Preference Mapping of Commercial Chocolate Milks

J.L. THOMPSON, M.A. DRAKE, K. LOPETCHARAT, AND M.D. YATES

ABSTRACT: The dairy beverage market is a competitive and growing category in the food industry. Within this arena, chocolate milks vary widely in flavor, color, and viscosity. Understanding what sensory properties drive consumer liking is critical for maximum market share. This study was conducted to identify and define sensory characteristics of commercial chocolate milks and to link these differences to consumer preferences through the application of internal and external preference mapping. A sensory language was identified to document the sensory properties (visual, flavor, mouthfeel) of chocolate milks. Twenty-eight commercial chocolate milks were subsequently evaluated by descriptive sensory analysis using the identified sensory language. Thirteen representative milks were chosen for consumer acceptance testing followed by internal and external preference mapping to identify key drivers. Instrumental color and viscosity measurements were also taken. Two different techniques were used for external preference mapping: cluster analysis with generalized procrustes analysis and landscape segmentation analysis. Chocolate milks were differentiated by descriptive sensory analysis ($P < 0.001$). Wide variability was also observed in consumer acceptability of chocolate milks ($P < 0.001$). Correlations were observed among descriptive and consumer, descriptive and instrumental, and instrumental and consumer results ($P < 0.001$). Generalized procrustes analysis revealed 2 groups of consumers with 1 nondistinguishing driver of liking: cocoa aroma. Landscape segmentation analysis confirmed and clarified generalized procrustes analysis results by identifying 3 consumer segments with 3 drivers: cocoa aroma, malty, and cooked/eggy flavors.

Keywords: preference mapping, chocolate milk, milk, sensory analysis, acceptability

Introduction

Preference mapping is a commonly used tool in understanding the descriptive sensory attributes that drive consumer preferences (Schlich 1995; McEwan 1996). The procedure requires an objective characterization of product sensory attributes, achieved by descriptive analysis, which is then related to preference ratings for the product obtained from a representative sample of consumers (Murray and Delahunty 2000). Internal preference mapping uses only consumer data to determine consumer preference patterns, whereas external preference mapping relates consumer preference data to descriptive sensory information and/or instrumental data (Lawlor and Delahunty 2000). These techniques can guide product optimization and development (McEwan 1996). Both internal and external preference mapping techniques have been implemented in a number of studies with a variety of products (Hough and Sánchez 1998; Yackinous and others 1999; Richardson-Harman and others 2000; Young and others 2004).

The beverage market is a competitive and growing category in the food industry. Flavored milk beverages offer specific benefits including flavor and nutrition. School children are more likely to drink milk and reach dietary requirements when offered chocolate milk at school (Garey and others 1990). There has been limited research on chocolate milk itself. A recent study by the American Dairy Council and the American School Food Service Assn. revealed that offering flavored milks was 1 way to increase milk consumption among children (Anonymous 2003). Chocolate is the most popular milk flavor and represents a popular option among children and adults. Within this arena, commercial chocolate milks vary widely in flavor, color, and viscosity. With the recent growth in volume of flavored milk sold, attention is needed to improve existing chocolate milks and guide new product introductions (Boor 2001).

There have been numerous studies evaluating the sensory properties of plain fluid milk. Frost and others (2001) studied the sensory attributes of fat in milk and determined that a combination of thickener, whitener, and cream aroma in 0.1.% milk succesfully mimicked the sensory properties of 1.3% fat milk. Chapman and others (2001) developed a descriptive sensory lexicon for ultrapasteurized milk. Few studies have addressed the sensory properties and consumer perceptions of chocolate milk. Yanes and others (2002) studied the rheological and optical properties of chocolate milk. Chapman and others (1998) studied the effects of carrageen and chocolate on light oxidized flavor development and vitamin A degradation of milk. Hough and Sanchez (1997) conducted sensory work on laboratory formulations of powdered chocolate milks. Specific preferences varied widely between adults and children. In a subsequent study, again with laboratory formulations of powdered chocolate milk, the authors conducted descriptive analysis and preference mapping to more specifically pinpoint sensory properties of powdered chocolate milk liked by adults and children (Hough and Sanchez 1998). The purpose of this study was to identify the descriptive sensory properties of commercially available fluid chocolate milks and to identify consumer preferences by applying internal and external preference mapping techniques. These findings will be directly applicable to the dairy foods industry in the creation and reformulaion of chocolate milk to better meet consumer demand.

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Table 1—Chocolate milks used for descriptive analysis[a]

Code	% milkfat[b]	Packaging: Refrigerated/shelf stable
1	3.25	Refrigerated
2	**2**	**Shelf stable**
3	**2**	**Shelf stable**
4	2	Refrigerated
5	**1**	**Refrigerated**
6	3.25	Refrigerated
7	2	Shelf stable
8	1	Refrigerated
9	**3.33**	**Refrigerated**
10	**3.33**	**Refrigerated**
11	0	Refrigerated
12	**2**	**Refrigerated**
13	**0**	**Refrigerated**
14	1.04	Refrigerated
15	**2.92**	**Refrigerated**
16	**4.17**	**Refrigerated**
17	**2**	**Refrigerated**
18	3.33	Refrigerated
19	**2**	**Refrigerated**
20	3.75	Refrigerated
21	2.92	Refrigerated
22	3.75	Refrigerated
23	**3.25**	**Refrigerated**
24	**1**	**Refrigerated**
25	2	Shelf stable
26	1	Shelf stable
27	2	Refrigerated
28	3.25	Refrigerated

[a]Products in bold-faced type represent those used for consumer testing.
[b]Milkfat content determined from product label.

Table 2—Sensory language used in descriptive analysis of chocolate milk

Term	Definition	Reference
Cocoa Aroma	Aromatics associated with alkali processedcocoa	Hershey's Cocoa Powder
Cocoa flavor	Aromatics associated with alkali processed cocoa	Hershey's Hot Chocolate recipe (on box) using whole milk
Caramelized	Aromatics associated with caramelized milk products	Autoclave whole milk at 121 °C for 25 min
Coconut	Aromatics associated with fresh coconut	Shredded coconut
Cooked/Eggy	Aromatics associated with scalded milk products	Scald whole milk in microwave on high for 8 min
Malty	Aromatics associated with malted grain	Post® Grape-Nuts® cereal (12 g) soaked in 130 mL of skim milk
Milkfat	Aromatics associated with milkfat	Heavy cream
Stale/fatty	Aromatics associated with oxidized fat	(E,E)-2,4-decadienal 2 ppb in skim milk
Paperboard	Aromatics associated withcardboard/carton	Cardboard paper squares soaked in water overnight
Burnt/ sulfurous/ cabbage	Aromatics associated with burnt protein or sulfurous compounds	Cabbage leaf microwaved in plasticbag for 10 s, burnt black toast
Vanilla	Aromatics associated with pure bourbon extract vanilla	Bourbon extract vanilla
Vanillin	Aromatics associated with vanillin	Imitation vanilla extract
Sweet[a]	Fundamental taste sensation elicited by sugars	Sucrose (5% and 10%)
Astringent[a]	Chemical feeling factor producing a dry sensation	Tea solution (6 teabags soaked in 1 quart of hot water for 1 h)
Salty[a]	Fundamental taste sensation elicited by salts	NaCl (2%)

[a]References taken from Meilgaard and others 1999.

Materials and Methods

Chocolate milks descriptive analysis

A broad spectrum of commercial chocolate milks ($n = 28$) were selected based on fat content, pasteurization type, and availability (Table 1). All milks were purchased and evaluated by sensory and instrumental analysis well within the pull date provided on the packaging. All milks were also tasted by 2 highly experienced sensory panelists (each with more than 1000 h of experience with dairy products) before any testing to confirm that they were free of spoilage flavors. Sensory testing was conducted in compliance with the NCSU Institutional Review Board for Human Subjects approval. Eight panelists were selected based on interest, time available, and knowledge of dairy associated flavors. Each panelist (2 male, 7 female) had at least 60 h of previous training on sensory analysis of dairy products using the Spectrum™ descriptive analysis technique (Meilgaard and others 1999). Twelve 45-min training sessions were conducted to focus on sensory properties of chocolate milks. Flavor, texture, and color terms identified and selected by the panelists are listed in Table 2. Throughout training sessions, panelists evaluated and discussed chocolate milks to clarify descriptor concepts and to consistently scale product attributes. Analysis of data collected from training sessions confirmed that panel results were consistent and that terms were not redundant (Drake and Civille 2003).

Descriptive analysis was conducted by each panelist in quadruplicate on each milk in a randomized block design. Samples (30 g) were served in 59-mL plastic cups fitted with plastic lids (Sweetheart Cup Co., Owings Mills, Md., U.S.A.) and labeled with 3-digit codes. Samples were served at 4 ± 2 °C. Panelists evaluated 4 milks per session individually in an odor-free room dedicated to sensory analysis. Ambient temperature spring water was available for palate cleansing. Based on descriptive sensory data including chocolate flavor, sweet taste, and color ranking, and principle component analysis, a total of 13 milks that represented the entire sensory space were selected for consumer evaluation.

Consumer testing

Thirteen milks were evaluated across 4 d with a constant control milk presented each day. The constant control milk presented all days was selected from descriptive analysis results based on its moderate flavor/texture/color intensities to reduce the sample testing bias that could be associated with testing across multiple days. Three milks plus the control milk were evaluated each day. Milks (60 mL) were dispensed into 5-oz clear plastic cups (Sweetheart Cup Co.) numbered with 3-digit codes. Milks were presented individually in a randomized balanced order (following presenta-

Table 3—Consumer attribute means for selected chocolate milks[a,b,c]

Trt	OA	OFL	OTL	CI	CIL	CF	CFL	ST	STL	T	TL
2	4.7e	4.3fg	5.8de	8.1a	5.8cd	6.7bc	4.8e	5.8efg	4.9d	6.1d	5.4ghi
3	4.2f	4.0g	5.0g	6.2f	5.8cd	5.3f	4.2fg	5.3gh	4.5e	5.2e	5.0l
5	4.6e	4.3fg	5.2fg	4.9g	5.8cd	5.0f	4.5ef	4.9h	5.0d	4.8f	5.1hi
9	5.3d	5.4de	5.8de	8.2a	5.5de	7.7a	5.5cd	6.9a	5.5c	7.0a	5.7defg
10	4.4ef	4.0g	5.5ef	3.7h	4.5f	4.1g	3.9g	5.5fg	4.8de	5.4e	5.4fgh
12	5.9c	5.8cd	6.3bc	7.8bc	6.1bc	6.4cd	5.8c	6.4bc	6.0b	6.4cd	6.3bc
13	5.2d	5.1e	5.8de	8.0ab	5.3e	6.0de	5.4d	5.9de	5.5c	6.0d	5.8def
15	4.7e	4.5f	5.7e	3.6h	4.4f	4.5g	4.4efg	5.7efg	4.9d	5.4e	5.6efg
16	6.9a	6.8a	6.7ab	7.3de	6.9a	7.8a	6.8ab	6.9a	6.6a	6.9ab	6.5ab
17	6.4b	6.3ab	6.4abc	7.6cd	6.9a	7.5a	6.3b	6.7ab	6.2b	6.5bc	6.3bc
19	5.8c	5.6d	6.1cd	6.5f	6.4b	5.9e	5.5cd	5.7ef	5.7bc	6.6bc	5.9cde
23	6.9a	6.8a	6.8a	7.1e	7.1a	7.1b	6.8a	6.5bc	6.7a	6.5c	6.7a
24	6.2bc	6.1bc	6.3c	3.8h	5.2e	5.0f	5.5cd	6.1cd	6.1b	5.4e	6.1bcd

[a]Means in a column followed by different letters represent significant differences ($P < 0.05$).
[b]Consumer acceptability or perceived intensity scored on a 9-point hedonic scale in which 1 = dislike extremely or low intensity and 9 = like extremely or high intensity.
[c]CF = chocolate flavor intensity; CFL = chocolate flavor liking; CI = color intensity; CIL = color intensity liking; OA = overall acceptability; OFL = overall flavor liking; OTL = overall texture/mouthfeel liking; ST = sweet taste intensity; STL = sweet taste intensity liking; T = mouthfeel/thickness; TL = mouthfeel/thickness liking; Trt = treatment. Codes are given in Table 1.

tion of the constant control milk). White lighting was used in all booths. Consumer (n = 120 each day) were recruited through personal communication, paper flyer advertisements, and e-mail invitations. Consumers were screened for allergies before tasting. Consumers were provided spring water for palate cleansing between samples. Consumers were provided with consent forms consistent with North Carolina State Univ. Human Subjects approval, screener forms, and a scoring ballot. Demographic information and chocolate milk consumption habits were polled. Each consumer evaluated each milk for overall liking, overall flavor liking, overall thickness/mouthfeel liking as well as the perceived intensity and liking, respectively, of color, chocolate flavor, sweet taste, and thickness/mouthfeel on a 9-point hedonic scale with 9 = "high intensity/like extremely" and 1 = "low intensity/dislike extremely." Consumers received a food treat and earned points toward a gift certificate for participation.

Instrumental measurements

Instrumental color and viscosity values were determined for the 13 milks selected for consumer testing. Color (L^*, a^*, b^*) was measured in duplicate on each milk using a Hunter Colorimeter, Spectrogard Color System Model 96 (BYK Gardner, Silver Spring, Md., U.S.A.). Viscosity measurements were determined using a Brookfield Digital Viscometer Model LVTDV-1 (Brookfield Engineering Laboratories, Stoughton, Mass., U.S.A.) with spindle nr 21 at 30 r.p.m. Measurements were taken in duplicate at 5 °C.

Statistical analysis

Univariate and multivariate statistical methods were used in analyzing the results. Descriptive and consumer data were analyzed individually and then together. Analysis of variance with means separation and principal component analysis (PCA) was used to analyze the descriptive data (SAS, version 8.2, Cary, N.C., U.S.A.). Frequency histograms of consumer results were created and investigated for each attribute to determine whether bimodal distributions occurred. Analysis of variance with means separation was then conducted. Correlation analysis was conducted on descriptive and consumer data individually and together to determine linear relationships. Possible nonlinear relationships between consumer and descriptive attribute intensities were visually assessed using scatterplots. Instrumental data were analyzed using analysis of variance with least square means separation. Linear correlations between instrumental values and corresponding descriptive and consumer attributes were also explored.

Two external preference mapping techniques, Two-step Cluster Analysis (TCA) followed by Generalized Procrustes Analysis (GPA) (TCA/GPA) and Landscape Segmentation Analysis (LSA) followed by TCA (LSA/TCA) were performed to classify consumers and identify drivers of acceptance of chocolate milks. TCA/GPA was conducted by segmenting consumers using acceptance scores of the 13 milks by TCA. Then, the overall acceptance profiles of segments identified were used to select the 8 most significantly different samples in overall acceptance scores between the identified segments. The raw acceptance scores of the 8 milks within each segment were subjected to GPA with the attribute means from descriptive analysis (Young and others 2004) LSA unfolds an acceptance space and estimates individual ideal locations in the space. Vectors of descriptive attributes are then overlaid on the acceptance space with significant linear correlations (at 95% confidence level) between the orders of samples projected on the vectors and the attribute–mean orders generated by descriptive analysis to determine drivers of acceptance. Consumers were segmented by TCA on their ideal points estimated by LSA. Density of individual ideal points per unit area on the unfolded space was shown by contour (the darker the color, the higher the density) (Ennis and others 1988; Ennis and Johnson 1993; Ennis 2003; Ennis and Anderson 2003). In all cases, TCA was performed using Log-likelihood as a distance measure and the number of segments was automatically determined using the combination of changes in Akaike's Information Criterion (AIC) and the greatest changes in the distance when clusters were divided sequentially (Banfield and Raftery 1993; Chiu and others 2001; Anonymous 2004). Discriminant analysis (DA) with cross-validation confirmed and determined final segmenation of the TCA solutions with at least 95% correct allocation. LSA and GPA were performed using IFProgram® version 7.6 (Institute of Perception, Richmond, Va., U.S.A.), and Sensetools® version 2.3.28 (OP&P, Utrech, the Netherlands), respectively. TCA and DA were performed using SPSS® version 11.5 (Chicago, Ill., U.S.A.).

Results and Discussion

The 28 commercial chocolate milks were differentiated using the identified descriptive language ($P < 01$) (Figure 1 and 2). Four principal components (PCs) described 72% of the variability. Based on Eigenvector loadings, PC1 differentiated chocolate milks by their chocolate aroma and chocolate flavor intensity (loading ≥ 0.4). Meanwhile, PC2 was characterized by caramel, cooked/eggy, and stale flavors and sweet taste and color intensitity positively loading and malty flavor negatively loading. PC3 was described by vanillin flavor, salty taste, and astringency, and PC4 consisted of coconut and milkfat flavors. There was wide variability in the sensory character of chocolate milks, even in chocolate flavor and aroma. Distinct intensities of stale/fatty, astringency, and burnt flavors were observed in the 4 shelf stable milks (treatments 3, 7, 25, 26). Consumers also displayed wide variability in overall acceptability as well as other consumer attributes for the chocolate milks (Table 3), indicating that consumers can also discern distinct differences in flavor and texture/mouthfeel. Instrumental measurements likewise confirmed differences in color and viscosity of the milks (Table 4).

Some linear correlations were noted among descriptive terms (Table 5). Many of these correlations were expected. For example, chocolate flavor and chocolate aroma were positively correlated. Similarly, burnt flavor and cooked/eggy flavor, both flavors indicative of high heat treatment of milk, were also positively correlated. Likewise, correlations were also noted among the consumer attributes evaluated (Table 6). Overall acceptability was correlated with flavor liking, texture liking, chocolate flavor liking, and sweet taste liking. Consumer perception of chocolate flavor intensity and sweet taste intensity were not correlated to overall liking, nor were color liking or intensity. These results suggest that high chocolate flavor, high sweetness, or dark color do not necessarily drive consumer liking. Instrumental viscosity and trained panel viscosity were significantly correlated ($P < 0.01$; $r = 0.72$). However, consumer perception of mouth thickness and instrumental viscosity were not correlated ($P > 0.01$), nor were consumer perception of mouth thickness and descriptive panel viscosity (Table 7). Although consumers did determine differences among the milks in thickness (Table 3), perception of thickness was not directly related to descriptive or instrumental viscosity. This consumer attribute was not positively correlated with any descriptive attribute ruling out the possibility that some other positive attribute such as milkfat or chocolate aroma or flavor influenced consumer perception of mouth thickness. Instrumental color measurement and descriptive panel color data were negatively correlated in L* ($P < 0.01$; $r = –0.80$) and b* ($P < 0.01$; $r = –0.67$) values. Correlations between consum-

Table 4—Instrumental color and viscosity means[a]

Trt	*L**	*a**	*b**	Viscosity (cP)
2	48.6h	9.99ab	11.6de	35.1e
3	59.7bcd	9.59abc	15.2a	39.9d
5	57.7de	8.77bcd	13.8ab	17.3h
9	42.6i	10.6a	11.5e	59.1a
10	61.7abc	8.1cde	14.9a	22.5g
12	53.6fg	7.8de	9.25f	50.1c
13	47.5h	6.5e	7.57g	31.8f
15	63.1ab	7.9de	12.0cde	24.9g
16	56.9def	10.1ab	13.2bc	53.7b
17	52.6g	10.2ab	12.2cde	24.1g
19	59.1cde	8.68bcd	13.1bcd	55.5b
23	56.2ef	9.77abc	13.7ab	50.6c
24	63.4a	6.94e	12.6bcde	30.7f

[a]Means in columns followed by different letters represent significant differences ($P < 0.05$). Trt = treatment. Codes are given in Table 1.

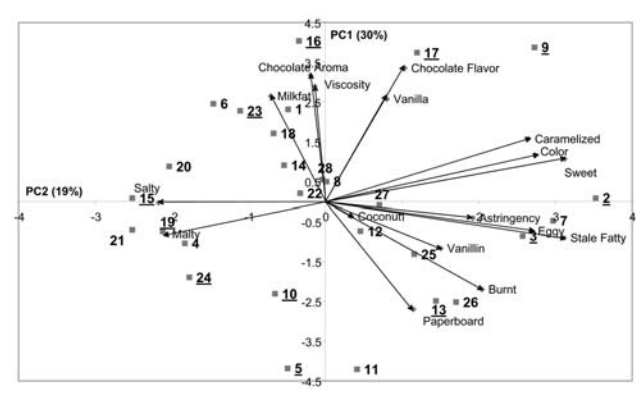

Figure 1—Principal component biplot of descriptive sensory analysis of chocolate milks. Numbers represent chocolate milks. Underlined numbers are those chosen for consumer testing. PC1 = principal component 1; PC2 = principal component 2.

Table 5—Correlations among descriptive terms[a,b]

	CA	CF	Van	Vani	Car	Eggy	PB	Coc	MF	M	S/F	Burnt	Sw	Sa	Astr	Color	Visc
CA	1.00	**0.84**	–0.27	**0.55**	0.30	–0.30	**–0.52**	–0.30	0.44	–0.12	–0.27	**–0.66**	0.24	–0.13	–0.12	0.36	**0.54**
CF		1.00	–0.31	**0.60**	**0.52**	–0.02	**–0.54**	–0.17	**0.60**	–0.24	–0.12	–0.41	0.39	–0.02	0.10	0.45	**0.71**
Van			1.00	**–0.50**	–0.06	0.06	0.15	**0.55**	–0.11	–0.20	0.02	0.21	0.29	–0.45	–0.23	0.23	–0.18
Vani				1.00	**0.50**	–0.15	–0.41	–0.21	0.35	–0.06	0.06	–0.26	0.29	–0.04	0.16	0.23	**0.45**
Car					1.00	0.28	–0.19	0.28	0.27	0.08	0.39	0.00	**0.51**	–0.14	0.19	0.14	0.27
Eggy						1.00	0.16	0.11	0.05	–0.25	**0.63**	**0.58**	0.02	0.16	0.24	0.07	0.09
PB							1.00	–0.23	0.72	0.18	0.38	0.39	–0.07	–0.03	0.41	0.00	**0.58**
Coc								1.00	0.34	0.12	0.03	0.20	0.15	–0.08	–0.26	–0.30	0.03
MF									1.00	–0.18	–0.11	–0.32	–0.06	0.26	–0.22	–0.08	0.84
M										1.00	–0.32	0.06	–0.14	0.35	0.03	–0.43	–0.26
S/F											1.00	0.38	0.07	–0.17	0.27	–0.02	–0.15
Burnt												1.00	0.01	0.12	0.39	0.00	–0.35
Sw													1.00	**–0.56**	0.12	**0.50**	0.08
Sa														1.00	0.32	–0.35	0.35
Astr															1.00	0.26	0.00
Color																1.00	0.18
Visc																	1.00

[a]Numbers in bold represent significant correlations ($P < 0.001$).
[b]Astr = astringent; CA = chocolate aroma; Car = caramelized; CF = chocolate flavor; Coc = coconut; M = malty; MF = milkfat; PB = paperboard; Sa = salty; SF = stale-fatty; Sw = sweet; Van = vanillin; Vani = Vanilla; Visc = viscosity.

Table 6—Correlations among consumer responses[a,b]

	OA	OFL	OTL	CI	CIL	CF	CFL	ST	STL	T	TL
OA	1.00	**0.99**	**0.96**	0.12	0.61	0.52	**0.96**	0.72	**1.00**	0.59	**0.97**
OFL	—	1.00	**0.95**	0.15	0.57	0.55	**0.96**	**0.78**	**0.99**	0.64	**0.96**
OTL	—	—	1.00	0.18	0.53	0.55	**0.93**	**0.77**	**0.95**	0.67	**0.98**
CI	—	—	—	1.00	0.49	**0.83**	0.38	0.43	0.15	0.69	0.17
CIL	—	—	—	—	1.00	0.63	0.71	0.32	0.60	0.47	0.55
CF	—	—	—	—	—	1.00	0.72	**0.79**	0.54	**0.86**	0.52
CFL	—	—	—	—	—	—	1.00	**0.79**	**0.97**	0.72	**0.95**
ST	—	—	—	—	—	—	—	1.00	0.72	**0.84**	0.74
STL	—	—	—	—	—	—	—	—	1.00	0.59	**0.97**
T	—	—	—	—	—	—	—	—	—	1.00	0.63
TL	—	—	—	—	—	—	—	—	—	—	1.00

[a]Numbers in bold represent significant correlations ($P < 0.001$).
[b]CF = chocolate flavor intensity; CFL = chocolate flavor liking; CI = color intensity, CIL = color intensity liking; OA = overall acceptability; OFL = overall flavor liking; OTL = overall texture/mouthfeel liking; ST = sweet taste intensity; STL = sweet taste intensity liking; T = thickness; TL = thickness liking.

er color data and instrumental color were also noted in L^* ($r = -0.87$) and b* ($r = -0.97$) values.

Internal preference mapping was used to model the chocolate milk consumer responses (Figure 3). Overall acceptance and other liking scores positively correlated with PC1 (53% variance explained). Milks with high positive loadings were 16, 17, and 23, and milks with high negative loadings were 3, 5, 10, and 15. Descriptive analysis indicated high intensities of cocoa aroma and flavor in milks 6, 17, and 23, and low intensities in milks 3, 5, 10, and 15 (Figure 1). This phenomenon suggests that cocoa aroma and flavor are drivers of liking of chocolate milk. However, it does not explain the locations of milks 9, 19, and 24 that received moderate to high overall acceptance scores. Milk 9 was described by trained panelists as exhibiting high cocoa aroma and cocoa flavor (Figure 1) but it was not as highly accepted by consumers as milks 17, 16, and 23 (Figure 3; Table 3). In contrast, milks 19 and 24 were characterized by descriptive analysis as medium to low in cocoa aroma and flavor, but these milks received comparable or higher consumer acceptance scores than milk 9 (Figure 3; Table 3). These discrepancies were clarified by external preference mapping.

External preference mapping provided more insight into consumer acceptance. TCA/GPA was used for external preference mapping (Young and others 2004), and the TCA/GPA results were confirmed by LSA/TCA (Figure 4, 5, and 6). TCA/GPA identified cocoa aroma as the major driver of acceptance (Figure 4 and 5) with 2 segments of consumers. Along dimension 1 (32%) (Figure 4), consumers, triangles (segment 1) and solid circles (segment 2), gravitated toward the left side of the axis that highly correlated with cocoa aroma, cocoa flavor, color, sweet taste, and vanilla flavor (correlation > 0.5). Members of segment 1 located further on the negative side of the axis than those of segment 2; however, there was no clear distinction between the 2 segments (Figure 4). Moreover, some members of segment 2 were located near cooked/eggy and malty flavor, even though these attributes were on the opposite direction of cocoa aroma and the other attributes driving the majority of overall acceptance. This negative relationship between cooked/eggy flavor and overall acceptance confirmed the negative linear correlation between cooked/eggy flavor and overall acceptance, and the lack of a correlation between malty flavor and overall acceptance reported in Table 7. Because consumers were scattered in a very wide pattern instead of a tight cluster by TCA/GPA, this indicates only moderate correlation between the average consumer overall acceptability and the attributes that correlated with dimension 1 (that is, cocoa aroma and flavor, sweet taste, and vanilla flavor). Only about 46% of the variance was explained by the first

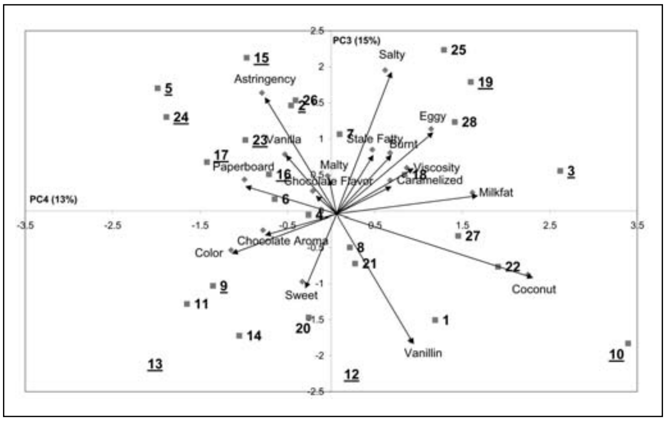

Figure 2—Principal component biplot of descriptive sensory analysis of chocolate milks. Numbers represent chocolate milks. Underlined numbers are those chosen for consumer testing. PC3 = principal component 3; PC4 = principal component 4.

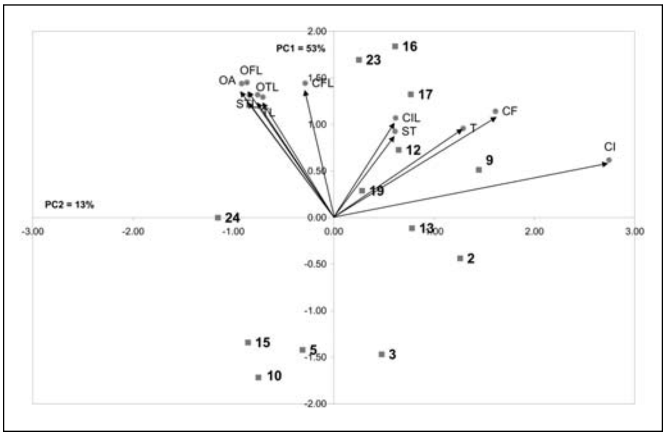

Figure 3—Internal preference map of consumer perception of chocolate milks. Numbers represent chocolate milks. CF = chocolate flavor intensity; CFL = chocolate flavor liking; CI = color intensity; CIL = color intensity liking; OA = overall acceptability; OFL = overall flavor liking; OTL = overall texture/mouthfeel liking; ST = sweet taste intensity; STL = sweet taste intensity liking; T = thickness; TL = thickness liking.

Table 7—Correlations among descriptive attributes and consumer responses[a]

	CA[b]	CF	Van	Vani	Car	Eggy	PB	Coc	MF	M	S/F	Burnt	Sw	Sa	Astr	Color	Visc
OA[c]	0.28	0.04	–0.59	–0.07	–0.57	**–0.67**	–0.24	–0.37	0.10	0.06	–0.61	**–0.75**	–0.45	0.41	–0.32	–0.26	0.10
OFL	0.35	0.13	–0.59	–0.03	–0.54	**–0.67**	–0.28	–0.40	0.13	–0.02	**–0.64**	**–0.82**	–0.35	0.35	–0.30	–0.18	0.19
OTL	0.31	0.08	**–0.67**	0.05	–0.45	–0.53	–0.15	–0.46	0.07	–0.12	–0.44	**–0.76**	–0.45	0.35	–0.25	–0.18	0.15
CI	0.54	0.44	–0.06	0.24	–0.24	–0.26	0.24	–0.62	–0.24	–0.42	–0.19	–0.18	–0.14	0.34	0.59	0.56	0.18
CIL	0.17	–0.09	–0.41	–0.21	–0.47	**–0.62**	0.14	–0.37	–0.36	0.36	–0.43	–0.14	–0.53	0.72	0.23	–0.22	–0.41
CF	**0.70**	0.56	–0.32	0.39	–0.19	–0.48	–0.12	–0.56	–0.05	–0.41	–0.46	–0.57	–0.04	0.26	0.44	0.37	0.26
CFL	0.42	0.16	–0.53	0.00	–0.56	**–0.69**	–0.22	–0.46	0.05	–0.05	**–0.65**	**–0.77**	–0.42	0.49	–0.15	–0.10	0.14
ST	**0.73**	0.62	–0.51	0.47	–0.13	–0.37	–0.39	–0.54	0.24	–0.57	–0.45	**–0.91**	0.06	–0.01	0.04	0.30	0.53
STL	0.31	0.06	–0.52	–0.07	–0.60	**–0.70**	–0.27	–0.34	0.14	0.04	**–0.66**	**–0.78**	–0.43	0.42	–0.34	–0.23	0.16
T	0.52	0.40	–0.60	0.25	–0.25	–0.47	0.13	**–0.75**	–0.24	–0.45	–0.26	**–0.66**	–0.08	0.24	0.43	0.24	0.23
TL	0.27	0.02	–0.60	–0.08	–0.52	–0.54	–0.17	–0.44	0.06	–0.06	–0.49	**–0.77**	–0.50	0.46	–0.33	–0.21	0.12

[a]Numbers in bold represent significant correlations (*P* < 0.001).
[b]Astr = astringent; CA = chocolate aroma; Car = caramelized; CF = chocolate flavor; Coc = coconut; M = malty; MF = milkfat; PB = paperboard; Sa = salty; SF = stale-fatty; Sw = sweet; Van = vanillin; Vani = Vanilla; Visc = viscosity.
[c]CF = chocolate flavor intensity; CFL = chocolate flavor liking; CI = color intensity; CIL = color intensity liking; OA = overall acceptability; OFL = overall flavor liking; OTL = overall texture/mouthfeel liking; ST = sweet taste intensity; STL = sweet taste intensity liking; T = thickness; TL = thickness liking.

2 TCA/GPA dimensions (Figure 4). Hence, it would be unwise to conclude that cocoa aroma and cocoa flavor were the only drivers of acceptance. Therefore, dimensions 3 and 4 were further explored. Figure 5 shows clearer separation between the 2 consumer segments than Figure 4. Clearly, the separation occurred along dimension 4. The majority of consumers in segment 1 gravitated toward cooked/eggy flavor, which had the highest correlation with dimension 4. On the other hand, almost all consumers in segment 2 gravitated toward malty flavor, which was negatively correlated with the same dimension (Figure 5).

Using TCA/GPA, 4 dimensions were needed to explain consumer segments properly, and this suggested that not only large variation in chocolate milk attributes (that is, cocoa aroma and cocoa flavor) contributed to consumer acceptance, but that small variation attributes (that is, malty and cooked/eggy) also contributed to and correlated with linear-acceptance vectors in the chocolate milk acceptance spaces for both segments (Greenhoff and MacFie 1994). Therefore, internal preference mapping, which operates on a linear relationship assumption and identifies large linear correlations or drivers of acceptance, did not indicate cooked/eggy flavor and malty flavors as drivers of acceptance. However, other techniques that take an account of both linear and nonlinear relationships should be used to confirm the results from TCA/GPA, and Landscape Segmentation Analysis (LSA) was selected.

LSA estimates and allocates individual consumer ideal points (these processes are sometime are called unfolding), which indicate ideal locations of chocolate milks for each consumer in the acceptance space (Figure 6). Consumers with the same type of preferences had their ideal points located near each other and created preference segments. The contour of the graph (Figure 6) indicated the density of the ideal per unit area in the space. The more crowded the area, the darker is the color of the contour. Visual inspection of the contour showed several potential segments. TCA on the ideal points identified 3 distinct segments and these segments were confirmed by DA (Figure 6). Overlaying sensory profiles obtained from descriptive analysis on the space revealed 3 drivers of liking: cooked/eggy, malty and cocoa aroma (Figure 6). These drivers differentiated consumers in the segments into segment 1 (cocoa aro-

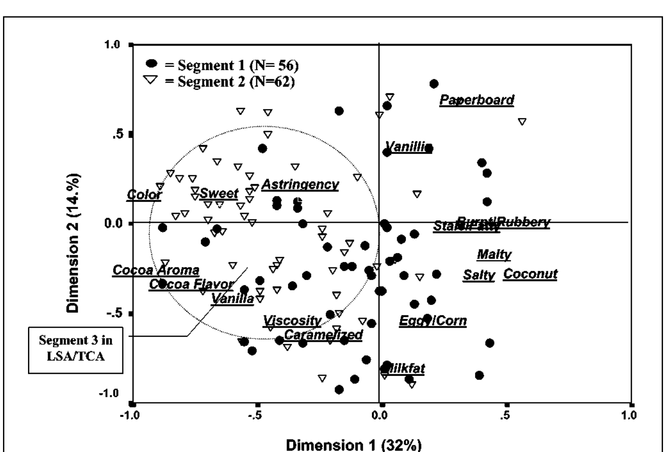

Figure 4—Two-step Cluster Analysis (TCA) followed by Generalized Procrustes Analysis (GPA) (TCA/GPA) analysis of chocolate milk overall acceptance (dimensions 1 and 2). Segments represent different groups of chocolate milk consumers. One of the 3 segments identified by Landscape Segmentation Analysis (LSA) followed by TCA (LSA/TCA) (Figure 6) is also indicated.

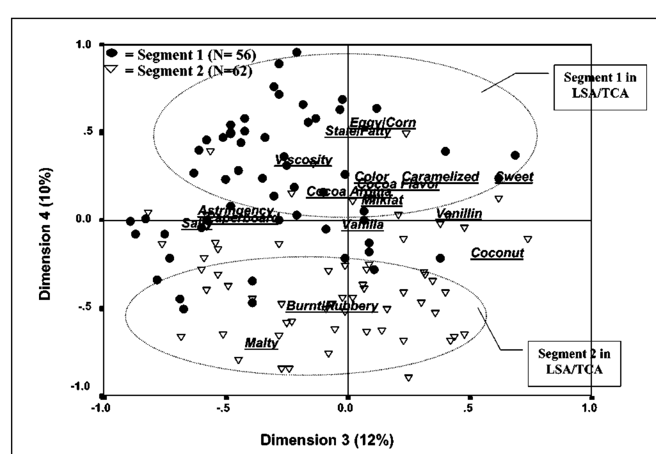

Figure 5—Two-step Cluster Analysis (TCA) followed by Generalized Procrustes Analysis (GPA) of chocolate milk overall acceptance (dimensions 3 and 4). Segments represent different groups of chocolate milk consumers. Two of the 3 segments identified by Landscape Segmentation Analysis (LSA) followed by TCA (figure 6) are also indicated.

ma lovers: 32.2%), segment 2 (cocoa aroma lovers, malty influenced: 32.2%), and segment 3 (cocoa aroma lovers, cooked/eggy influenced: 35.6%).

Inspection of the overall acceptance profiles of each segment (Figure 7), in conjunction with the LSA space, confirmed the conclusions from TCA/GPA, which identified cooked/eggy and malty as the differentiating drivers for the 2 segments found previously (Figure 5). Additionally, cocoa aroma was identified as a general driver by both TCA/GPA and LSA. The notion of cocoa aroma as a general driver of acceptance was established from the overall acceptance ratings of samples 16, 17, and 23 (for high acceptance) and samples 5 and 10 (for low acceptance). Consumers regardless of segments rated the first 3 samples within the top 4 samples (acceptance scores > 6.0) and the last 2 samples within the last 5 (acceptance scores < 5.5). Cooked/eggy and malty flavor positively influenced acceptance scores of chocolate milks within comparable ranges of cocoa aroma intensity, that is, high intensity (> 5.0: milks 9, 17, and 23) and low intensity (< 3.0: samples 3, 5, and 10).

Segment 1 consumers (cocoa aroma lovers) were located in the lower left area of the LSA acceptance space (Figure 6) with loose density. Consumers in segment 1 rated milks 23 and 17 as the top 2 most-liked milks (Figure 6 and 7). The contour of Figure 6 showed a high density of consumers near milk 23; therefore, this sample was the closest to the ideal chocolate milk by the majority of consumers in segment 1. The effect of cocoa aroma on the overall acceptance for segment 1 was obvious when the overall acceptance of milks 3 and 10 were compared with milks 23 and 17. Samples 3 and 10 were the last 2 milks in terms of consumer acceptance and these samples also had very low cocoa aroma (< 3.0). Milk 24 was located near milk 17 but in a non-crowded area (light color) of the LSA space; therefore, this milk received low overall acceptance scores from consumers in segment 1. Descriptive analysis confirmed that milk 24 had a low cocoa aroma (approximately 3); hence it received low acceptance scores.

Segment 2 consumers (malty influenced) were located on the right side of the LSA space. The majority of consumers in segment 2 were located near milks 16 and 23. The LSA contour shows the center of the segment nearer to milk 16; thus milk 16 received higher acceptance ratings from this segment (7.4) followed by milk 23 (6.7) (Figure 7). The overall acceptance of consumers in this segment was influenced by malty flavor in addition to cocoa aroma. A good example is comparing milk 19 (cocoa aroma < 4 and malty flavor of approximately 3) with milk 9 (cocoa aroma > 4 and malty flavor < 3). High in malty flavor, milk 19 was accepted by the consumers in segment 2 as well as high cocoa aroma milks (9, 16, 23, and 17). However, the influence of cocoa aroma surpassed the influence of malty flavor when cocoa aroma was lower than 3 (see milks 5 and 10) (Figure 7).

Segment 3 consumers (cooked/eggy influenced) were located in the middle and the upper part of the LSA acceptance space with its majority centered in the middle of the space near milks 17 and 24 (Figure 6). The influence of cooked/eggy flavor was stronger than that of malty flavor on the consumers of segment 3 as indicated by a large correlation coefficient (0.7) between the rank-order of average cooked/eggy intensity from descriptive analysis and the segment 3 consumer acceptance scores when projected on the cooked/eggy flavor intensity vector imposed on the LSA map (Figure 6). However, there was no actual milk at the center of the consumer segment 3 (Figure 6). These results indicate a space to develop a new chocolate milk with higher cocoa aroma and more or less cooked/eggy flavor than sample 7 to capture both subgroups of consumers in this segment. The subgroups differed by the influence of cooked/eggy intensity. A smaller group located in the upper area of the LSA map preferred high cooked/eggy flavor (more than that of milk 7); meanwhile, the bigger group (located in the center of the LSA map) preferred moderate cooked/eggy flavor (less than that of milk 7).

Milks 7 and 19 were good examples to demonstrate the influence of cooked/eggy flavor on consumers in segment 3. Consumers in segment 3 rated both of these milks highly (acceptance scores > 6), despite relatively low cocoa aroma intensity by descriptive analysis (3.2 and 2.5, respectively). Both milks had high cooked/eggy flavor compared with the other milks by descriptive analysis (1.6 and 1.4, respectively). Milk 7 had higher cooked/eggy flavor than that of milk 9; therefore, milk 7 received higher acceptance scores by these consumers (Figure 7). Unlike the influence of malty flavor in segment 2, the influence of cooked/eggy flavor was exerted across a wider range of cocoa aroma intensity (cocoa aroma range 2 to 6) than malty flavor did in segment 2 (cocoa aroma range 3 to 5). Comparing milk 2 with milk 3 is another good example of how

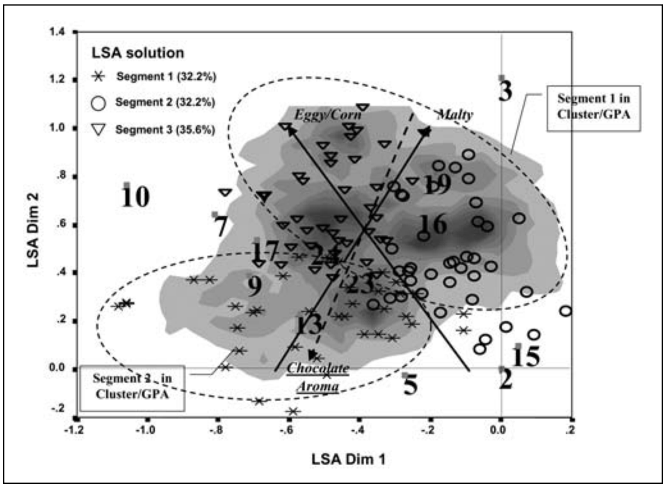

Figure 6—Landscape Segmentation Analysis (LSA) followed by Two-step Cluster Analysis (TCA) of chocolate milk overall acceptance. Segments represent different groups of chocolate milk consumers. Dim1 = dimension 1; Dim2 = dimension 2. The 2 segments identified by TCA/Generalized Procrustes Analysis (GPA) (Figure 4 and 5) are also indicated.

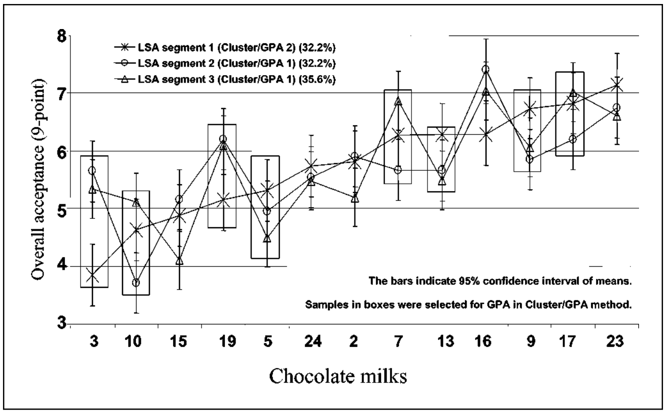

Figure 7—Overall acceptance profiles of the individual consumer segments identified by Landscape Segmentation Analysis (LSA) followed by Two-step Cluster Analysis (TCA) (LSA/TCA).

cooked/eggy flavor influenced acceptance. Both milks received the same acceptance scores from consumers in segment 3 (approximately 5.2) (Figure 7). Cocoa aroma scores for these 2 milks were different by descriptive analysis (3.4 and 1.9, respectively [$P < 0.05$]), whereas cooked/eggy flavor was not different (1.9 and 1.7, respectively [$P > 0.05$]). However, cocoa aroma was still the general driver of acceptance for these consumers as milks 5, 10, and 15 (cocoa aromas < 3.5) were rated the lowest in acceptance scores, even though these samples were not the lowest in cooked/eggy flavor.

Conclusions

Both LSA/TCA and TCA/GPA revealed complementary conclusions, yet LSA/TCA identified drivers of acceptance with a simpler format (2 dimensional space) compared with TCA/GPA (4 dimensional space). Usually, not more than 2 dimensions should be inspected when TCA/GPA is used because of complex interpretation (Lawless and Heymann 1999). However, in this case, higher dimensional solution from TCA/GPA was necessary to correctly identify drivers of acceptance. Using both approaches allowed us to validate our findings and helped to capture subtle but important information that may not be obvious, if only 1 approach was used. Cocoa aroma is, not surprisingly, a major driver influencing acceptability of chocolate milks. Other flavor attributes including cooked/eggy and malty flavors also positively influence acceptability within market segments.

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