Running Title: Sensory analysis of lactose-free milks

Sensory Characteristics of Commercial Lactose-free Milks Manufactured in the United States

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A B S T R A C T

This study was designed to determine the sensory characteristics of ultrapasteurized (UP) lactose-free milk of different fat contents, and to compare them with regular milk. Nine milk samples (six UP lactose-free and three regular) containing 0, 2 or 3 g milkfat/100 mL were tested by a descriptive panel. A consumer test with three UP lactose-free milk and three regular samples also was conducted. The skim milks (UP lactose-free and regular) were found to be lacking in freshness and the dairy notes were lower compared to the higher fat content milks. The UP lactose-free milks also were different from the regular milk because of higher intensities of cooked, processed, and sweet attributes. UP Lactose-free milks tended to score higher than the regular milks at the same fat content for dairy-related attributes, but this difference was not significant for the reduced-fat milks. Although majority of the consumers in the present study were aware that UP lactose-free milks existed in the market, only few had tasted them before. The higher intensities of cooked and sweet flavor attributes in the UP lactose-free milks might be a hindrance to their consumption by the lactose-intolerant population. More efforts are needed on the part of the dairy industry to develop better lactose-free products and to educate consumers about lactose-free dairy products.

Keywords: Ultrapasteurized lactose-free milk; Descriptive analysis; Consumer acceptability; PLS regression

1. Introduction

Between 30-50 million consumers in the U.S. (approximately 25% of the U.S. adult population) and more than 70% of the world's population are lactose-intolerant, which varies by race and age (Messia, Candigliota, & Marconi, 2007). Lactose-intolerance occurs when the human body is unable to produce the lactase enzyme required to break down lactose to glucose and galactose for the body to metabolize. As a result, the lactose is fermented in the intestine where it can produce unpleasant conditions such as gas, bloating, and diarrhea. Commercial lactose-free milk contains less than 0.25g lactose per 100g of milk and is manufactured via enzymatic hydrolysis by breaking down the lactose in milk to glucose and galactose. Lactose usually is present in milk at levels of 4-6g/100 mL. Glucose and galactose resulting from hydrolysis of lactose are sweeter than lactose, and thereby can increase the sweetness of the lactose-free milks. The demand for lactose-free dairy products has increased by approximately 20% per year since 1997 in the U.S. (Jelen & Tossavainen, 2003). Generic brands of lactose-free milk also are making their way into the market.

While lactose-free milks have addressed the needs of lactose-intolerant consumers, there still needs to be a strong similarity to regular milk for the consumer to purchase the product and be satisfied. Dairy product acceptance is primarily sensory-driven (Claasen & Lawless, 1992). Milk flavor can be affected by many variables, including chemical reactions and microbial growth (Francis, Chambers, Kong, Milliken, Jeon, & Schmidt, 2005). However, not only is flavor an important component of the milk sensory experience, so too are texture and appearance. Flavor has a direct relationship to

consumer acceptance, and is the most important factor for adults when consuming milk (Deane, Chelesvig, & Thomas, 1967; Francis et al., 2005).

Because the demand for lactose-free dairy products may increase to provide alternatives for the large lactose-intolerant population, it is important to understand the sensory characteristics of lactose-free milks as compared to regular milk. Thus, the main objective of this study was to compare sensory characteristics, including descriptive characteristics and liking, of ultrapasteurized lactose-free milks with different fat contents to their regular milk counterparts.

2. Experimental

2.1. Milk samples

Nine commercial pasteurized or ultrapasteurized (UP) milk samples were selected for the descriptive study. Three ultrapasteurized lactose-free milks of two different brands (A and B) and three regular/control milk varieties (pasteurized), and containing 0, 2 or 3 g milkfat/100 g milk were used. UP lactose-free milks of brand A and the regular milks only (six samples) were used for the consumer study. Lactose-free and organic milks that are available in the U.S. market are ultrapasteurized and packaged in gable-top containers. The regular milks consumed in U.S. households are usually pasteurized, and packaged in plastic containers. Although the type of pasteurization is a confounding variable with lactose content in this study, that is the reality of commercial availability and provides a real-life comparison of regular and lactose-free milks available to consumers in the United States.

66 *2.2. Sensory analysis*

67 *2.2.1. Sample Serving*

68 For both descriptive analysis and the consumer studies, the milk samples were served
69 at 7 °C in 100-mL individual cups (Solo Cup Company, Highland Park, IL, U.S.A.).
70 Unsalted crackers and water (deionized, reverse-osmosis and carbon-filtered) at room
71 temperature (~22 °C) were provided for palate cleansing between samples. A five-
72 minute break between samples was also used to help reduce carry-over from one sample
73 to the next.

74 A nine-by-nine modified William's Latin Square Design was used to determine the
75 serving order of the milk samples to the descriptive panelists (Hunter, 1996). Each of the
76 nine samples was served individually with three-digit codes to every panelist each day
77 during a 90-minute session. Three replications of the tasting were conducted over a 3 day
78 period.

79 For the consumer test, six samples were served with three-digit codes, and the
80 serving order was randomized using several 6 × 6 William's Latin Square Designs to
81 accommodate 120 consumers.

82 *2.2.2. Descriptive Analysis*

83 Descriptive analysis was performed using nine highly trained panelists. All panelists
84 were affiliated with the Sensory Analysis Center at Kansas State University and had
85 completed over 120 hours of descriptive sensory analysis training and had more than
86 2000 hours of sensory testing experience, including milk and other dairy products. Two
87 orientation sessions were conducted to familiarize the panelists with the samples to be
88 tested, and to formulate the appropriate terms and definitions for inclusion on the ballot.

During these orientation sessions, the panelists were presented with the nine samples that were tested. For the lexicon development, terminology from prior studies on related products were given to the panel. The panel was given various milk samples and instructed to taste them and develop a lexicon for this study. This procedure has been used for other sensory studies (Lee & Chambers, 2007; Yates & Drake, 2007; Karagul-Yuceer, Isleten, & Uysal-Pala, 2007; Hongsoongnern & Chambers, 2008). A comprehensive vocabulary of 21 descriptors for appearance, texture, flavor, and aftertaste categories was generated (Table 1). A 0 to 15-point interval scale with 0.5 increments was used for the sensory ballot.

2.2.3. Consumer Testing

A consumer test was conducted with 115 consumers (67 females and 48 males) who had to consume milk at least once a week and be between the ages of 18 to 55 years. Each consumer rated the six milks on a 9-point hedonic scale (1=dislike extremely to 9=like extremely) for five liking attributes and a similar 9-point scale (1=none to 9 =high) for six intensity attributes. In addition, three background question were asked: 1) What type of milk do you usually consume?; 2) Are you aware of the presence of lactose-free milk in the market?; and 3) Do you think lactose-free milk is more beneficial to your health?

2.3. Data treatment and analysis

All sensory data was collected using Compusense Commuter® data collection software (version 4.6.702; Compusense Inc., Guelph, Ontario, Canada). For the descriptive data, the effect of milk type (skim, reduced-fat or whole) and the effect of processing (lactose-free and pasteurization technique) within each milk-type was

analyzed using analysis of variance (ANOVA) with post-hoc mean separation using Fisher's least significant difference. ANOVA was also performed on the consumer data, and post-hoc means separation was done by using Fisher's LSD. The analyses were carried out in SAS® (version 9.1.3; SAS Institute, Cary, NC, U.S.A.). The data was analyzed at 5% level of significance.

To understand the relationship between consumer awareness/use data and consumer acceptability/descriptive data, partial least square regression was also carried out (Unscrambler®, version 9.0, 2004; Camo Process AS, Oslo, Norway). This methodology is becoming extremely popular for creating external preference maps for determining the relationship between descriptive data (X-matrix) and consumer acceptability data (Y-matrix). Both the data sets (descriptive and consumer acceptability) were standardized before analysis (Thybo, Kühn, & Martens, 2004; Tenenhaus, Pagès, Ambroisine, & Guinot, 2005).

3. Results and Discussion

3.1. Descriptive Sensory data

3.1.1. Effect of Type of Milk

Sixteen of 21 descriptive sensory attributes were found to be significantly different when studying the effect of fat content of the milk samples (Table 2). The three skim milks scored significantly higher ($P \leq 0.05$) for color intensity than the other six milks in this attribute (Fig. 1), indicating a slightly blue/green tint to the skim milks, as opposed to white. This is consistent with the removal of fat content because the surface is not uniform and light is not as reflective from the milk's surface resulting in a colored

appearance (Quiñones, Barbano & Phillips, 1997; Quiñones, Barbano, & Phillips, 1998). Phillips & Barbano (1997) showed that titanium dioxide could be used to enhance the sensory properties of lowfat milks. They emphasized that those whiteners that are not titanium dioxide based need to be developed to improve the sensory properties of skim and lowfat milks. Such ingredients might have added nutritional benefits as opposed to titanium dioxide. Frøst, Dijksterhuis, & Martens (2001) were able to show that the color of 0.1% fat milk could be matched to 1.3% fat milk using a combination of thickeners, cream flavor and titanium dioxide.

A clear delineation for the 'fat feel' attribute also was noted among milks with varying fat levels. As expected, whole milks had significantly ($P \leq 0.05$) more fat feel than the three skim milks. The viscosity of the skim milks was significantly lower ($P \leq 0.05$) than the reduced-fat and whole milks. Similar results for viscosity were reported by Chapman, Lawless, & Boor (2001) who found significant differences between skim milks and higher-fat milks.

The panel found the skim milks to have higher "lack of freshness" than the reduced-fat or whole milks. Lower intensities of dairy related flavor in the skim milk might have increased the perception of lack of freshness and light oxidized flavors. The reduced-fat and whole milks were similar ($P > 0.05$) in all the dairy-related attributes because of the presence of higher amounts of fat. No significant differences were found for 'astringent', which is substantiated by Quinones et al. (1998) who also found that astringency for texture was not influenced by fat content.

The aftertaste attributes of 'overall dairy', 'dairy fat' and 'overall sweet' were significantly lower for the skim milks when compared with the reduced-fat and whole

158 milks. No differences were evident between the reduced-fat milks and the whole milks
159 for aftertaste attributes. Francis et al. (2005) observed that regular skim milk scored lower
160 than the regular whole milk for 'dairy fat' and 'overall sweet' aftertastes. A study by
161 Porubcan & Vickers (2005) concluded that milks with higher fat content had higher
162 aftertaste intensities, which agrees with our findings.
163
164 *3.1.2. Effect of Processing (lactose-free and pasteurization technique)*
165 Ten attributes were found to be significantly different ($P \leq 0.05$) among the three
166 skim milks (Table 3). The UP lactose-free milk samples were observed to be higher in
167 four key negative attributes: chalky texture, lack of freshness, light oxidized, and
168 processed flavors. These differences may be caused by the ultrapasteurization for the
169 lactose-free milks, by the enzymatic reactions that result in lactose-free milk or a
170 combination of those factors. The ultrapasteurization most likely contributed to the
171 processed flavor and chalkiness from the high temperature processing that can begin
172 Maillard browning reactions and cause some denaturation of the whey proteins. The
173 addition of lactase to give lactose free milk also results in twice the amount of reducing
174 monosaccharides (glucose and galactose) in the lactose-free milks that can participate in
175 Maillard reactions. That may impact the presence of lack of freshness and processed
176 flavors. Monosaccharides are more reactive than reducing disaccharides when
177 participating in Maillard reaction. Higher levels of Maillard reaction products, such as
178 furosine, probably were produced during the processing of the lactose-free milks as
179 compared to the regular milks (Messia et al., 2007).

Two findings suggest that the differences are not solely related to high temperature pasteurization. First, no difference was found in the intensity of cooked flavor between the lactose-free ultrapasteurized skim milk samples and the regular skim milk, which would be expected if the ultrapasteurization was the main cause of differences in the milks. The effect of processing should be even more obvious in the skim milk because fat is not present to mask the cooked flavor (Francis et al., 2005). This is also apparent from our observation that the higher fat milks were perceived to be higher in cooked flavor than their regular counterparts. Secondly, the UP lactose-free samples were significantly higher ($P \leq 0.05$) in sweetness attributes than the regular skim milk because of the hydrolysis of lactose to glucose and galactose. Chapman et al. (2001) found that the main difference between lactose-free ultrapasteurized milk and regular ultrapasteurized milk was the intensity of sweetness. Messia et al. (2007) reported that a small quantity of fructose is also formed because of the isomerization of glucose; fructose being almost six or three times sweeter than lactose and glucose, respectively. The UP lactose-free skim milks, and one reduced-fat sample (brand A) had a slight animal (sulfur) flavor that could be because of sulfur compounds (e.g. dimethyl sulfide) formed during processing in the lactose free milk. Dimethyl sulfide is a nonpolar compound whose odor can be masked by the presence of fat in milk (Christensen & Reineccius, 1992; Simon, Hansen, & Young, 1999).

Eight attributes were significantly different ($P \leq 0.05$) in the reduced-fat milks (Table 3). As with the skim milks, the reduced-fat UP lactose-free milks were significantly higher in chalkiness than the regular milk sample. A significant difference also was noted in cooked flavor, while the samples were similar in processed flavor; although the mean

score for the regular milk was lower than the UP lactose-free milks. The intensity of the sweetness attributes was also higher in the lactose-free milks.

Ten attributes were observed to be significantly different ($P \leq 0.05$) for the three whole milk samples (Table 3). Major differences were found in chalky texture, sweetness, cooked, lack of freshness and processed flavors. Both, reduced-fat and whole lactose free milks were perceived to be higher in viscosity as compared to their regular counterparts. It should be noted here that differences in viscosity of the milks within a fat level was much lower than across the three fat levels. Chapman et al. (2001) inferred that higher levels of sweetness and higher processing temperatures in the UP lactose-free milks are probable reasons for the increased perception of viscosity. It was observed that the UP lactose-free milks of both brands were very similar to each other for all the sensory characteristics across all fat levels. The only exception was cooked flavor for reduced-fat UP lactose-free milks; the Brand A milk had a higher intensity of cooked flavor.

3.2. Consumer Sensory Data

Overall, the regular whole milk was liked significantly more ($P \leq 0.05$) than the other milks for all five liking attributes, while the UP lactose-free skim milk used in the consumer study (Brand A) was the least acceptable, with all mean scores (except texture liking) for that product being less than 5 (Table 4). The intensity scores show that the sweetness was significantly higher ($P \leq 0.05$) for the UP lactose-free milk samples than the regular milk samples. The liking scores showed that the consumers liked the sweetness of the regular whole milk the most indicating that the higher sweetness intensity in the UP lactose-free milks might not be acceptable to consumers. UP

Reduced-fat and whole lactose-free milks were equal in acceptability to the regular skim-milk and reduced fat milks, suggesting that it would be best to recommend these fat levels (reduced-fat and whole) of lactose free milks to consumers first. The intensity of aftertaste of the lactose-free milks also was higher in general compared to the regular milks. This might be because the higher sweetness intensity of the UP lactose-free milks left a lingering aftertaste. This is also evident from the descriptive study, where the trained panelists perceived higher intensity of overall sweet aftertaste.

Overall liking scores were similar between men (range: 4.59-6.58) and women (4.24-6.94), although men favored both skim milks and the UP lactose-free samples slightly more than did the women. Similar results were reported by Brewer, Blake, Rankin, & Douglass (1999) where they observed that women liked whole milk more than skim milk, although many of them indicated that they drank skim milk as part of their diet. However, Weaver & Brittin (2001) observed that men liked whole milk significantly more than did women. For skim milk, that study found men's and women's scores to be comparable.

The PLS regression map (Fig. 1) shows the relationship between consumer awareness/use data and consumer acceptability/descriptive data. If the first two dimensions (PLS1 and PLS2) of the PLSR biplot are considered, 86% variation in the descriptive analysis data explained 54% variation in the overall acceptability data. As seen in the univariate analysis on the consumer data, most of the consumers liked the higher fat-content milk samples more. The consumers' preference for the higher fat-content milk samples might have been driven by the dairy related attributes (example – overall dairy and dairy fat flavor). The UP lactose-free skim milk was characterized by negative attributes such as light oxidized, lack of freshness, processed and astringent.

249 This milk was not liked by the majority of the consumers. This is also because of the
250 lower intensities of dairy-related attributes in the UP lactose-free skim milk. Very few
251 consumers (n=16; denoted by "■" in the PLS map) were not aware that UP lactose-free
252 milks were available in the market. Most of these consumers indicated primary
253 acceptance for the regular milks. The same was true for the question associated with the
254 benefits of UP lactose-free milks; few consumers (n=15; denoted by "■" in the PLS
255 map) indicated awareness. Most of those consumers seemed to accept the UP lactose-free
256 milks. Approximately, 50% of the consumers said that they consume whole or reduced-
257 fat milk, while the rest consume either lowfat or skim milk. Although ~50% of the
258 consumers said that they consumed lowfat or skim milk, ~75% of the consumers actually
259 liked the whole and reduced-fat milk samples more than the skim milk samples.
260
261 **4. Conclusions**
262 Based on the results obtained from the descriptive panel, it is clear that differences
263 exist between UP lactose-free milk and regular milk, mainly because of the higher
264 intensities of sweetness, cooked and processed flavors, and presence of chalkiness in the
265 lactose-free milk. The panel also found the perception of viscosity to be higher in the
266 reduced-fat and whole lactose-free milks, which may be attributed to higher sweetness
267 levels and higher processing temperature for these milks. The consumer study showed
268 that although most consumers consume lower fat milks, they gave higher scores to the
269 reduced-fat and whole milk samples. Although the majority of the consumers were aware
270 of the presence of UP lactose-free milks in the market, they are unaware of the benefits
271 associated with lactose-free milks. These results can be very useful to the dairy industry

to get a better understanding of the differences between regular milks and lactose-free milks in order to produce better tasting lactose free products, and to educate the lactose-intolerant consumers about the benefits of UP lactose-free milks. UP reduced-fat and whole lactose-free milks should first be recommended to lactose-intolerant consumers as these were found to be acceptable in this study.

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Table 1

A glossary of descriptors used for descriptive sensory

Terms/descriptors	Definition
Appearance	
Color	A visual evaluation of the color hue of the sample from white (low) to green (high).
Texture	
Chalky	A measure of dry, powdery sensation in the mouth.
Fat Feel	Related to the perceived fat content. Refers to the intensity of the oily feeling in the mouth when the product is manipulated between the tongue and the palate.
Viscosity	The measure of the flow as the product moves across the tongue.
Flavor	
Animal	The aromatic reminiscent of wet animal hair. It tends to be pungent, musty, and somewhat sour.
Cooked	The combination of brown flavor notes and aromatics associated with heated milk.
Overall Dairy	A general term for the aromatics associated with products made from cow's milk.
Dairy Fat	Aromatics associated with dairy fat.
Dairy Sweet	The sweet aromatics associated with fresh dairy products.
Grainy	A general term used to describe the aromatics associated with grains such as corn, oats, and wheat. It is an overall grainy impression characterized as sweet, brown, sometimes dusty.
Lack of Freshness	The overall rounded dairy notes, commonly associated with fresh milk are altered. A combination of changes in amount or interactions of such attributes as sweet, bitter, sour, dairy fat, butyric acid and/or brown.
Light-Oxidized	Flavor caused by light catalyzed oxidation. Characterized by aromatics that may be described as burnt feathers, slightly sour burnt protein, tallowy and/or medicinal: may include increased astringency or metallic mouthfeels.
Processed	Non-natural characteristic that may be slightly powdery resulting from the change or adulteration of the product (e.g. drying, canning, irradiation).
Overall Sweet	Aromatics associated with the impression of all sweet substances.
Sweet	The basic taste sensation of which sucrose in water is typical.
Sour	Fundamental taste factor of which citric acid in water is typical.
Astringent	The drying, puckering sensation on the tongue and other mouth surfaces.
Aftertaste terms	
Overall Dairy	A general term for the aromatics associated with products made from cow's milk.
Dairy Fat	Aromatics associated with dairy fat.
Overall Sweet	Aromatics associated with the impression of all sweet substances.
Overall Sour	Fundamental taste factor of which citric acid in water is typical.

Table 2

Effect of milk type (based on fat content) on the descriptive attributes of the milk samples

Attributes	MILKS[1]		
	Skim Milks	**Reduced-fat Milks**	**Whole Milks**
Color	8.81[a]	6.37[b]	5.74[c]
Chalky	2.51[a]	1.87[b]	2.04[b]
Fat Feel	1.77[c]	2.98[b]	3.54[a]
Viscosity	1.34[b]	1.84[a]	2.11[a]
Animal	0.11	0.05	0.04
Cooked	1.99	2.11	2.33
Overall Dairy (Flavor)	4.27[b]	6.46[a]	6.78[a]
Dairy Fat (Flavor)	2.16[b]	4.18[a]	4.54[a]
Dairy Sweet	2.38[b]	3.56[a]	3.83[a]
Grainy	0.41[a]	0.10[b]	0.16[b]
Lack of Freshness	2.15[a]	1.25[b]	1.19[b]
Light Oxidized	1.05[a]	0.44[b]	0.50[b]
Processed	2.94[a]	1.73[b]	1.61[b]
Overall Sweet (Flavor)	3.80[b]	4.49[a]	4.61[a]
Sweet	1.82[b]	2.04[a]	2.18[a]
Sour	1.51	1.52	1.58
Astringent	1.55	1.23	1.41
Overall Dairy (Aftertaste)	2.22[b]	3.51[a]	3.89[a]
Dairy Fat (Aftertaste)	1.27[b]	2.24[a]	2.45[a]
Overall Sweet (Aftertaste)	1.68[b]	2.22[a]	2.05[a]
Overall Sour	1.50	1.49	1.51

[1]Milks of the same fat level has three varieties: one regular commercial milk samples, and two lactose-free commercial samples.

[abc]Means within each row with different letters are significantly different ($P \leq 0.05$). A row without any letters indicates that the attribute was not significant.

Table 3

Effect of processing (lactose-free and pasteurization technique) on the descriptive attributes within each milk type (skim, reduced-fat or whole)

Attributes	MILKS								
	Skim Milks			Reduced-fat Milks			Whole Milks		
	UP-LFA[1]	UP-LFB[2]	REG[3]	UP-LFA	UP-LFB	REG	UP-LFA	UP-LFB	REG
Color	8.87	8.96	8.59	6.57[a]	6.70[a]	5.83[b]	5.74	5.69	5.78
Chalky	2.92[a]	2.57[ab]	2.01[b]	2.15[a]	2.13[a]	1.33[b]	2.39[a]	2.13[ab]	1.59[b]
Fat Feel	2.13[a]	1.74[ab]	1.44[b]	3.11	3.00	2.81	3.65	3.54	3.42
Viscosity	1.30	1.42	1.30	1.98[a]	1.87[ab]	1.68[b]	2.13[ab]	2.26[a]	1.94[b]
Animal	0.22	0.11	0.00	0.15[a]	0.00[b]	0.00[b]	0.13	0.00	0.00
Cooked	1.89	2.20	1.87	2.61[a]	2.15[b]	1.57[c]	2.74[a]	2.61[a]	1.65[b]
Overall Dairy (Flavor)	4.26	4.30	4.26	6.65	6.07	6.67	6.89[ab]	7.00[a]	6.44[b]
Dairy Fat (Flavor)	2.30[a]	2.42[a]	1.76[b]	4.33	4.15	4.06	4.89	4.44	4.30
Dairy Sweet	2.42[ab]	2.81[a]	1.89[b]	3.66	3.59	3.41	3.96[a]	4.22[a]	3.31[b]
Grainy	0.39	0.46	0.37	0.15	0.07	0.07	0.15	0.22	0.11
Lack of Freshness	2.83[a]	2.17[b]	1.44[c]	1.57	1.30	0.87	1.67[a]	1.20[ab]	0.70[b]
Light Oxidized	1.35[a]	1.06[ab]	0.74[b]	0.55	0.42	0.33	0.53	0.35	0.61
Processed	3.54[a]	2.98[a]	2.31[b]	2.15	1.81	1.22	1.61[ab]	2.01[a]	1.20[b]
Overall Sweet (Flavor)	4.04[a]	4.37[a]	3.00[b]	4.81[a]	4.56[ab]	4.09[b]	4.89[a]	4.92[a]	4.02[b]
Sweet	2.00[a]	2.04[a]	1.41[b]	2.18[a]	2.15[a]	1.80[b]	2.24[a]	2.46[a]	1.83[b]
Sour	1.59	1.44	1.50	1.63	1.46	1.46	1.87	1.46	1.41
Astringent	1.74	1.18	1.72	1.59	1.06	1.06	1.59	1.07	1.57
Overall Dairy (Aftertaste)	2.28	2.15	2.22	3.42	3.61	3.50	3.87	3.98	3.81
Dairy Fat (Aftertaste)	1.07	0.94	1.80	2.55	2.22	1.94	2.65	2.30	2.41
Overall Sweet (Aftertaste)	1.70[ab]	2.15[a]	1.20[b]	2.37[ab]	2.57[a]	1.70[b]	2.22[a]	2.20[a]	1.72[b]
Overall Sour	1.89	1.31	1.30	1.39	1.33	1.74	1.35	1.46	1.72

[1,2,3]Ultrapasteurized lactose-free milk (Brand A), ultrapasteurized lactose-free milk (Brand B), and regular commercial milk, respectively.

[abc]Row means within each type of milk (skim, reduced-fat or whole) with different letters are significantly different ($P \leq 0.05$). A row within each type of milk without any letters indicates that the attribute was not significant.

Table 4

Mean scores for consumer data (n = 115) for six samples of milk

Attributes	Milk Samples					
Liking[7]	**UP-LFA0**[1]	**UP-LFA2**[2]	**UP-LFA3**[3]	**REG0**[4]	**REG2**[5]	**REG3**[6]
Overall	4.30[c]	5.33[b]	5.25[b]	5.54[b]	5.52[b]	6.87[a]
Flavor	4.25[c]	5.33[b]	5.16[b]	5.35[b]	5.31[b]	6.83[a]
Texture	5.27[c]	6.02[b]	6.02[b]	5.90[b]	5.94[b]	6.94[a]
Aftertaste	4.21[c]	4.99[b]	4.88[b]	5.16[b]	4.72[b]	5.93[a]
Sweetness	4.31[c]	5.32[b]	5.11[b]	5.34[b]	5.43[b]	6.40[a]
Intensity[8]						
Sweetness	6.14[a]	6.08[a]	6.16[a]	3.66[c]	3.92[c]	4.48[b]
Cooked Flavor	3.95[a]	4.18[a]	4.16[a]	3.50[b]	3.84[ab]	3.51[b]
Dairy Flavor	4.89[bc]	5.20[ab]	5.26[ab]	4.62[c]	5.37[a]	5.22[ab]
Mouthcoating	4.65[b]	4.88[ab]	5.06[a]	3.92[c]	4.73[ab]	4.68[b]
Viscosity	4.44[ab]	4.48[ab]	4.77[a]	3.53[c]	4.24[b]	4.36[b]
Aftertaste	5.56[ab]	5.20[bc]	5.62[a]	4.33[d]	5.10[c]	4.33[d]

[1,2,3]Ultrapasteurized lactose-free milks (Brand A): skim, reduced-fat, and whole milk, respectively.

[4,5,6]Regular commercially available milks: skim, reduced-fat, and whole milk, respectively.

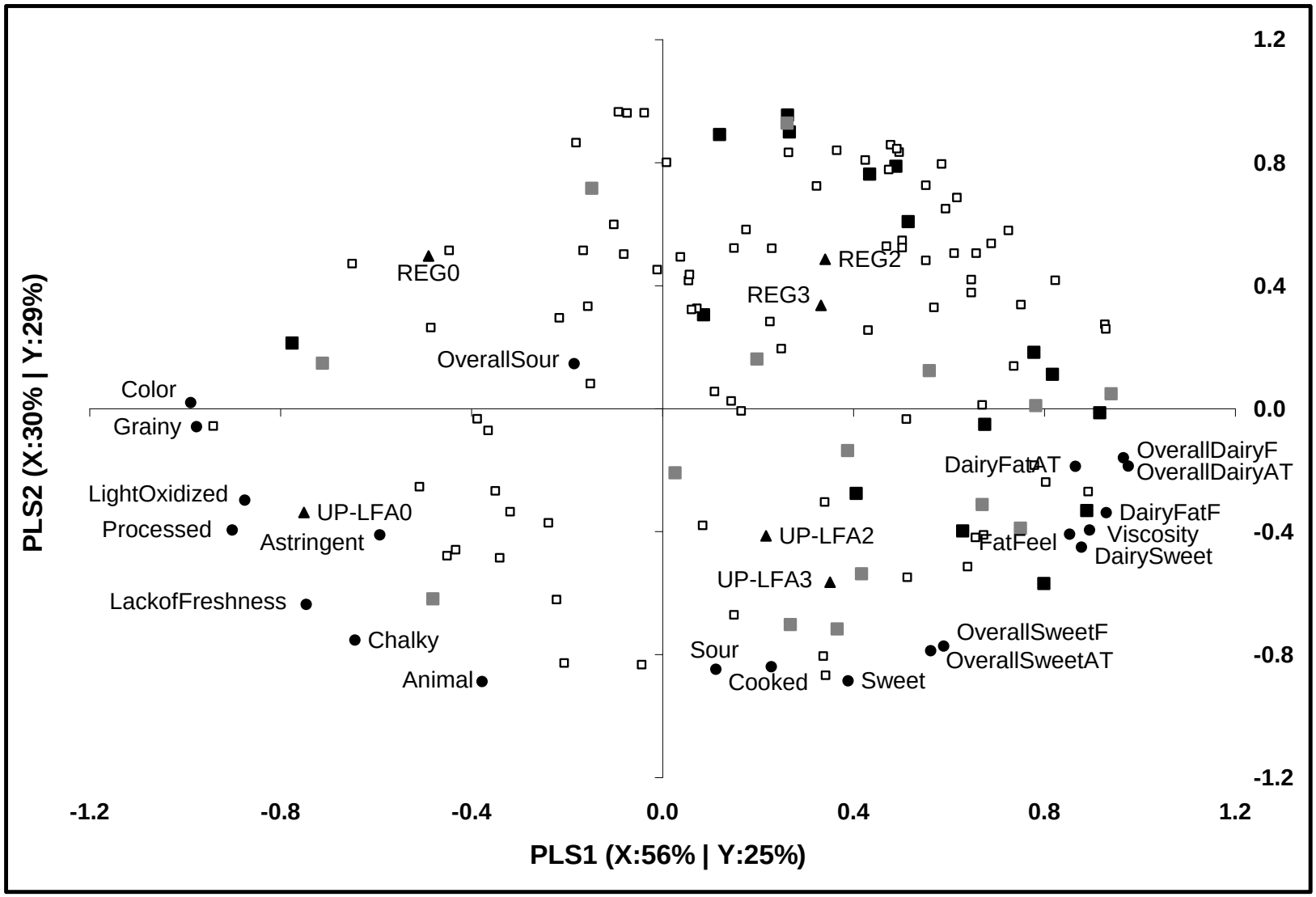
[7]A 9-point hedonic scale was used for the liking questions.

[8]A 9-point category scale was used for the intensity questions.

[a,b,c,d]Row means within an attribute with no common superscripts differ ($P \leq 0.05$).

Fig. 1. PLS regression map showing the relationship between consumer awareness/use data and acceptability/descriptive data. Legend: ■ – consumers who were not aware that lactose-free milks were available in the market; ■ – consumers who were aware about the benefits of lactose-free milks; □ – other consumers; ● – sensory descriptors, the overlapping flavor and aftertaste terms are denoted by "F" for flavor or "AT" for aftertaste in the map; and ▲ – the milk samples, UP-LFA represents brand A ultrapasteurized lactose-free milk, REG represents the regular milks, and 0, 2, 3 represents the fat content of the milks in g/100 mL.

1 Fig. 1.


PLS2 (X:30% | Y:29%)
PLS1 (X:56% | Y:25%)
1.2
0.8
0.4
0.0
-0.4
-0.8
-1.2
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
REG0
REG2
REG3
OverallSour
Color
Grainy
LightOxidized
UP-LFA0
Processed
Astringent
LackofFreshness
Chalky
Animal
DairyFatAT
OverallDairyF
OverallDairyAT
DairyFatF
UP-LFA2
Viscosity
FatFeel
DairySweet
UP-LFA3
OverallSweetF
Sour
OverallSweetAT
Cooked
Sweet

2