheese and how production choices may modify these flavors, no work has examined what flavor characteristics consumers desire. Thus, the main objective of this research was to relate consumer liking of Swiss cheese to its specific flavor characteristics. To this end, a large group of commercially available Swiss-type cheeses were assessed both by trained panelists for flavor and by consumers for overall liking. In addition, a separate consumer panel rated the same cheeses for dissimilarity. These 3 sets of information were combined to determine the flavor characteristics most desired by consumers. Although the focus of the research was to understand the preferences of US consumers for domestic Swiss cheeses, an imported Swiss Emmenthal and several domestic Baby Swiss cheeses were included for comparison.

MATERIALS AND METHODS

Samples

Fifteen retail cheeses were collected from member companies of the Swiss Cheese Consortium, including 10 domestic Swiss cheeses (S06 to S15), 4 domestic Baby Swiss cheeses (B1 to B4), and 1 imported Swiss Emmenthal (E5), which served as a point of reference. As summarized in Table 1, domestic cheeses were from

the Midwest and Northeast regions of the United States and were produced with either pasteurized or thermalized milk, whereas the imported Swiss Emmenthal was produced with raw milk. Fat and protein contents of all the cheeses were quite similar (see Table 1). In accordance with the main objective of this study, the 10 Swiss cheeses were chosen to represent a wide range of flavor characteristics typical of Swiss cheeses in the Midwest and Northeast regions of the United States, whereas Baby Swiss cheeses and Emmenthal cheese were included for purposes of comparison.

Approximately 15 kg of each cheese was obtained. Cheeses were vacuum-packed in the manufacturer's original packaging, and package size varied from 2- to 15-kg blocks. To handle variation among samples, the cheeses were cut into uniform 2-cm cubes. Cubes with large eyes were discarded. For serving, 2 cubes at approximately 10°C were placed into a 1-oz (~30 mL) translucent plastic soufflé cup (Solo Cup Co., Urbana, IL) labeled with a neutral 3-digit number.

Panelists

Descriptive Analysis. Twelve panelists trained in the Spectrum method, each having at least 100 h of descriptive analysis experience with cheese flavor, evaluated the samples at North Carolina State University.

Consumer Liking. A total of 101 untrained consumers (48 male and 53 female, ages 18 to 65) were recruited via intercept from the lobby of the Parker Food Science & Technology Building on the Columbus campus of The Ohio State University. Panelists were selected based on willingness to assess "Swiss cheese." Because this investigation was focused on US domestic Swiss cheese, liking of imported Emmenthal was not a preselection requirement for participants, nor was "Emmenthal" mentioned to participants. Collected demographics indicated that 35% of these consumers ate Swiss-

Table 2. Swiss cheese descriptive analysis lexicon, adapted and modified from the Cheddar cheese lexicon¹

Descriptor	Definition	Reference
Cooked/milky	Aromatics associated with cooked milk	Skim milk heated to 85°C for 30 min
Whey	Aromatics associated with Cheddar cheese whey	Fresh Cheddar whey
Diacetyl	Aromatic associated with diacetyl	Diacetyl
Milk fat	Aromatics associated with milk fat	Fresh coconut meat, heavy cream, δ -dodecalactone
Vinegar	Aromatics associated with vinegar	Distilled white vinegar, acetic acid
Dried fruit	Aromatics associated with dried fruits, specifically peaches and apricots	Dried apricot half
Fruity	Aromatics associated with different fruits	Fresh pineapple, ethyl hexanoate
Sulfur/eggy	Aromatics associated with cooked eggs	Hard-boiled egg (mashed)
Sulfur/cabbage	Aromatics associated with cooked cabbage	Boiled cabbage, dimethyl trisulfide
Cheesy/butyric acid	Aromatics associated with butyric acid	Butyric acid
Brothy	Aromatics associated with boiled meat or vegetable stock	Canned potatoes, Wyler's low-sodium beef broth cubes, methional
Nutty	The nutlike aromatic associated with different nuts	Lightly toasted unsalted nuts, unsalted cashew nuts, unsalted Wheat Thins
Sweaty	Aromatic associated with human sweat	Hexanoic acid
Cow/phenolic	Aromas associated with barns and stock trailers, indicative of animal sweat and waste	Band-Aids, <i>p</i> -cresol, phenol
Sour	Fundamental taste sensation elicited by acids	Citric acid (0.08% in water)
Bitter	Fundamental taste sensation elicited by various compounds	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)
Umami	Chemical feeling factor elicited by certain peptides and nucleotides	Monosodium glutamate (1% in water)
Prickle	Chemical feeling factor of which the sensation of carbonation on the tongue is typical	Soda water
Metallic	Chemical feeling factor elicited by metallic objects in the mouth	Aluminum foil

¹Drake et al. (2001).

type cheeses at least once a week and 73% ate Swiss-type cheeses at least once a month.

Consumer Perception of Dissimilarity. Twenty-four untrained panelists (9 male and 15 female, ages 18 to 45) were recruited via e-mail from the Department of Food Science & Technology at The Ohio State University. Panelists were selected based on availability and willingness to assess Swiss cheese.

All 3 groups (descriptive analysis, consumer liking, and consumer dissimilarity) evaluated the same cheeses during the same time period (April 2004). The number of panelists in each group was consistent with standard sensory science practices (Meilgaard et al., 1999).

Procedure

Descriptive Analysis. The descriptive analysis of Swiss cheese flavor was conducted at North Carolina State University in compliance with institutional human subjects regulations. Panelists used a previously developed cheese flavor sensory language (Drake et al., 2001) adapted to Swiss cheese flavor and typical sensory science techniques (see Table 2). For assessment, panelists used a 15-point universal intensity scale in

accordance with the Spectrum method. With the universal scale, panelists score intensities in the same manner across all attributes and all products. Advantages to this approach are that one panel can be readily trained on multiple products, different types of products can be directly compared, and panel scaling is less prone to drift with time (Drake and Civille, 2003).

Consistent with Spectrum descriptive analysis training, panelists were presented with reference solutions of sweet, sour, salty, and bitter tastes to learn to use the universal intensity scale consistently (Meilgaard et al., 1999). Following consistent use of the Spectrum scale with basic tastes, panelists learned to identify and scale flavor descriptors by using the same intensity scale through presentation and discussion of flavor definitions, references (Table 2), and a wide array of cheese types, including Swiss-type cheeses. Discussion and evaluation of a wide array of cheeses were also conducted during training to enable panelists to differentiate and replicate samples consistently. Analysis of data collected from training sessions confirmed that panel results were consistent and that terms were not redundant, consistent with previous use of the developed language (Drake et al., 2001). Cheeses were evaluated monadically in triplicate in a randomized balanced

block design. Evaluations were conducted individually on paper ballots in booths dedicated to sensory analysis and free from external aromas, noise, and distractions. Panelists were instructed to expectorate samples after evaluation. Spring water (Ice Mountain Water Co., Hilliard, OH) was available to each panelist for palate cleansing.

Consumer Liking. The Office of Responsible Research Practices at The Ohio State University approved all methods and procedures. Panelists evaluated samples individually in separate booths and entered their own responses directly into a computer by using Compusense five data collection and analysis software (version 4.6, Compusense Inc., Guelph, Ontario, Canada). Panelists were allowed to swallow or expectorate samples, as desired; retasting was allowed; and each panelist proceeded at his or her own pace. Room-temperature spring water was provided for rinsing.

Panelists began by giving informed consent for participation. Subsequently, a tray containing 15 samples was presented. Panelists were instructed to evaluate the samples in the order indicated on the computer screen and to rate each sample for overall liking on a 9-point vertical hedonic category scale. The order of samples was counterbalanced across panelists.

Consumer Perception of Dissimilarity. As in the consumer liking panel, all methods and procedures were preapproved before testing began. Also as before, panelists evaluated samples individually, were allowed to retaste samples, were allowed to either swallow or expectorate samples, proceeded at their own pace, and entered their own responses by using Compusense. Room-temperature spring water was again provided for rinsing.

Subsequent to giving informed consent, a tray containing 15 pairs of samples was presented. Panelists were instructed to evaluate the pairs in the order indicated on the computer screen and to rate the dissimilarity of the samples in each pair on a 15-cm continuous horizontal line scale that went from "identical" to "totally different." The scale was sectioned into 3 equal intervals with tick marks labeled "somewhat similar" and "somewhat dissimilar," going from left to right. The order of pairs was counterbalanced across panelists, as was the order of samples within a pair.

Every panelist followed the same procedure over 4 sessions, with sessions being separated by one day. The 60 pairs assessed for dissimilarity were chosen from the 105 possible pair combinations based on a cyclic design (see Figure 1), which generates a partially balanced incomplete block design (Jarrett and Hall, 1978). The use of a cyclic design allows for the testing of a representative set of sample pairs in a systematic fashion when it is not feasible to test every possible pair

(Malhotra et al., 1988). One cycle was presented in each session.

Statistics

Descriptive Analysis. Descriptive data were evaluated by a series of one-way repeated-measures ANOVA, followed by Fisher's least significant difference, when appropriate, to ascertain specific differences between cheeses. Analyses were conducted by using SAS (version 9.1, SAS Institute Inc., Cary, NC).

Consumer Liking. Liking ratings were analyzed by using repeated measures ANOVA and Tukey's honestly significant difference post hoc comparison to determine whether there were significant differences in liking between the samples. Analyses were conducted with Statistica (version 7.1, StatSoft Inc., Tulsa, OK).

Cluster Analysis. Cluster analysis is an exploratory statistical technique used to group data into segments or categories based on shared characteristics. Consumers were segmented based on liking ratings of the Swiss cheeses by using cluster analysis (complete linkage, city-block distance). Analysis was conducted with Statistica.

Partial Least Squares Regression. Partial least squares regression (PLSR) attempts to model the variance in Y (overall liking) that can be explained by the variance in X (descriptive attributes). Using attribute means from the descriptive analysis data and liking means from the consumer liking data, PLSR was conducted with XLStat (version 2006.5, Addinsoft, New York, NY).

Probabilistic Multidimensional Scaling. Probabilistic multidimensional scaling (pMDS) attempts to estimate "ideal" products based on consumer responses to similar products. Using liking ratings of the products and dissimilarity ratings between pairs of products, pMDS was performed with ProScaL (version 4.5, www.proscal.com) for S-PLUS (version 6.0 for Windows, Insightful Corporation, Seattle, WA). The consistent Akaike's information criterion, or CAIC, a statistic that evaluates the complexity of the pMDS model, was used to choose the model that best fit the data (MacKay and Zinnes, 2006).

RESULTS AND DISCUSSION

Descriptive Analysis

Analysis of variance and least significant difference of the descriptive analysis results indicated that the Swiss-type cheeses differed in their flavor profiles (see Table 3). In general, mean flavor intensities of Swiss cheeses were low, falling between 0 and 4. These intensities are typical for cheeses (Drake et al., 2001). In

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2	C1													
3		C1												
4	C3		C1											
5		C3		C1										
6	C4		C3		C1									
7		C4		C3		C1								
8	C2		C4		C3		C1							
9	C2	C2		C4		C3		C1						
10		C2	C2		C4		C3		C1					
11	C4		C2	C2		C4		C3		C1				
12		C4		C2	C2		C4		C3		C1			
13	C3		C4		C2	C2		C4		C3		C1		
14		C3		C4		C2	C2		C4		C3		C1	
15	C1		C3		C4		C2	C2		C4		C3		C1

Figure 1. Cyclic design used for consumer dissimilarity. Sample pairs marked by C1 were evaluated in session 1, C2 in sessions 2, and so on.

general, cheeses were characterized by low aroma intensities and relatively stronger intensities of sweet and umami; in all cases, sweet and umami intensities

of a cheese were higher than the aroma intensities of that cheese. Cooked/milky, milk fat, vinegar, and cabbage flavors were present in all assessed cheeses. In

Table 3. Mean values of descriptive analysis attributes for Swiss cheeses¹

Attribute	B1	B2	B3	B4	E5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	LSD ²
Cooked	1.1	1.2	1.5	1.7	1.0	1.8	1.3	1.1	1.2	1.0	1.2	1.4	1.3	1.4	1.2	0.3
Whey	1.0	ND ³	1.3	1.5	ND	1.3	1.2	ND	ND	ND	1.2	1.0	1.0	ND	1.2	0.3
Diacetyl	ND	ND	1.0	1.5	ND	1.8	ND	ND	ND	ND	1.1	ND	ND	ND	1.2	0.3
Milk fat	1.3	1.6	1.8	2.1	1.5	2.3	1.6	1.5	1.7	1.3	1.1	1.4	1.3	1.5	1.7	0.3
Vinegar	1.0	1.2	1.0	1.0	1.8	1.6	1.2	1.9	1.3	1.2	1.6	1.1	1.7	1.2	1.4	0.3
Dried fruit	ND	1.9	ND	ND	1.4	1.1	ND	1.2	ND	1.1	ND	1.0	1.2	1.3	1.0	0.4
Cabbage	1.5	2.0	1.3	1.4	2.5	1.9	1.9	2.0	1.6	2.0	1.9	2.2	1.6	1.9	1.9	0.3
Brothy	ND	1.0	ND	ND	1.1	ND	ND	ND	1.0	ND	ND	ND	ND	ND	ND	0.2
Nutty	ND	1.0	ND	ND	ND	ND	ND	ND	1.6	ND	ND	ND	ND	ND	ND	0.3
Sweaty	1.0	ND	ND	1.2	1.3	ND	1.2	1.4	1.0	1.5	1.2	ND	ND	1.0	ND	0.3
Bitter	1.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	— ⁴
Sweet	2.4	3.5	2.8	2.6	3.2	3.2	2.5	3.2	2.9	2.7	3.0	2.6	3.0	3.0	2.9	0.2
Umami	3.0	3.5	3.2	3.2	3.5	3.6	3.3	3.4	3.3	3.4	3.6	3.4	3.4	3.3	3.2	0.3
Prickle	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.2	ND	ND	ND	ND	—
Metallic	1.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	—

¹Baby Swiss cheeses (B1 to B4), Swiss Emmenthal (E5), and Swiss cheeses (S06 to S15). Attributes were scored on a 15-point universal Spectrum scale, where 0 = absence of the attribute and 15 = very high intensity of the attribute (Meilgaard et al., 1999). Attributes not shown in the table (fruity, sulfur/egg, butyric, cowy, sour, and salty) were not detected in any of the Swiss cheeses.

²Means in a row that differ by more than the LSD are different ($P < 0.05$).

³ND = not detected (i.e., the mean panel value was <0.5).

⁴A dash (—) indicates that ANOVA failed to indicate a significant difference for the attribute.

contrast, the other aromas assessed were detected in some cheeses but not in others. For example, both dried fruit and sweaty aromas were found in 9 of the 15 cheeses (although not the same 9). Brothy was found in only 3 of the cheeses, and nutty was found in only 2 cheeses (B2 and S09).

Contrary to the literature (e.g., Beuvier et al., 1997; Lawlor et al., 2003), nutty aroma and flavor were not prevalent in the Swiss-type cheeses assessed and were detected in appreciable intensities in only 2 of the 15 cheeses. This discrepancy may represent differences between domestic and international Swiss cheeses, but because no detectable nutty aroma was found in the imported Emmenthal, this seems unlikely. A more likely explanation is that in this study, unlike in previous studies, "nutty" was defined and anchored with physical standards (lightly toasted unsalted nuts, unsalted cashew nuts, and unsalted Wheat Thins; Avsar et al., 2004). In the studies by Beuvier et al. (1997) and Lawlor et al., (2003), nutty flavor was not defined by a specific reference. Without the use of physical or chemical references, the nutty concept may not have been consistent across studies, and was apparently inconsistent with the nutty concept defined and used in this study.

Differences in the intensity of attributes such as dried fruit, brothy, and sweaty could be due to a variety of manufacturing variables, including differences in starter cultures, holding temperatures and times, milk sources, and so on. The precise impact of each of these variables is beyond the scope of this study. During the training and calibration of the descriptive analysis panel, fresh fruit, sulfur/eggy, butyric, and cowy aromas were detected in commercial Swiss cheeses that were not detected in the 15 assessed cheeses, but it was not possible to specify how those cheeses differed from the assessed cheeses. As one would expect for Swiss-type cheeses, sour and salty tastes were not distinct in any of the cheeses evaluated. One Baby Swiss evaluated (B1) had a distinct bitter taste and metallic feeling. One Swiss evaluated (S11) had a distinct prickle feeling. There were no general distinguishing flavor characteristics of Baby Swiss cheeses compared with regular Swiss cheeses. The Emmenthal cheese was distinguished by a higher intensity of cabbage flavor compared with other Swiss cheeses. It may be tempting to attribute this difference to the fact that the Emmenthal was produced from raw milk and that the remaining cheeses were produced from pasteurized or thermalized milk. However, this would be a dangerous assumption, because any of a variety of processing conditions or their combination could have contributed to this noticeable flavor difference. Despite the absence of certain sensory attributes in the samples assessed and the fact that

the processing variables responsible for these differences are unknown, the samples assessed were varied enough in their characteristics for the primary objective of this investigation: to determine the flavor characteristics most desired by consumers.

Consumer Liking

Of the samples tested, there were minimal differences in liking, with only 5 of the 15 cheeses being rated significantly lower than the most liked sample (see Table 4). The 2 most liked samples, one Swiss (S11) and one Baby Swiss (B3), had average liking ratings equivalent to "like slightly" on the 9-point hedonic scale, and the 8 remaining samples (S06, S07, S10, S14, S15, B1, B2, and B4) had mean ratings of "neither like nor dislike." All 10 of these samples were rated significantly higher than S12, the least liked sample. Five samples (B3, S11, B1, S06, and B4) were rated significantly higher than the Emmenthal (E5), which was rated "dislike slightly" along with S09, S12, and S13. Mean liking for S08 was significantly lower than the 3 most liked samples and was not significantly different from the other 11 samples. All of the Baby Swiss samples were interspersed among the 10 liked samples, accounting for 4 of the 6 highest rated samples (see Table 4). Although the mean liking ratings might seem low, liking scores are generally specific for the product type or category evaluated. That is, high liking scores for a particular product or product category are not necessarily in the 7- to 9-point range on a 9-point scale. Young et al. (2004) conducted preference mapping with Cheddar cheeses, and consumer liking scores ranged from 5.7 to 7.2 on a 9-point scale. More recently, Yates and Drake (2007) noted consumer liking scores of 5.5 to 6.5 on a 9-point scale for a range of Gouda cheeses. The liking scores for the Swiss cheeses in this study are in general agreement with these other studies on cheeses.

PLSR

Using PLSR, we combined the descriptive and consumer liking data into a single analysis to determine which attributes had the greatest impact on liking of the cheeses. Flavor attributes that were either undetectable in the products (fruity, sulfur/egg, butyric, cowy, sour, and salty) or on which the products did not differ significantly (prickle and metallic) were excluded from the analysis. With a predictability of 24%, the initial model used 53% of the descriptive information to explain 93% of the liking on 3 normally distributed components (data not shown).

Cluster analysis (results not shown) identified 2 segments of consumers. One segment ($n = 40$) assigned similar hedonic ratings to all products (nondistinguish-

Table 4. Mean values of consumer liking for Swiss cheeses¹

Item	B3	S11	B1	S06	B4	B2	S07	S15	S10	S14	S08	S13	S09	E5	S12
Average	6.0	6.0	5.9	5.8	5.7	5.5	5.4	5.3	5.2	5.2	5.0	5.0	4.8	4.8	4.4
SD	1.7	1.8	2.1	2.0	2.2	2.2	1.6	1.7	2.0	1.8	2.0	2.0	2.0	2.2	1.9
Tukey's ²	a	a	a	ab	abc	abcd	abcd	abcd	abcd	abcd	bcde	cde	de	de	e

¹Baby Swiss cheeses (B1 to B4), Swiss Emmenthal (E5), Swiss cheeses (S06 to S15). Overall liking was scored on a 9-point hedonic category scale, where 1 = dislike extremely and 9 = like extremely.

²Cheeses with the same letter (a–e) do not differ in mean liking (Tukey's honestly significant difference, $P < 0.05$).

ers), whereas the second segment ($n = 61$) gave varied hedonic ratings to products, resulting in significant differences (varying responders). Because the purpose of the study was to determine drivers of product liking and because there were known differences among the products, only the latter segment of consumers was retained for subsequent analyses.

In a new model based on the responses of the varying responders, 56% of the modeled descriptive attribute ratings were used to explain 93% of the liking, and predictability increased to 29% (data not shown). However, B1 was poorly explained by the descriptive portion of the model. Statistical outlier analysis, which compares the distance of each sample from the model against a critical value, determined B1 to be an outlier because the distance between B1 and the model of explanatory variables was larger than the expected distance. This analysis does not reveal why B1 is an outlier, but examination of the descriptive attribute scores indicated that B1 was the only sample in this product set to contain detectable amounts of bitterness and metallic, and it is likely these unique features resulted in the sample's poor fit in the model. Removing B1 (and its unique attributes: bitter and metallic) from the model increased the use of included descriptive information to 65% and increased predictability to 49% while maintaining the ability to explain 93% of the liking on 3 normally distributed components.

In this third and final model (see Figures 2 and 3), the first component accounted for 50% of the variability in liking and was characterized by cabbage and brothly on the negative end and diacetyl and whey on the positive end. The second component, accounting for 28% of the variability in liking, was characterized by umami and prickle at the positive end with no definitive characteristic on the negative end. These findings indicate that diacetyl was the largest driver of liking (as exemplified by B4 and S06, 2 of the most liked cheeses) and that other positive drivers included whey, milk fat, and umami (which were higher in the better liked B3 and S11). Negative drivers included cabbage, cooked, and vinegar (which were higher in the less liked E5 and S08). Sample S06 was unique in that it contained both

diacetyl (a positive driver) and cooked (a negative driver). It was one of the better liked samples (Table 3), which suggests that diacetyl has a greater impact on liking than does cooked flavor. Nutty was the only characteristic that loaded highly on component 3 and, as indicated by its weak positive correlation with liking, it was not a driver of liking or disliking for these consumers.

pMDS

The pMDS estimates “ideal” products from consumer responses of dissimilarity between pairs of products and liking of those products (MacKay and Zinnes, 2006). Whereas PLSR can be used to determine what measured attributes or instrumental measures are predictive of consumer acceptance, pMDS relies entirely on consumer assessments. One difficulty that can arise with PLSR is that it can build its model only from the measured attributes and instrumental measures that were provided. This means that if consumers are responding to an aspect of the products not captured by these measures, the resulting model may be low in predictability. Because pMDS relies purely on consumer assessments, it is impossible to inadvertently leave out such a measure. However, the disadvantage of pMDS is that it can be difficult to determine what attributes are determining liking without examining the measured attributes and instrumental measures. Another advantage of pMDS over PLSR is that, as a probabilistic model, it can separate variance from means in the model (for a more detailed explanation of probabilistic models, see Delwiche, 2007). Finally, pMDS can model multiple ideals when more than one market segment exists.

In this instance, cluster analysis indicated 2 market segments (nondistinguishers and varying responders). Furthermore, because the descriptive analysis assessments focused on flavors, characteristics that may have been important to consumers, such as texture and appearance, were not captured in the PLSR. Thus, pMDS was conducted to gain additional insight into the factors that drive consumer acceptance of Swiss-type cheeses.

Figure 2. Partial least squares 1 (PLS1) and PLS2 of the partial least squares regression product map (excluding outlier B1) for varying responder segments ($n = 61$). Diacetyl, whey, milk fat, and umami were drivers of liking; cabbage, cooked, and vinegar were drivers of disliking. Samples B2 to B4 are Baby Swiss cheeses, E5 is Swiss Emmenthal, and S06 to S15 are regular Swiss cheeses.

By using the CAIC criterion (MacKay, 2005), the best fit model (shown in Figure 4) for this data was an isotropic Euclidean space (which is depicted by circles) with unequal variances across products and ideals (which is depicted by different circle sizes). Because the cluster analysis indicated 2 consumer segments, these segments were entered into the model and one ideal was derived for each. As shown in Figure 4, although these 2 ideals overlapped in the product space, their variances differed. This difference in variance supports the existence of 2 different market segments. Specifically, the ideal for the varying responders (IDEAL1) had less variance than the ideal for the nondistinguishers (IDEAL2). The larger variance found for the group of nondistinguishers reflects the reality

that their ideal was less defined and that a greater range in sensory properties would be equally accepted by this group. For both segments, the ideals fell within the boundaries of sample B1 and overlapped with the boundaries of the other Baby Swiss samples. The ideal of the varying responders had less overlap with the Emmenthal and other regular Swiss cheeses, with the exception of S6, to which this segment gave relatively high hedonic ratings. The ideal of the nondistinguishers overlapped with more of the other cheeses, suggesting that varying profiles would be equally accepted, but it is not known whether this consumer segment simply found the cheeses to be equally acceptable or whether they were less sensitive to the differences between the cheeses.

Figure 3. Partial least squares 1 (PLS1) and PLS3 of the partial least squares regression product map (excluding outlier B1) for varying responder segments ($n = 61$). Diacetyl, whey, milk fat, and umami were drivers of liking; cabbage, cooked, and vinegar were drivers of disliking. Samples B2 to B4 are Baby Swiss cheeses, E5 is Swiss Emmenthal, and S06 to S15 are regular Swiss cheeses.

The perceptual space mapped by PLSR (Figures 2 and 3) was different from that mapped by pMDS (Figure 4). This was expected because B1 was removed from the PLSR but not from the pMDS. Recall that B1 was removed from the PLSR model because it was an outlier from the descriptive information. Because the calculations in pMDS are independent of the descriptive ratings, B1 was not removed for this latter analysis. In PLSR, proximity to overall liking suggested that S06 and B4 were the closest to the ideal (Figure 2). Similarly, pMDS also indicated that S06 and B4 were quite close to the ideal, but in this analysis, B1 was the closest to the ideal. Given its hedonic rating, it is not surprising that B1 was closest to the ideal. It appears that in this

instance, pMDS was able to provide additional insight beyond what could be determined from PLSR. Taken together, these findings suggest that B1 was high in some desirable aspect that was not measured in the descriptive analysis, given its poor fit to the model of descriptive variables and the fact that it did not contain detectable levels of diacetyl, a predicted driver of liking. The descriptive analysis focused on flavor and feeling factors, whereas the consumer assessments of dissimilarity were based on all relevant perceptual characteristics, which could have included flavor, feeling factors, texture, appearance, or other differences. It seems probable that B1 had a highly desirable characteristic that was not measured in the descriptive analysis, which

Figure 4. Probabilistic multidimensional scaling product map (isotropic with unequal variances) of all 15 cheeses with 2 ideals, one for each consumer segment (IDEAL1 for varying responders, and IDEAL2 for nondistinguishers). Variance is depicted by the size of the circle, with circle size increasing with variance.

raised its hedonic score and influenced its distance from the ideal in pMDS despite the fact that it was an outlier in its flavor characteristics in PLSR.

CONCLUSIONS

Overall, the 15 cheeses evaluated were differentiated by 15 of 21 descriptive attributes. Partial least squares regression indicated that diacetyl, cabbage, cooked, whey, milk fat, umami, and vinegar were most important to liking, with diacetyl, whey, milk fat, and umami being positively correlated with liking and cabbage, cooked, and vinegar being negatively correlated with liking. The pMDS suggested that the Baby Swiss samples were closest to the consumer ideals, and this seemed to be due to a combination of flavor, feeling factors, and other characteristics not measured by the trained panel, possibly texture or appearance. These findings further suggest that liking of Swiss-type cheeses was driven largely, but not entirely, by differ-

ences in flavor, and suggest which flavors appealed to more consumers. According to the model, processing decisions that minimize cabbage, cooked, and vinegar and enhance diacetyl, whey, milk fat, and umami will result in a Swiss cheese with the widest consumer appeal.

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