



Sensory profile, acceptability, and their relationship for diabetic/reduced calorie chocolates

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ABSTRACT

The purpose of this study was to determine the sensory properties and acceptability of lab developed prototypes of conventional, diabetic (with no sugar), and diabetic/reduced calorie milk chocolates (no sugar and 25% calorie reduction) with high-intensity sweeteners, sucralose and stevioside, and partial fat replacement with whey protein concentrate (WPC). PLS was performed in order to relate sensory properties and consumer acceptability and to determine drivers of liking and disliking. There was no difference between conventional, diabetic and diabetic/reduced calorie milk chocolates for brightness, cocoa aroma, cocoa butter aroma, and cocoa flavor ($p > 0.05$). Acceptability was higher for sucrose substitution by sucralose than by stevioside and partial fat replacement reduced acceptability of flavor even more ($p \leq 0.05$). Crucial attributes which determine consumer acceptability in samples are sweet aroma, melting rate, and sweetness, whereas bitterness, bitter aftertaste, adherence, and sandiness were drivers of disliking.

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1. Introduction

There is an increasing interest in low-calorie foods and beverages (Parpinello, Versari, Castellari, & Galassi, 2001). Alternatives to sucrose serve a number of purposes. It is important that such alternatives don't cause significant changes in the sensory characteristics of the product (Bolini-Cardello, Da Silva, & Damasio, 1999). It is also very important that diabetic (with no sugar) or reduced calorie foods have as few differences as possible from conventional foods. A very effective way of comparing conventional food with lab developed prototypes of diabetic or reduced calorie food is to perform sensory evaluations, such as descriptive analysis and consumer affective testing. Prindiville, Marshall, and Heymann (1999) suggested that consumers consider flavor quality when selecting the level of fat in foods they purchase. Sensory evaluation gives a realistic opinion about the likes and dislikes of a particular flavor (Hariom, Shyamala, Prakash, & Bhat, 2006).

Descriptive techniques are frequently used in product development to measure how close a new introduction is to the target or to assess suitability of prototype products (Lawless & Heymann, 1999). In consumer sensory analysis the investigator is interested in whether the consumer likes the product, prefers it to another product, or finds the product acceptable based on its sensory characteristics (Lawless & Heymann, 1999). Preference mapping is a

sensory tool to accomplish integration between consumer reactions and descriptive data (Geel, Kinnear, & de Kock, 2005). By relating consumer data with descriptive data, the researcher can discover the relationships between product attributes and the ultimate bottom line, consumer acceptance (Meilgaard, Civille, & Carr, 1999). One of the more recent topics in product research is the notion of "drivers of liking", or the nature of sensory features that drive acceptance (Moskowitz, Gofman, & Beckley, 2006).

Sensory properties are some of the most important factors on consumer liking and preference; thus, it is very important to determine factors affecting the product attributes, acceptance and preference especially for foods and drinks (Dos, Ayhan, & Sumnu, 2005). Understanding what sensory properties drive consumer liking is critical for maximum market share (Thompson, Drake, Lopetcharat, & Yates, 2004). Luckow and Delagunty (2004) reported that consumers would not be interested in consuming a functional beverage if the ingredients caused noticeable off-flavors that consumers found unpleasant despite the added health advantages. However, conflicting research does exist. A study performed with elderly consumers demonstrated that sensory appeal was less important than health perception and fat content, with regard to the purchase intent of fat-modified foods. Although high-intensity sweeteners are essentially calorie free, some of these sweeteners impart undesirable flavors and aftertastes, such as bitterness, that can limit their applications in foods and beverages. However, sucralose is reported to have a relatively clean, sweet taste with little persistence of bitterness (Zhao & Tepper, 2007).

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During the rush of publicity of the new nutritional recommendations in the early 1980s, the first strategy to evolve was simply to remove fat from standard products, such as milk or meat, without any attempt to address the organoleptic changes resulting from the reduction in fat. Such a strategy is not feasible for most other food products (as milk chocolate) because physical stability, functional properties and microbiological stability may be adversely affected. The major challenge in the development of reduced-fat foods is to achieve fat reduction while matching as closely as possible the flavor and mouthfeel of traditional full-fat products (Jones, 1996). Whey protein-based fat replacers can mimic milk fat in terms of texture and flavor retention (Prindiville, Marshall, & Heymann, 2000).

The objective of this study was to study the influence of sucrose and fat replacement and to correlate consumers' data with sensory data. Traditional milk chocolate was compared with lab developed prototypes of diabetic and diabetic/reduced calorie chocolates as well as with a diabetic but not reduced calorie commercial product (Com), using quantitative descriptive analysis (QDA), principal component analysis (PCA), affective testing, internal preference mapping, and partial least squares (PLS) regression to relate consumer preference data to data from QDA.

2. Materials and methods

2.1. Samples

The lab developed prototype of conventional milk chocolate was prepared with sucrose (Sucro). Diabetic prototypes were prepared substituting sucrose with high-intensity sweeteners, sucralose (Sucra) or stevioside (Ste), and a polydextrose/lactitol (60/40) blend as a bulking agent. Both conventional and diabetic chocolates were formulated to be equi-sweet at the most acceptable sweetness intensity as determined by the time-intensity methodology by Melo, Bolini, and Efraim (2007a). Diabetic/reduced calorie milk chocolates were prepared through substitution of sucrose in the same way as diabetic chocolates but with partial replacement of cocoa butter with whey protein concentrate (WPC) in order to reduce the calorie content by 25% (Sucra/WPC and Ste/WPC) (Melo, Bolini, & Efraim, 2007b). A 25% calorie reduction was considered because Brazilian Legislation determines that this is the minimum calorie reduction in order to use a "low-calorie" or "reduced calorie" claim. Chocolates were conventionally produced following the steps of mixing, in a KITCHEN AID planetary mixer, model K5SS (Kitchen-Aid, St. Joseph, MI); refining, in a DRAISWERK GMBH three-roll refiner (Draiswerke GmbH, Mannheim Waldo, Mahweh, NJ); conching in a FRIWESSA longitudinal conche (Friwessa, Parsippany, NJ); temper in a ACMC laboratory temper (ACMC, Bohemia, NY); moulding in polycarbonate molds; cooling in a SIAHT tunnel cooler (Siaht, Jundiaí, SP, Brazil) and packaging (Beckett, 1994). Chocolates were produced in batches of 1250 g. Formulations developed on this work are presented in Table 1. Cocoa mass and cocoa butter were provided by Barry Callebaut Brasil S/A, sucralose by Danisco do Brasil, stevioside by Sterviafarma Industrial S.A., polydextrose and lactitol by Danisco do Brasil and WPC by Kraki Kienast & Kratschmer Ltda. The commercial (Com) product (diabetic but not reduced calorie) was produced and provided by Nestlé Brasil Ltda.

2.2. Quantitative descriptive analysis

Judges generated 16 attribute terms with definitions and references through Kelly's Repertory Grid Method (Moskowitz, 1983), using same lab developed prototypes and other commercial non-diabetic and diabetic chocolates (Table 2). References were

Table 1

Formulations of diabetic and reduced calorie milk chocolates

Ingredient (%)	Sample				
	Sucro	Sucra	Ste	Sucra/WPC	Ste/WPC
Sucrose	43	–	–	–	–
Sucralose	–	0.061	–	0.061	–
Stevioside	–	–	0.22	–	0.22
Polydextrose	–	25.8	25.8	25.8	25.8
Lactitol	–	17.2	17.2	17.2	17.2
Cocoa mass	14	14	14	14	14
Cocoa butter	21.4	21.4	21.4	15.8	15.8
WPC	–	–	–	5.6	5.6
Powdered milk	12	12	12	12	12
Skim powdered milk	9	9	9	9	9
Soy lecithin	0.5	0.5	0.5	0.5	0.5
Vanilla flavor	0.1	0.1	0.1	0.1	0.1

determined by consensus of all judges and then panelists were further trained on the product attributes using identified references. Analysis of variance (ANOVA) for each panelist and each attribute was employed and ten panelists out of eighteen were chosen for participation according to their discriminating capability ($p \leq 0.30$) and repeatability ($p > 0.05$), using data collected during training sessions; individual consensus was also considered (Damasio & Costell, 1991). The experimental samples were used during attribute determination, panelist selection and training sessions. The ten selected panelists were further trained and samples were evaluated using previously determined references in four replications for all attributes using a 9-cm unstructured line scale with anchors "none" or "weak", depending on the attribute, and "strong". Samples were presented monadically on disposable plates bearing appropriate three-digit codes using a balanced block design (MacFie, Bratchell, Greenhoff, & Vallis, 1989). Sensory analyses were carried out in individual air-conditioned (22 °C) booths with white light. Crackers and taste-free water were provided for palate cleansing.

2.3. Affective testing

Consumers evaluated both the lab developed chocolate and commercial chocolate to determine liking of appearance (APP), aroma (ARO), flavor (FLV), texture (TEX) and overall liking (OAL). They were recruited to taste regular, diabetic and diabetic/reduced calorie chocolates but they were not informed which ones they were tasting and about ingredients. Consumer affective testing was carried out using a 9-cm unstructured line scale with anchors "dislike extremely" and "like extremely". Sensitivity in defining consumer perception is greater with use of line scales than with the 9-point hedonic scale (Greene, Bratka, Drake, & Sanders, 2006). Samples coded with three-digit numbers were presented monadically in a balanced block design to 116 chocolate consumers on disposable plates. The 116 consumers consisted of 38.8% men and 61.2% women who consume milk chocolate at least once a week. Age distribution was 18–29:57.8%; 30–39:22.4%; 40–49:15.5%; and 50–69:4.3%. Sensory tests were carried out in individual air-conditioned booths. Crackers and taste-free water were provided for palate cleansing. Consumers' decisions were based solely on the sensory characteristics of the chocolates, since product information and formulation were not provided.

2.4. Statistical analyses

QDA results were analyzed by ANOVA, using two factors (panelist and sample) and interaction amongst them, followed by a Tukey's honestly significant difference (HSD) test. The acceptability results were analyzed by ANOVA, using two factors (consumer

Table 2
Descriptors used for sensory profiling of different milk chocolates

Descriptor	Definition	References
Brown color (BrC)	Light brown to dark brown (under white light)	Weak: Milka™ milk chocolate Strong: Garoto™ semi-dark chocolate
Brightness (Bri)	The degree to which the sample reflects light in one direction	Weak: Baton™ milk chocolate (Garoto) Strong: Amaro™ dark chocolate (Lacta)
Cocoa aroma (CoA)	Refer to cocoa mass used in sample production	Weak: Baton™ milk chocolate (Garoto) Strong: Barry Callebaut™ cocoa mass
Powdered milk aroma (PMA)	Refer to powdered milk used in sample production	Weak: none Strong: Milka™ white chocolate
Cocoa butter aroma (CBA)	Refer to cocoa butter used in sample production	Weak: none Strong: Naturavene™ Luxo lip protective
Sweet aroma (SwA)	Refer to sucrose	Weak: 1.0% Toddy™ cocoa powder beverage in distilled water Strong: Lacta™ white chocolate
Sweetness (Swe)	Refer to sucrose in aqueous solution	Weak: Garoto™ semi-dark chocolate Strong: Hershey's™ white chocolate
Sweet aftertaste (SAf)	Refer to sucrose in aqueous solution	Weak: none Strong: 12.5% Toddy™ cocoa powder beverage and 0.2% aspartame in Shefa0™ whole milk
Bitterness (Bit)	Refer to caffeine in aqueous solution	Weak: Baton™ milk chocolate (Garoto) Strong: Nestlé™ soluble powdered chocolate
Bitter aftertaste (BAf)	Refer to caffeine in aqueous solution	Weak: none Strong: 12.5% Toddy™ cocoa powder beverage and 0.15% stevioside in Shefa™ whole milk
Cocoa flavor (CoF)	Refer to cocoa mass used in sample production	Weak: Chokolápis™ milk chocolate (Pan) Strong: Nestlé™ soluble powdered chocolate
Powdered milk flavor (PMF)	Refer to powdered milk used in sample production	Weak: none Strong: Ninho™ powdered whole milk (Nestlé)
Hardness (Har)	The force required to cut using central incisor teeth	weak: refrigerated Polenguinho™ UHT processed cheese Strong: Amaro™ dark chocolate (Lacta)
Melting rate (MeR)	Amount of time required for solid chocolate turn into liquid while moving the tongue	Weak: Chokolápis™ milk chocolate (Pan) Strong: Suflair™ aired milk chocolate (Nestlé)
Sandiness (San)	Amount of realizable particles while chewing	Weak: none Strong: Moça™ condensed milk (Nestlé)/ Ninho™ powdered whole milk (Nestlé)/ Toddy™ cocoa powder beverage blend (3:1:1)
Adherence (Adh)	The degree to which the sample sticks on molar teeth	Weak: none Strong: Ninho™ powdered whole milk (Nestlé)

and sample), and Tukey's HSD average test. PCA with descriptive data and internal preference mapping based on overall liking data were also performed. Descriptive information obtained from the trained panel was related to the consumer preference data using partial least squares regression (PLS). All statistical analyses were carried out using XLSTAT Software at a 5% significance level.

3. Results and discussion

3.1. Quantitative descriptive analysis

Results for each sample are shown in Table 3. In relation to the brown color appearance attribute, sucralose samples (with or without WPC) were not statistically different from the conventional milk chocolate (with sucrose) or chocolates with stevioside (with or without WPC). However, the mean of the conventional chocolate was different from the samples made with stevioside ($p \leq 0.05$). There was no difference among all samples regarding brightness ($p > 0.05$), including samples with partial fat substitution. The appearance of the chocolates with partial fat replacement was similar to the appearance of conventional chocolate which is important because appearance is one of the four main sensory characteristics that plays a role in sensory acceptability (Jones, 1996).

Compared to conventional chocolate, chocolates made with high-intensity sweeteners, sucralose and stevioside, had an increase in bitterness and bitter aftertaste; this increase was smaller for sucralose than for stevioside ($p \leq 0.05$). The chocolates made with the high-intensity sweeteners were also found to have an increase in sweet aftertaste, but the increase in sweet aftertaste was similar in magnitude for both sucralose and stevioside ($p \leq 0.05$). It is important to realize that the presence of WPC as a partial fat replacer

Table 3
Attribute means for each sample^a

Attribute	Sucro	Sucra	Ste	Sucra/WPC	Ste/WPC	Com
BrC	5.1 b	5.7 ab	5.8 a	5.7 ab	6.0 a	3.0 c
Bri	4.4 a	4.2 a	4.0 a	4.0 a	4.2 a	4.0 a
CoA	4.2 a	4.2 a	4.7 a	4.2 a	4.4 a	3.3 b
PMA	3.2 bc	4.1 a	3.8 ab	4.2 a	4.2 a	2.8 c
CBA	2.5 b	2.5 b	2.3 b	2.1 b	2.2 b	6.6 a
SwA	5.4 ab	5.3 ab	4.5 c	4.8 bc	4.7 bc	5.6 a
Swe	6.2 a	5.5 b	4.5 c	5.3 b	4.2 c	5.4 b
SAf	2.4 b	4.4 a	3.9 a	4.1 a	4.1 a	1.3 c
Bit	1.5 c	3.3 b	5.7 a	2.8 b	5.5 a	1.0 c
BAf	0.8 c	2.4 b	6.3 a	2.0 b	6.2 a	0.3 c
CoF	4.7 a	4.5 a	5.0 a	4.5 a	4.8 a	3.3 b
PMF	2.9 c	4.2 ab	3.4 bc	5.0 a	4.1 b	2.8 c
Har	4.5 b	5.7 a	6.2 a	5.9 a	6.1 a	2.9 c
MeR	5.9 b	3.7 c	3.8 c	2.9 d	2.7 d	7.7 a
San	1.0 c	6.2 a	4.4 b	6.0 a	6.2 a	0.4 c
Adh	2.0 c	5.2 b	4.5 b	6.1 a	6.2 a	1.1 d

^a Means in a row followed by different letters are significantly different ($p \leq 0.05$).

did not affect bitterness, bitter aftertaste, sweet aftertaste and sweetness ($p > 0.05$). Other studies have shown that some fat replacers can affect food product attributes. Wiet, Ketelsen, Thomas, and Beyts (1993) studied the sensory characteristics of sucralose, aspartame, and sucrose in an unflavored lipid model system varying in fat levels. This study investigated the effects of fat on the sweetness intensity (vs. sucrose) of sucralose and aspartame. Results indicated a modest decrease in the intensity of sucralose and aspartame across fat concentrations, especially at lower sweetness levels. Armbrister and Setser (1994) ascertained similarities and differences in sensory

properties of control chocolate chip cookies and cookies made with two levels of selected protein, lipid, and carbohydrate-based fat replacers. They reported that carbohydrate-based fat replacers produced cookies with greater textural differences from the control than the protein or lipid-based replacers.

Sucrose replacement by high-intensity sweeteners and bulking agents with partial fat replacement by WPC caused an increase in hardness ($p \leq 0.05$). High-intensity sweeteners and bulking agents reduced the melting rate and addition of WPC caused further reduction in this attribute ($p \leq 0.05$). Sandiness was higher for diabetic and diabetic/reduced calorie chocolates (but different among them) than for the conventional chocolate ($p \leq 0.05$). Adherence was significantly increased by sugar substitution and partial fat replacement with fat replacement causing a greater increase in adherence. In addition, about 500 volatile compounds have been detected in cocoa, and each may react differently with milk fat and fat replacers (Prindiville et al., 1999). Therefore, a concern with replacing fat with WPC was that an undesirable increase in powdered milk flavors characteristic of milk chocolate could result. However, WPC in diabetic/reduced calorie samples did not affect powdered milk aroma and powdered milk flavor attributes ($p > 0.05$) compared to diabetic chocolates.

For many attributes, there was no difference between conventional, diabetic and diabetic/reduced calorie lab developed milk chocolates, such as brightness, cocoa aroma, cocoa butter aroma, and cocoa flavor ($p > 0.05$). Thompson et al. (2004) reported that

cocoa aroma is a major driver influencing acceptability of chocolate milks. Principal component analysis (PCA) was performed (Fig. 1) and the first and second principal components described 93.79% of the variance and confirmed QDA results. Since Sucra and Sucra/WPC samples and Ste and Ste/WPC samples were closer to each other than the other samples. PCA suggested that chocolates produced with the same sweetener are more similar. It also suggested that stevioside causes bitter taste which is negatively correlated with sweet taste.

3.2. Affective testing

The 116 consumers evaluated the chocolate samples for liking of appearance (APP), aroma (ARO), flavor (FLV), texture (TEX) and overall liking (OAL). Results are presented in Table 4. For appear-

Table 4
Attribute means for each sample*

Acceptance	Sucro	Sucra	Ste	Sucra/WPC	Ste/WPC	Com
APP	7.1 a	6.9 ab	7.0 ab	6.8 b	6.7 b	7.0 ab
ARO	6.3 a	5.5 c	5.8 bc	5.9 abc	5.5 c	6.3 ab
FLV	6.2 a	4.9 b	4.0 c	4.9 b	3.6 c	5.9 a
TEX	6.7 a	4.7 b	4.7 b	4.4 b	3.6 c	7.0 a
OAL	6.5 a	5.0 b	4.6 b	5.0 b	4.0 c	6.4 a

* Means in a row followed by different letters are significantly different ($p \leq 0.05$).

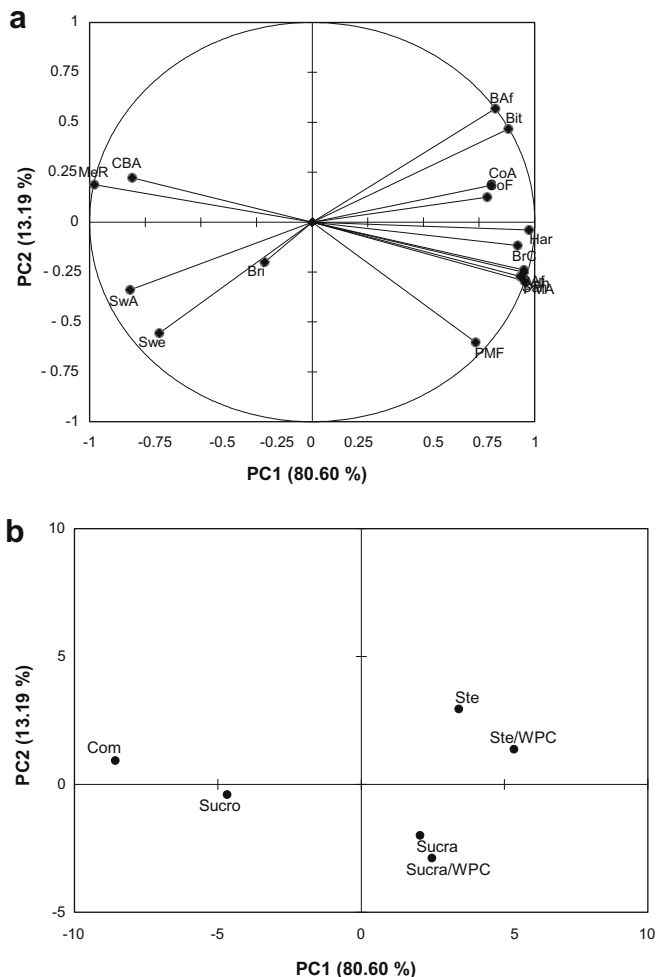


Fig. 1. Principal component analysis (PCA) loadings for descriptors (a) and chocolate samples (b).

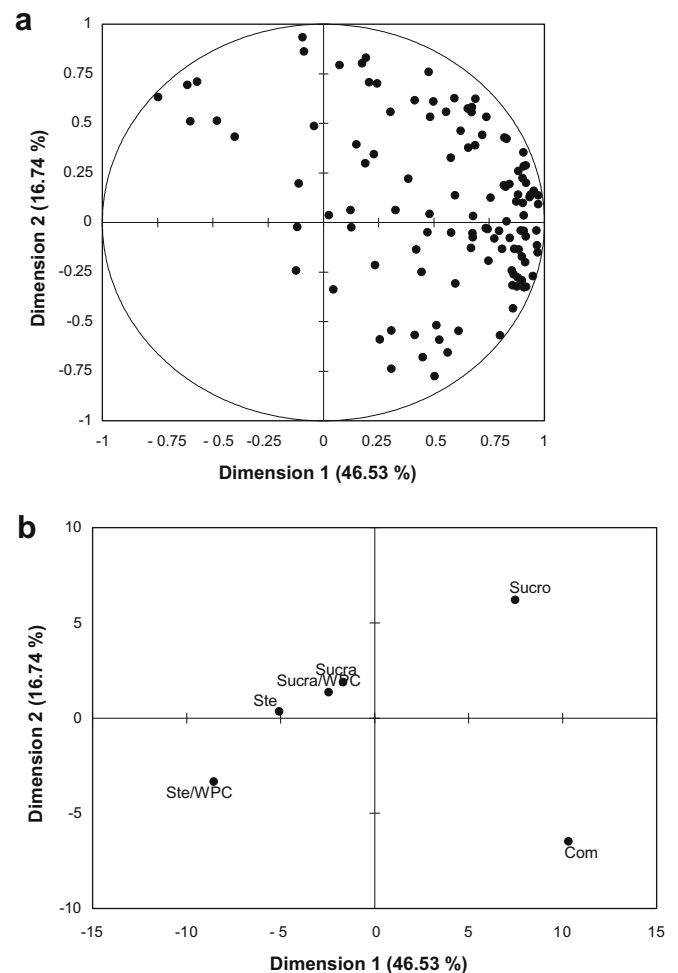


Fig. 2. Internal preference mapping indicating the positions of the consumers ($n = 116$) (a) and chocolate samples (b).

ance acceptability, there was no significant difference ($p > 0.05$) among conventional (sucrose), diabetic (sucralose and stevioside), and commercial chocolates. In addition, there was no significant difference relating to diabetic, diabetic/reduced calorie (sucralose/WPC and stevioside/WPC), and commercial samples. The mean for appearance acceptability was higher for the conventional sample than for the diabetic/reduced calorie samples ($p \leq 0.05$). Therefore, sucrose substitution by high-intensity sweeteners, sucralose or stevioside, and bulking agents did not affect APP acceptability ($p > 0.05$). On the other hand, when this substitution is combined with partial fat replacement with WPC, there was significant reduction in APP acceptability compared to the conventional chocolate.

In relation to flavor acceptability, the conventional and the commercial chocolates scored highest with no significant difference among them ($p > 0.05$). The Sucra and Sucra/WPC samples scored the second highest in FLV acceptability ($p \leq 0.05$) with no significant difference among them ($p > 0.05$). They were significantly different from and followed by Ste and Ste/WPC (also no significant difference among them). These results show that sucrose substitution by sucralose is more acceptable than substitution by stevioside since a reduction in FLV acceptability was lower for sucralose ($p \leq 0.05$). This can be due to bitter characteristics referred to stevioside in some works. Bolini-Cardello et al. (1999) reported that panelists observed that stevia leaf extract presented an increased bitter aftertaste with increased concentration, nearly covering the sweet taste starting at concentration equi-sweet to 20% sucrose. In addition, QDA results indicated a bigger increase

in attributes bitterness and bitter aftertaste when diabetic chocolates are made with stevioside instead of with sucralose, compared to conventional milk chocolates. Partial fat replacement by WPC caused an additional reduction in FLV acceptability ($p \leq 0.05$).

Conventional and commercial chocolates scored highest ($p \leq 0.05$) in TEX and OAL acceptability. They were followed by Sucra, Ste, and Sucra/WPC samples with no significant difference among them. Ste/WPC was significantly lower in TEX and OAL than all other samples. Internal preference mapping is presented in Fig. 2. A total of 63.07% of the variability was explained by the two first principal components.

Fig. 3 shows the relationship between OAL and QDA data using partial least squares regression (PLS). PLS is another modeling approach that can be used when predictive variables are inter-correlated (Tang, Heymann, & Hsieh, 2000). Fig. 3 shows that sweet aroma (SwA), melting rate (MeR), and sweetness (Swe) attributes are highly positively correlated with overall liking (OAL). In addition, acceptability is determined mainly by lack of bitterness (Bit), bitter aftertaste (BAf), adherence (Adh), and sandiness (San) attributes, which are drivers of disliking.

4. Conclusions

A perceptible sensory difference exists between conventional milk chocolate and their diabetic/reduced calorie counterparts. Results from this study have shown that on an overall basis, consumers prefer the sensory characteristics of conventional chocolate to their alternative counterparts when tasted without product information such as health claims. This result can only be attributed to the sensory attributes associated with the alternative chocolate options, since no information was provided to influence preference. The findings of this current study indicate that the crucial attributes which determine consumer acceptability in chocolate samples are sweet aroma, melting rate, and sweetness, whereas bitterness, bitter aftertaste, adherence, and sandiness were drivers of disliking. The present study indicated that the sucrose substitution by high-intensity sweeteners, sucralose and stevioside, in conjunction with bulking agents and partial fat replacement by WPC have potential as a palatable food in the formulation of diabetic/reduced calorie milk chocolates. The findings of this study could be applied by the chocolate industry to develop and reformulate the recipes of diabetic and/or reduced calorie chocolates to better meet consumer requirements.

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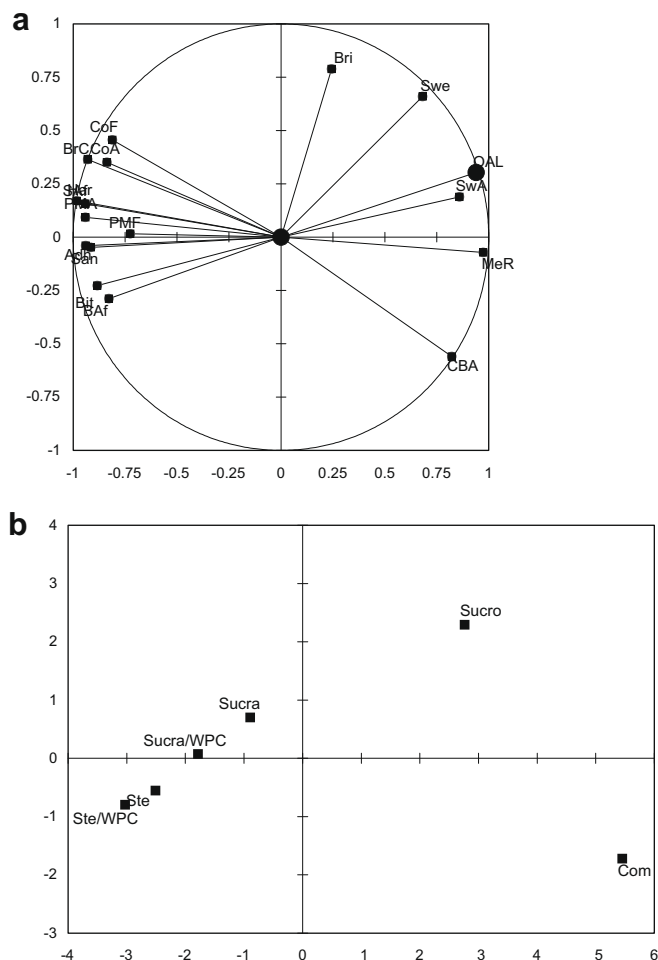


Fig. 3. Relation of acceptance (overall liking, OAL) to QDA data (a) and the positions of chocolate samples (b), using PLS regression.

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