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Preference mapping: relating acceptance of “creaminess” to a descriptive sensory map of a semi-solid

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Abstract

Creaminess is used by consumers to describe the texture of many food products. The overall objective of this study was to investigate the underlying sensations to the acceptance of textural creaminess. Eight puddings varying in thickness, mouthcoating, rate of melt and smoothness were developed by altering the amount and type of starch, amount of milk-fat and amount of sodium salts. Puddings were evaluated by descriptive analysis for appearance, texture and flavor characteristics. Concurrently, consumers evaluated the puddings for “liking of creamy texture”. Sensory descriptive data were subjected to principal component analysis, resulting in a multidimensional product space that was related to the consumer acceptance data using the AUTOFIT selection strategy. More than 90% of consumer responses were selected and validated by AUTOFIT. A dimension related to thickness seemed important to consumer acceptance of creamy texture. In general, hedonic scores for creamy texture were higher for samples that were smoother and had more dairy flavor, although, hedonic scores for creamy texture varied considerably on dimensions related to dairy flavor and smoothness. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

“Creamy” is a term often used by consumers to describe the appearance, flavor or texture of food products (Howe, 1993). More specifically, creaminess is used to describe the texture of a broad array of products including peanut butter, soup, and most dairy products. The perception of a product’s textural creaminess may be affected by the removal of, or reduction, of fat due to changes in the viscosity, rate of disappearance, and spreadability/pourability (Hegenbart, 1993; Timms, 1994). Understanding textural “creaminess” has become more important with heightened awareness of fat content and demand for low-fat and fat-free products.

Fats are a common ingredient in foods due to their desirable influence on flavor, texture and appearance (Drewnowski, 1987). Fats are specifically associated with textural creaminess that may be related to acceptability of many products (El-Gharby & Lawless, 1994; Kokini & Cussler, 1987; Szczesniak, 1987).

Although creaminess is a descriptor for many food products, our understanding is limited. Creamy was defined by Jowitt (1974) as a mouthfeel characteristic “possessing the textural property producing the sensation of the presence of a miscible, thick, smooth liquid in the oral cavity”. Civille and Lawless (1986) expanded the description of “creamy” not only to depend on smoothness and thickness, but also a fatty mouthfeel.

Wood (1974) investigated the effect of a wide range of starches and gums on the creamy and slimy mouthfeel of soup. Using a quantitative descriptive panel of 25–30 respondents, he observed that perceived creaminess increased rapidly when the viscosity was between 50 centipoise (cps) and 70 cps. Above 70 cps, the sensory response continued to increase, but at a slower rate. In general, he concluded that a “creamy” soup was completely smooth with viscosity above 50 cps and had some degree of sliminess.

Kokini and Cussler (1983) investigated the relationship of “creaminess” with “smoothness” and “thickness” as

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assessed by small, untrained panels. The panel used magnitude estimation to evaluate the creaminess, thickness and smoothness of 14 liquid and semi-liquid foods. These foods varied from skim milk to cream to frozen orange juice. Based on their work, perceived creaminess could be predicted ($R^2 = 0.81$) using scores of perceived thickness and smoothness. Although this suggests that thickness and smoothness are key to the perception of creaminess, they are not all-encompassing.

Daget (1987) and Daget & Joerg (1991) used a panel of 15 trained panelists to investigate the perception of creaminess of caramel creams and cream soups, respectively. Besides panel evaluations, the samples were submitted to various viscometric measures. The panel evaluated the perceived creaminess and thickness, and their liking for consistency of the samples. For both systems, as perceived creaminess increased, viscosity (measured instrumentally) increased and the flow index behavior decreased.

Although a standard definition for creaminess and a method of measuring it may not be readily apparent from the literature cited, it appears that thickness and smoothness are characteristics common to the definition and are independent of the samples evaluated. Previous research has several areas for improvement. First, to use trained instead of untrained panelists for descriptive analysis and second, to use descriptive analysis to evaluate parts of an integrated term, creaminess.

The basis of descriptive analysis is that the human sensory system is sensitive and able to gather information about stimuli. We assimilate this information using one or both of the following processeses: data driven (bottom-up) and conceptual driven (top-down) (Matlin & Foley, 1992). Descriptive techniques rely on the bottom-up process, tapping into the process after the parts have been recognized. To obtain objective information of perceived sensory sensations, a panel must be carefully selected and trained. In particular, the training must focus on overcoming the obstacles of topdown processing. This includes selecting motivated and interested individuals, but also providing an environment free of distractions that would hinder the subject from completing the task. This subsequently alters how an individual perceives a food (Lawless & Claasen, 1993; O'Mahoney, 1995; Ross, 1995; Roukhkian, 1995).

Using descriptive analysis techniques, trained panelists characterize and describe the intensity of the sensory characteristics of food (Heymann, Holt & Steff, 1993; Meilgaard, Civille & Carr, 1987; Stone & Sidel, 1993). The resulting information has been used to evaluate the effect of ingredient substitutions or process improvements on a product, or to identify the sensory characteristics that differentiate a given product from competing products. The relationship of these sensory characteristics to consumer responses is often of interest. While the human sensory system is quite sensitive, consumers often have difficulty articulating the nuances of a product's characteristics. Collecting sensory profiles from consumers is accepted and practiced frequently. If practiced, it assumes the following: (1) attributes selected are relevant to *each* consumer; (2) Attributes relevant to *each* consumer have been included and (3) meaning of the attributes are clear (Steenkamp, Trijp & Ten Bergue, 1994). Therefore, while one may request consumers to provide sensory profiles of products, integrating consumer evaluations with descriptive data may provide additional insight.

Preference mapping provides valuable information about each consumer's response in a visual format (MacFie & Thomson, 1988). Preference information for each consumer participating in a study is presented within a multidimensional space representing the products evaluated (Kuhfeld, 1995). The resulting perceptual map provides a clear presentation of the relationship among the products and the individual differences in preference by consumers for these products. If the same information were presented in tables, understanding the key features of the products and their relationship to acceptance would be much more difficult. Thus, the visual format of the product set aids in interpreting how product characteristics affect consumer responses.

Preference mapping will be used to relate sensory characteristics of vanilla pudding to consumer responses. With this methodology consumers hedonically evaluate products, while sensory profiles of the same product set are concurrently developed by a descriptive panel. The resulting descriptive data is decomposed using a multivariate technique such as principal component analysis (PCA). This reduces the number of sensory dimensions required to describe the product set. Individual consumer scores are then integrated into the sensory space by regressing each consumer's response onto the coordinates obtained from PCA. Since the data analysis is on an individual not aggregated level, the shortcoming of traditional product testing that assumes liking to be similar across individuals may be overcome (Greenhoff & MacFie, 1994).

2. Methods

2.1. Materials

Preliminary qualitative research (Howe, 1996) with individuals who consume pudding on a regular basis suggested pudding was considered "creamy" in texture. The consensus was that a creamy pudding was smooth, thick, slow to melt, and adhesive. Preliminary descriptive evaluations (Howe, 1996) of JELL-O® instant vanilla pudding indicated that the thickness, mouth coating, rate of melt, and smoothness was affected by the milk-fat content level. Eight puddings were developed by altering the amount and type of starch, amount of milkfat, and amount of sodium salts. The amount of food coloring was also altered in an attempt to maintain a more constant yellow color across samples. The samples were chosen to represent a range of perceived smoothness and thickness as summarized in Table 1. The rate of melt, adhesion, and denseness were also felt to vary in these samples. The formulas for the eight samples are located in Table 2. All raw ingredients, except dairy products, were obtained from various ingredient suppliers (Table 3) and stored at room temperature until use. Fluid milk from the same dairy with the same "sell-by" date was used within each session. Due to the extensive duration of the product evaluations, the same "sell-by" date was not used for all sessions.

Each batch was approximately 1400 g. Each formula, except sample 6, was prepared in the manner described here. All dry ingredients were combined and double sifted with a Fairgrove 5 Cup Sifter (Aluminum Housewares Col., Inc., Maryland Heights, MO). The wet ingredients (milk, half-and-half, Myvacet 9-45) were weighed and transferred to a mixing bowl (Cuisinart®, East Windsor, NJ 08520). The wet ingredients were mixed (power "on") in the Cuisinart® Food Processor for approximately 15 s while the dry ingredients were added. Approximately 30 g of pudding were immediately dispensed into 2 ounce plastic souffle containers (Solo® Cup Co., Urbana, 111) labeled with random 3-digit codes, capped and stored at 4°C until served.

Table 1
Formulated characteristics of pudding samples

Sample ID	Thickness	Fat content	Smoothness
1	Mid	Mid	Smooth
2	Mid	High	Smooth
3	Mid	Low	Smooth
4	Thin	Mid	Smooth
5	Thick	Mid	Unsmooth
6	Mid	Mid	Unsmooth
7	Thin	High	Smooth
8	Thin	Low	Smooth

Sample 6 contained unmodified corn starch and could not be prepared in the same way as the other samples because the shearing of the food processor appeared to minimize the desired unsmooth characteristic that was to be represented by this sample. Instead, the wet ingredients were mixed with a wire whisk in a large bowl while the dry ingredients were added. Mixing continued for approximately 30 s or until the mixture was homogeneous. Dispensing of the samples was the same as with the other samples.

Preliminary evaluations (Howe, 1996) indicated that the visual, flavor and textural sensory characteristics of instant vanilla pudding refrigerated 5–20 h remained unchanged. Therefore, the puddings were prepared approximately 5 h prior to the first scheduled evaluation, but no more than 20 h before the last.

2.2. Sensory method

2.2.1. Descriptive panel

Descriptive analysis was conducted by 11 University of Missouri-Columbia faculty, staff and students. They were selected based on their previous experience on pudding descriptive panels and/or availability and willingness to participate. Panel training and product evaluations were completed over a period of 5 weeks. Prior to training, panelists completed a consent form. The

Table 2
Ingredients (%) for the pudding samples

	Sample identification							
Ingredient	1[a]	2	3	4	5	6	7	8
Sugar	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Salt	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
TSP	0.5	0.5	0.5	–	0.5	0.5	–	–
DSP	0.3	0.3	0.3	–	0.3	0.3	–	–
NFDM	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vanilla powder	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Coloring	0.3	0.4	0.25	0.3	0.3	0.4	0.4	0.05
Vanilla custard flavor	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Modified starch	3.5	2.63	3.5	3.5	4.2	–	3.5	3.5
Unmodified starch	–	–	–	–	–	3.5	–	–
Myvacet 9–49	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Wholemilk	82	–	–	82.8	78.7	–	–	–
1% milk	–	20.7	82	–	–	61.4	62.0	–
Half-and-half	–	62	–	–	–	61.4	62.0 3	–
	100	100	100	100	100	100	100	100

[a] Sample 1 = warmup.

Table 3
Pudding ingredients

Ingredient	Source
Sugar (Imperial pure cane sugar, Baker granulated, 100 lb. bag, #41Q1)	International Distributing Corporation, St. Louis, MO
Salt (star flake dendritic salt)[a]	Morton Salt, Chicago, IL
TSP (tetrasodium pyrophosphate, food grade powder)[a]	FMC Corporation, Philadelphia, PA
DSP (disodium phosphate, food grade powder)[a]	FMC Corporation, Philadelphia, PA
NFDM (agglomerated instant NFDM, #21931)[a]	Land O Lakes, Inc., Minneapolis, MN
Vanilla powder (pure "k", #WG05, sample #42001)[a]	Virginia Dare, Brooklyn, NY
Vanilla custard flavor (vanilla flavor artificial, custard type, #DY03390)[a]	Quest International, Owings Mill, MD
Modified starch (7721–554, #00010960)[a]	National Starch and Chemical Co., Bridgewater, NJ
Unmodified strach (721–551, #00009406)[a]	National Starch and Chemical Co., Bridgewater, NJ
Myvacet 9–45 (distilled acetylated monoglycerides, lot#D1819–0794)[a]	Eastman Chemical Company, Kingsport, TN
1% Milk	Schnuck's, Columbia, MO
Whole milk	Schnuck's, Columbia, MO
Half-and-half	Schnuck's, Columbia, MO

[a] Denotes donated by source.

eight samples were presented in five 1-h training sessions. During the first session, two samples were presented and a list of terms describing the products' sensory characteristics were generated. In two subsequent sessions, the remaining six samples were presented (three new samples in each session) and a tentative score sheet was introduced to orient panelists to the test protocol. During these two sessions, judges focused on identifying terms that discriminated among the samples and began defining terms previously generated. Judges reached consensus on 22 appearance, texture, and flavor terms and definitions (Table 4) to describe the samples in the fourth training session. Two products were informally evaluated with the final score sheet during the fifth training session to verify consistent use of terms.

The 22 attributes were scored on a 16.1 cm unstructured line scale that had verbal anchors at both ends. Evaluations were completed in temporary booths with fluorescent overhead lighting. For each session, all eight samples were presented monadically in random order following the evaluation of a warmup sample (Sample 1). Panelists cleansed their palates with Culligan® Sodium Free Drinking Water (Culligan® Water, Columbia, MO) and unsalted crackers prior to each sample evaluation. All samples, water and crackers were expectorated. Five minute breaks were taken after the third and sixth sample evaluation.

2.2.2. Consumer panel

Seventy-five adult consumers (18–65 years in age) participated in this study. Respondents were chosen if they were accepting of vanilla flavored pudding and willing to participate. Respondents were recruited to a central location to participate in one of three sessions. This room provided ample space and overhead fluorescent lighting for up to 24 panelists. Upon arriving, respondents checked in and completed a consent form. Respondents were then given an orientation to the test protocol before initiation of product evaluations.

Table 4
Definitions of attributes used in descriptive analysis of puddings

Yellow color: The yellow color from pale to bright yellow
Evenness: The evenness of distribution of the color (i.e not blotchy, mottled, swirled)
Surface shine: Amount of light reflected from the product's surface
Opaque: The degree to which one can NOT see into the sample from not opaque (translucent) to very opaque (can NOT see into)
Product surface: Amount of bumps/lumps on product surface
Airy: The appearance of whipped air (like marshmallow creme)
Thickness: The viscosity or readiness of flow (visual evaluation)
Thickness: The viscosity or readiness to flow (evaluated by manipulation in the mouth)
Denseness: The compactness of the sample from airy to compact
Smooth: The absence of detectable particles from gritty to smooth. Evaluated by pushing the sample to the roof of the mouth
Rate of melt: The shortness of duration of the sensation of substance from slow to quick melt
Mouth coating: The amount of residual "feel" on the mouth surface and teeth with the tongue after the product has been expectorated
Vanilla flavor: The intensity of vanilla flavor
Dairy flavor: The intensity of dairy flavor from fresh milk
Sweet flavor: The intensity of sweetness
Nonfat dry milk (NFDM/cooked milk): The intensity of NFDM or cooked milk
Pudding mix: The intensity of flavor associated with dry vanilla pudding mix or raw cake batter
Vanilla aftertaste: The intensity of vanilla flavor upon expectorating the sample
Dairy aftertaste: The intensity of diary flavor from fresh milk upon expectorating the sample
Sweet aftertaste: The intensity of sweetness upon expectorating the sample
NFDM aftertaste: The intensity of NFDM/cooked milk upon expectorating the sample
Mouth drying: Amount of mouth drying upon expectorating the sample

Samples were evaluated for liking of creamy texture using the nine-point hedonic scale (1 = dislike extremely, 9 = like extremely). Therefore, future references to acceptance, hedonic ratings or preference are all relative to the hedonic evaluation of creamy texture. The first sample evaluated was a "warmup" sample (formulation of Sample 1). This sample was used to orient the respondent to the task while providing a frame of reference against which subsequent judgements may be made (Foley, 1995), thus minimizing potential first order bias (Fletcher, Heymann & Ellersieck, 1991; Vickers, Christensen, Rahenholtz & Gengler, 1993).

Data for the "warmup" sample were not analyzed. Including the "warmup" sample, nine samples were evaluated sequentially in a single session. Respondents were instructed to cleanse their pallets with Culligan® Sodium Free Drinking Water (Culligan® Water, Columbia, MO 65202) and unsalted crackers before each sample evaluation, and set their own pace for the evaluations. Expectoration of the samples, water and unsalted saltine crackers was optional.

Following the final sample evaluation, each respondent completed a "background information questionnaire". This questionnaire included demographic (i.e. age and sex) and product usage information (i.e. brands, variety and frequency of usage). The duration of the session varied by consumer, lasting from approximately 30 to 60 min.

2.3. Experimental design

2.3.1. Descriptive analysis

A completely randomized block design was used for both the descriptive and consumer evaluations. For the descriptive evaluations, all eight samples were evaluated in each of five sessions (replications) by each judge. Consumers evaluated each sample once in a single session.

2.4. Statistical techniques

2.4.1. Descriptive data

A digitizer (Sigma Scan™ Scientific Measurement System version 1.10, Jandel Scientific, Corte Madera, CA) was used to measure the distance from the left end of the unstructured line scale to the mark made by the panelist. The resulting descriptive data of the 11 panelists who completed all five replications were analyzed by one way multivariate analysis of variance (MANOVA) using SAS® (1989) with samples (puddings) as main effect. This analysis suggested a significant multivariate effect for samples and the data were subsequently analyzed by three-way analysis of variance (ANOVA) with main effects of judge, sample and replication and all two-way interactions using the PROC ANOVA procedure of SAS® (1989). Least significant differences (LSDs) were used to separate the means when the main effect was significant. LSDs were calculated by SAS® at 95% confidence level. Characteristics which did not significantly discriminate among the samples were eliminated from subsequent analyses.

Principal component analysis was performed on the correlation matrix of the mean attribute scores averaged across judges for the characteristics which significantly discriminated among the samples. A quartimax rotation was completed using the PROC FACTOR procedure in SAS®. The plot for samples was averaged across replicates to aid in interpretation among attributes and samples.

2.4.2. Consumer panel

Consumers' ratings of the puddings were analyzed by PROC GLM in SAS® (SAS, 1989). The samples' means were calculated and separated using the LSMEANS procedure in SAS®.

2.4.3. Integration of descriptive and consumer panel data

Individual consumer scores for liking of creamy texture were integrated into the sensory space by regressing each consumer's response onto the coordinates obtained from PCA. With this research, the number of samples (degrees of freedom) statistically limited the models that could be considered (McEwan, 1996). Eight samples were evaluated and three sensory dimensions were of interest to incorporate into the model(s). Therefore, regressing each respondent's acceptability score (Y_i) onto the first 3 principal components (X_1, X_2 and X_3) resulted in three possible preference models as shown below:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3$$
(vector model)
$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + c\left(X_1^2 + X_2^2 + X_3^2\right)$$
(circular model)
$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + c_1X_1^2 + c_2X_2^2 + c_3X_3^2$$
(elliptical model)

The AUTOFIT selection strategy was used to decide which model best fit the consumers' responses into the sensory space (Schlich, 1995). This selection strategy is composed of two series of *F*-tests. The first series selected the best model for each consumer, testing a full versus a reduced model ($p \leq 0.15$). The basis of this test is the fact that the models are nested models. The selected model was subsequently validated with a second series of *F*-test ($p \leq 0.30$) used to determine if the selected model fits the data adequately.

Possible patterns of consumer responses were investigated using cluster analysis. Parameter estimates of the models selected and validated were used as input for clustering consumer responses. The FASTCLUS procedure in SAS® (SAS, 1989) was used to create two and three clusters solutions. The CANDISC and DISCRIM procedures in SAS® were subsequently used to study the resulting clusters.

3. Results and discussion

3.1. Sensory map

MANOVA was performed on the 22 descriptive attributes. This analysis revealed a significant multivariate effect for sample (Wilks' lambda = 0.99, $F_{8,10715} = 15.15$; $p = 0.0001$). Therefore, ANOVA with fixed main effects (sample, judge and replicate) and all 2-way interactions were computed on each individual descriptive attribute. The re-analysis was completed to investigate which attributes significantly differentiated among the samples. Random effect *F*-values were calculated for all attributes with significant "judge∗pudding" and "replicate∗pudding" interactions. Based on the ANOVA results and random effect *F*-values, 16 of the 22 attributes significantly discriminated among the samples at a 95% confidence level (Table 5). Attributes which did not significantly discriminate among the samples were flavor and aftertaste attributes: vanilla, NFDM/cooked milk and pudding mix flavor, and vanilla, NFDM and mouth drying aftertaste. These attributes were eliminated from further analyses.

Data from the 16 attributes which discriminated among the samples were subjected to PCA. Only the first three components had eigenvalues larger than 1 indicating they should be retained. The results of the scree plot also suggested that the first three components be retained. Therefore, the first three components were retained for rotation. Principal component 1 (PC1) accounted for 50% of the total variance, whereas PC2 and PC3 explained 18 and 13%, respectively. Combined, components 1, 2 and 3 accounted for 81% of the total variance.

To assist in intepreting the dimensions, the factor pattern was rotated. Varimax and quartimax rotations were completed. The correlations between the sensory attributes and corresponding factor loadings of the three-dimensional solution were almost identical. The factor loadings of the quartimax rotated dimensions are presented in Table 6. Using guidelines provided by Stevens (1992) to inspect for significance of attribute loadings, an attribute was considered to load heavily on a given component if the factor loading was greater than 0.72. A total of 13 attributes loaded heavily on the three dimensions. The loadings of yellow color, opaque appearance and smoothness of the product surface, while not necessarily low, did not meet Stevens' guidelines.

Nine of the sensory attributes loaded heavily on the first component, indicating strong correlations of these attributes with PC1. Airy appearance, thickness (visual and oral), denseness and mouth coating were positively loaded on the first PC, while surface shine, rate of melt,

Table 5
Means[a] and least significant difference (LSD) values for the pudding descriptive analysis

	Sample identification								
Attribute	1	2	3	4	5	6	7	8	LSD
Yellow color[b]	7.1c	2.0e	12.9a	6.2c	8.8b	3.5d	3.5d	2.7de	0.99
Evenness[b]	11.4abc	11.0bc	12.6a	10.9bc	10.6bc	3.8d	10.2c	11.6ab	1.34
Surface shine[b]	8.6d	7.2e	10.3bc	13.0a	8.7d	9.5cd	10.9b	14.1a	1.14
Opaque[b]	13.6ab	14.3a	11.2d	11.3d	13.1bc	13.1bc	12.4c	8.4	0.91
Product surface[b]	6.7d	9.0c	8.0c	12.2a	8.3c	10.5b	10.4b	10.7b	1.25
Airy[b]	12.6a	12.2a	9.5b	3.3e	11.7a	5.7c	3.4e	4.5d	1.06
Thickness[b]	13.3b	11.1c	11.6c	1.6e	14.3a	8.6d	2.2e	1.4e	0.83
Thickness (oral)[c]	13.0b	10.2c	10.8c	1.3e	14.9a	7.9d	2.2e	1.3e	0.94
Densness[c]	11.1b	7.9d	9.3c	5.7e	12.7a	7.6d	3.6f	2.8f	1.32
Smooth[c]	14.0a	13.9ab	13.0abc	13.9ab	13.1abc	7.4d	12.9bc	12.7c	1.08
Rate of melt[c]	4.2d	8.2b	7.1c	14.9a	3.2d	8.8b	14.7a	15.2a	1.12
Mouthcoating[c]	8.0b	7.8b	6.4c	3.3e	9.5a	7.8b	4.6d	3.0e	1.19
Vanilla[c]	7.7	9.2	7.4	9.4	8.1	8.5	9.2	8.5	–
Dairy[c]	7.1c	9.0a	5.2d	6.7c	6.8c	8.5ab	8.0b	5.0d	0.83
Sweet[c]	6.8c	7.1c	6.8c	9.3a	7.1c	6.9c	8.2b	9.1a	0.88
NFDM/cooked milk[c]	4.3	3.9	5.0	5.0	4.5	4.1	4.0	5.8	–
Pudding mix[c]	3.2	3.0	3.1	3.2	3.3	3.8	3.4	3.5	–
Vanilla[c]	5.6	6.9	4.8	6.1	6.2	7.1	7.4	5.6	–
Dairy[d]	4.6d	7.2a	3.3e	4.6d	4.8cd	6.3b	5.6bc	3.0e	0.86
Sweet[d]	4.6b	5.2b	4.3b	6.3a	5.1b	4.7b	6.2a	6.8a	0.96
NFDM[d]	3.6	2.7	4.1	3.6	4.0	3.0	3.0	3.9	–
Mouth drying[d]	6.5	6.6	6.4	7.9	6.9	6.9	7.8	7.6	–

[a] Means with the same letter are not significantly different from each other.

[b] Evaluated visually.

[c] Evaluated orally.

[d] Aftertaste evaluated after expectoration.

sweet flavor and sweet aftertaste were negatively loaded. A similar relationship between thickness and rate of melt, mouth coating and sweet flavor was observed by Solheim and Lawless (in press). Thicker pudding-like samples prepared with amylopectin melted slower, coated the mouth more and were perceived to be less sweet than thinner samples prepared with amylose and iotacarrageenan.

Inspection of the pattern of sample scores in Table 6 revealed that the sample formulated to be "thickest" had the largest sample score on the PC1, while the "thinner" samples had the smaller (negative) scores on this dimension. This PC contrasts thickness, airiness and mouth coating to melt-rate, surface shine and sweetness (flavor and aftertaste). These terms, except for sweetness, are all texture related, however, we cannot call the axis textural since PC3 is loaded heavily with smoothness (also a texture attribute). Therefore, we will refer to the combination of terms loading on PC1 as the consistency–sweetness axis.

Dairy flavor and aftertaste were loaded heavily on the second PC, which will be referenced as the dairy flavor component or PC2. Samples with the highest fat content had larger positive scores, while samples with the lower fat content had negative scores. Finally, evenness of color and smooth texture were loaded heavily on the third PC which will be referenced as the smooth component or PC3. Sample six containing the unmodified starch and high fat content had the most negative (less smooth) score.

Table 6
Percentage variance, variable loadings and sample scores[a] for three-factor principal component factors extraction and quartimax rotation for the decriptive evaluations

Parameter	PC1	PC2	PC3
Percentage variance	50	18	13
Loadings[b]			
Yellow color	0.48	−0.71	0.02
Evenness	0.01	−0.22	**0.92**
Surface shine	**−0.73**	−0.45	0.04
Opaque	0.63	0.64	0.01
Product shine	−0.60	−0.09	−0.51
Airy (visual)	**0.85**	0.02	0.21
Thickness (visual)	**0.99**	−0.03	0.04
Thickness	**0.98**	−0.05	0.04
Denseness	**0.89**	−0.19	0.01
Smooth	0.00	−0.07	**0.92**
Rate of melt	**−0.98**	0.09	−0.16
Mouth coating	**0.88**	0.21	−0.16
Dairy flavor	0.20	**0.92**	−0.08
Sweet flavor	**−0.82**	−0.09	0.10
Dairy aftertaste	0.22	**0.90**	−0.16
Sweet aftertaste	**−0.75**	0.00	0.05
Sample 1	0.51	−0.04	0.28
Sample 2	0.24	0.76	0.26
Sample 3	0.33	−0.74	0.11
Sample 4	−0.58	−0.09	0.11
Sample 5	0.58	−0.21	0.00
Sample 6	0.10	0.36	−1.0
Sample 7	−0.47	0.40	0.07
Sample 8	−0.71	−0.42	0.14

[a] Sample scores are averaged over replications.

[b] Factor loadings marked in bold indicate situations where the attribute loadings meet the criteria of significance (0.72$p = 0.01$).

While not meeting Steve's guidelines, opaque, product surface and yellow color were related to the retained dimensions. Both yellow color and opaque were loaded positively on PC1, while product surface had a negative score. Therefore, the more yellow and opaque samples with less surface bumps/lumps were generally thicker. Yellow color and opaque were also loaded on PC2. The loading was negative for yellow color and positive for opaque. As previously noted, the samples that loaded heavily on this dimension were relatively higher in fat, the fat caused the samples to be more opaque and less yellow. While an attempt was made to formulate samples to minimize the change in yellow color by altering the amount of food coloring, differences were still noted. The individual samples were plotted on the first three PCs (Fig. 1) using the factor loadings from Table 6. The eight vanilla puddings were clearly spread out on all three PCs, indicating that they varied considerably along all three dimensions in the perceptual space.

3.2. Consumer assessments

The mean hedonic scores for creamy texture of each sample are listed in Table 7. Significant differences were found. In general, liking of creamy texture was higher for the thicker than thinner samples, and samples containing more fat were liked more than those containing less fat. Individual consumer hedonic scores for creamy texture of the eight puddings were regressed against the first three PCs of the descriptive analysis.

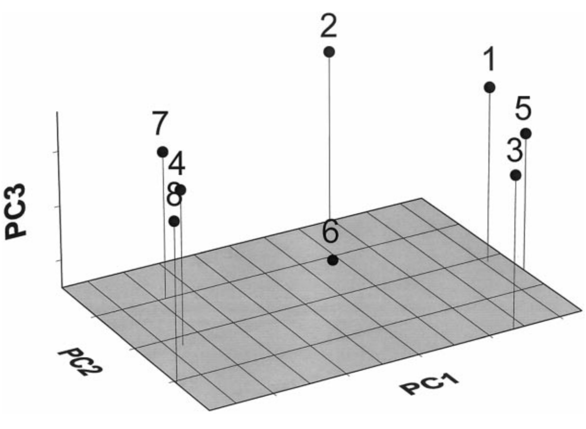

Fig. 1. Mean factor scores for samples after principal component analysis, with quartimax rotation.

3.3. AUTOFIT and preference mapping

More than 90% of the consumer responses were selected and validated by AUTOFIT. Table 8 shows the summary of the AUTOFIT results. Seventy per cent of the consumer responses were fitted by the vector model, while the others were fitted by the elliptical and circular model. The large number of responses validated by AUTOFIT may be due to several factors: (1) Consumer responses may have been directly related to the 16 sensory dimensions in the product space, (2) Small number of samples that would allow for overfitting the model, (3) A result of careful selection of the samples to vary on several product characteristics (thickness, fatty mouthfeel and smoothness) that created considerable variability along the three dimensions of the perceptual space influencing the hedonic rating of creamy texture. Preference mapping plots for the vector model were produced using the regression coefficients as coordinates showing the direction of increasing or decreasing consumer acceptability of creamy texture in relation to the sensory dimensions and the degree to which a consumer's response may be impacted by the sensory dimensions.

Figs. 2, 4 and 6 show the preference maps for individual consumers, two dimensions at a time. All but one consumer liked the creamy texture of samples with positive sample scores on the first PC as observed by positive regression coefficients. In general, most consumers appeared to like the samples that loaded heavily on the second and third PCs. Although, preferences for creamy texture varied considerably on these PCs.

Table 7
Mean consumer acceptance scores of puddings

Sample ID	Creamy texture	Standard deviation
1	6.8a	1.65
2	6.9a	1.99
3	6.0b	1.89
4	3.0d	1.69
5	6.4ab	2.14
6	3.8c	2.12
7	3.1d	1.94
8	2.1e	1.33

Table 8
AUTOFIT results of pudding data

Model	Selected[a]		Validated[b]	
	Frequency	Mean R^2	Frequency	Mean R^2
Vectorial	54	0.800	48	0.838
Circular	12	0.941	12	0.941
Elliptical	9	1.000	9	1.000
All models	75	0.846	69	0.877

[a] Significance level of model selection = 0.15.

[b] Significance level of model validation = 0.30.

Based on the cluster and subsequent discriminant analyses of the vectorial models, three clusters were identified for consumer responses fitting the vector model. The correlations of consumer response with the sensory dimensions and resulting average regression coefficients by cluster and average across all respondents are found in Table 9. Preference maps for the overall average response and average response by cluster are in Figs. 3, 5 and 7. The consumers in all of the clusters liked the creamy texture of samples that were loaded positively on PC1 and PC3 as observed by the positive regression coefficients for these dimensions. The relative weighting of the various dimensions differentiated the clusters of consumer response. Compared to the other clusters, attributes weighting heavily on PC1 and PC3 may be more critical to preference of creamy texture for cluster 3. The primary characteristic for preference of creamy texture for cluster 2 was PC1, while PC2 and PC3 appeared to play a minor role. Finally, preference for cluster 1 appeared to be influenced by a combination of all three PC's, as observed with similar weightings for the three dimensions.

Twelve consumers' responses were validated by the circular model. Six of these twelve had positive or negative ideal points (location $[X_1, X_2$ and $X_3]$ or response $[Y_i]$) outside the sample space tested. McEwan (1996) suggests that the vector model may be more

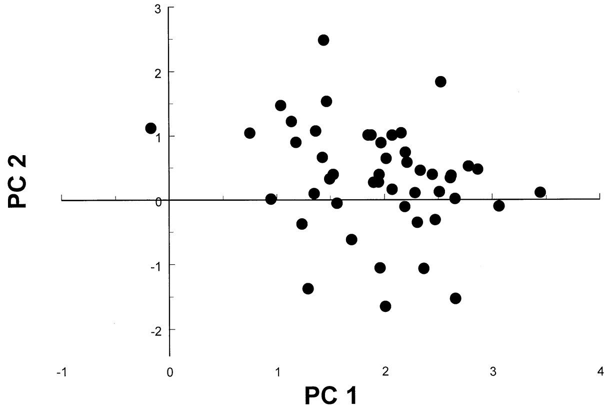

Fig. 2. Preference map of PC1 and PC2 for individual consumers modeled by the vector model and validated by AUTOFIT.

Table 9
Correlations and regression coefficients for vectorial models by cluster and average

Consumer	Mean R^2	Intercept (a)	b_1	b_2	b_3
Average ($n = 48$)	0.84	4.83	1.92	0.36	0.87
Cluster 1 ($n = 12$)	0.81	5.12	1.32	1.28	0.81
Cluster 2 ($n = 15$)	0.83	5.02	1.96	−0.36	0.20
Cluster 3 ($n = 21$)	0.86	4.57	2.28	0.31	1.38

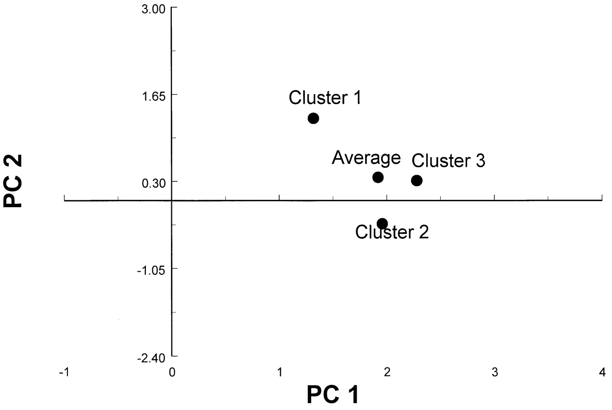

Fig. 3. Preference map of PC1 and PC2 for the overall average response and average response by consumer cluster for the vector model.

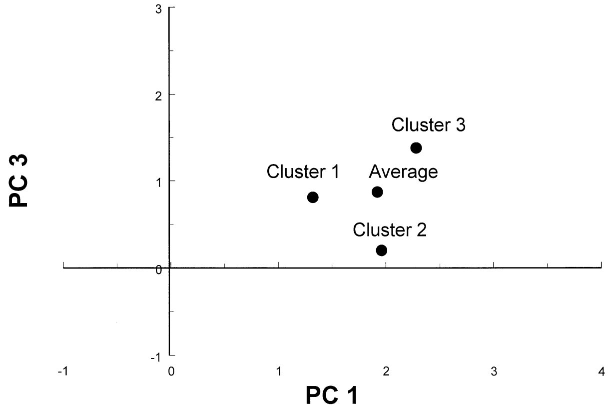

Fig. 5. Preference map of PC1 and PC3 for the overall average response and average response by consumer cluster for the vector model.

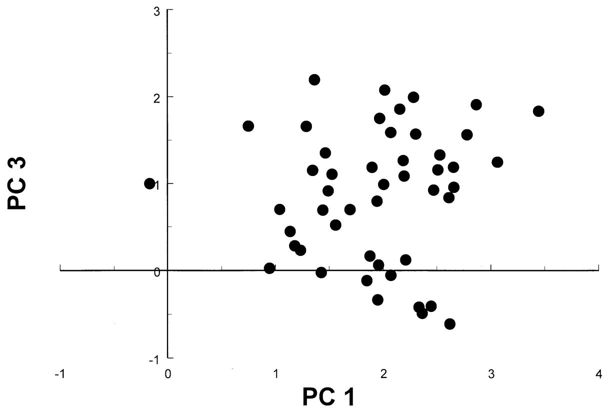

Fig. 4. Preference map of PC1 and PC3 for individual consumers modeled by the vector model and validated by AUTOFIT.

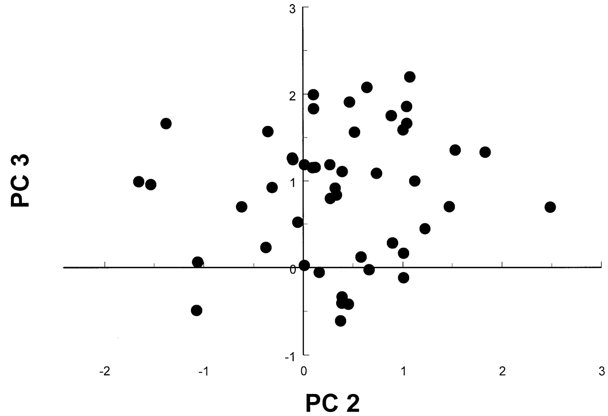

Fig. 6. Preference map of PC2 and PC 3 for individual consumers modeled by the vector model and validated by AUTOFIT.

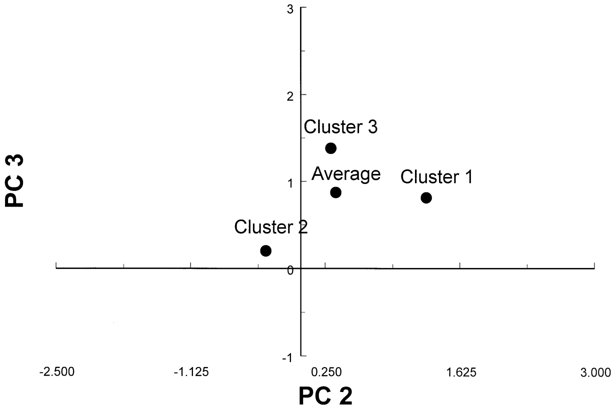

Fig. 7. Preference map of PC2 and PC3 for the overall average response and average response by consumer cluster for the vector model.

appropriate for these individuals. Of the remaining 6 models, 2 had negative ideal points, and 4 had positive ideal points. This suggests that 2 had a minimum and 4 had a maximum level of acceptance. Increasing or decreasing the intensity of the sensory dimensions around this point would result in decreasing or increasing acceptability, respectively. The locations of the maxima and minima were found throughout the product space (Fig. 8) on all three dimensions suggesting they preferred products with different sensory characteristics.

The AUTOFIT procedure selected and validated 9 consumers for the elliptical preference model. Only 1 model contained an ideal point within the product space tested.

As with previous research using a variety of food products, (Daget & Joerg, 1991; Daget et al., 1987; Kokini & Cussler, 1983; Wood, 1974) creaminess appears to be related to consistency (comprised of thickness, slow melt rate, denseness, mouth coating and visual airiness) and smoothness. Fatty mouthfeel was not identified as a dimension independent of smoothness or thickness as suggested by Civille and Lawless (1986). This might be because in the samples chosen fatty mouthfeel was not independent of the texture dimensions. It might also be due to fatty mouthfeel being highly correlated to smoothness in this system.

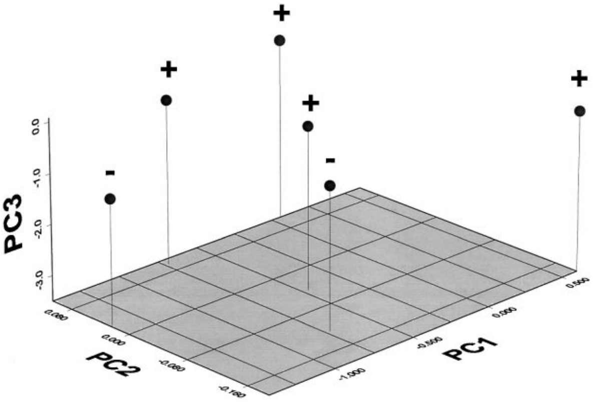

Fig. 8. Three dimensional preference map of consumers fitted by the circular model and validated by AUTOFIT. +indicates a positive ideal point and −indicates a negative ideal point.

Flavor and visual attributes have generally been ignored in previous research on the perception of textural creaminess. While the focus of this study was on the textural characteristics of the products, flavor and visual cues may have influenced consumers' hedonic ratings of creamy texture. Therefore, future research on creamy texture should acknowledge and possibly include flavor and visual cues.

Data analysis on creaminess has been completed on an aggregated level that assumed consumer behavior (i.e. liking of creamy texture) was homogenous. With this research, data analysis was completed on an individual level. While most of the consumers were best fit by the vector model, many were fit by the circular and elliptical models. These models suggest that a maximum or minimum level of response exists which contradicts previous research implying "more is better" (i.e. vector model). In aggregating consumer responses in prior research, this type of information may have been overlooked.

4. Conclusions

Sixteen sensory characteristics from the descriptive analysis significantly discriminated the eight samples. A low-dimensional display or product space was obtained through PCA. The samples were clearly separated along the three principal components of the low-dimensional display, indicating that the samples varied considerably along the dimensions in the product space. Eighty-one per cent of the total variance in the data was explained by the resulting product space.

Preference mapping provided insight into the sensory aspects that are important to individual consumer acceptability of creamy texture in vanilla pudding. The underlying sensations encompassing liking of "creaminess" of instant vanilla pudding appeared to be related to consistency, smoothness and dairy flavor. Consumers generally appeared to prefer thicker, more visually airy, more mouth coating, denser and slower melting samples. Hedonic responses varied considerably on the dairy flavor and smoothness dimensions. While the circular or elliptical model appeared to fit consumer responses to the sensory space, the vectorial model best fit most of the consumer responses. Flavor and visual attributes appeared to influence consumer's ratings. Therefore, future research on creamy texture should acknowledge and possibly include attributes other than those related to texture.

While this technique provided insight by providing a visual format to present differences by consumer, it may still be considered exploratory due to the nature of the products and analysis. To further confirm these findings and further investigate the importance of other attributes (i.e. flavor and appearance) additional testing is warranted to separate unresolved issues.

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