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Sensory profile and physicochemical characteristics of mango nectar sweetened with high intensity sweeteners throughout storage time

Rafael Silva Cadena [a,*], Adriano Gomes Cruz [b], Rubens Rolim Netto [a], Wellington Freitas Castro [b], José de Assis Fonseca Faria [b], Helena Maria André Bolini [a]

[a] Department of Food and Nutrition, University of Campinas, SP, Brazil
[b] Department of Food Technology, University of Campinas, SP, Brazil

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ABSTRACT

The objective of this study was to determine the physicochemical characteristics and sensory profile of mango nectar sweetened with different high intensity sweeteners throughout storage time. The mango nectar samples were sweetened with: acesulfame-K/sucralose/neotame blend (100:50:1), sucrose, stevia with 97% rebaudioside, neotame, sucralose and a thaumatin/sucralose blend (1:1). The physicochemical analyses carried out included color (L*, a*, b*), pH, titratable acidity, soluble solids (°Brix) and ratio (Brix/titratable acidity). The sensory profile was studied using the Quantitative Descriptive Analysis (QDA). All analyses were carried out at Day zero, 60 days and 120 days of storage. The sensory descriptive and physicochemical data were correlated with an acceptance test by Partial least square (PLS) regression and External preference map (PREFMAP). Changes in sensory profile during storage time were also evaluated using Multiple Factor Analysis (MFA) and agreement between configurations was evaluated by Rv coefficient. Sucralose was shown to be the best substitute for sucrose when compared with the other high intensity sweeteners at both zero time and after 120 days of storage. The sample sweetened with sucralose showed acceptance (mean at storage time 6.4) and sensory profile equal to control (sucrose). In addition, the sweeteners stevia with 97% rebaudioside did not show off-flavor and the thaumatin/sucralose blend (1:1) also presented similar acceptance (6.16 at Day zero) and sensory profile in relation to control.

1. Introduction

The consumption of fruits and vegetables has been associated with a low incidence of degenerative diseases due to protective effects associated with the antioxidant components contained in these foods (Kauer & Kapoor, 2001). Linked to this the market of fruit juices and nectars is increasing significantly and has attracted the attention of agriculturalists, distributors and the juice and nectar industry in order to meet the demand (Renuka, Kulkami, Vijayanand, & Prapulla, 2009).

The mango (*Mangifera indica*) is considered to be a good dietetic source of antioxidants (Kim, Brecht, & Talcott, 2007), and also of ascorbic acid (Franke, Custer, Arakaki, & Murphy, 2004), carotenoids (Godoy & Rodriguez-Amaya, 1989) and phenolic compounds (Berardini, Carle, & Schieber, 2004; Berardini et al., 2005; Martinez et al., 2012). Twelve flavonoids and xanthans can be found in mangoes, mangiferin being the antioxidant is mostly encountered both in the pulp and in the skin and seeds (Ribeiro, Barbosa, Queiroz, Kno, & Schieber, 2008).

In addition, interest in healthy eating with well-balanced nutrients and calories is increasing due to dissemination of the knowledge that such eating habits are beneficial in combating the metabolic syndrome (Bayarri, Mart, Carboneel, & Costel, 2012). According to Gardner et al. (2012) nonnutritive sweeteners could facilitate reductions in added sugar intake and weight loss/weight control promoting beneficial effects on related metabolic parameters. Thus the development of fruit beverages with low calorie contents and reduced sucrose levels, without altering the sensory characteristics, is an alternative aimed at increasing the consumption of fruit juices and nectars.

Sensory analysis could be an important tool to the development of food product and to evaluate them at storage time (Gimenez, Ares, & Ares, 2012). Studies with trained panel can determine how changes at storage time affect sensory attributes and consumers can determine how these changes affect the acceptability of food product. Quantitative descriptive analysis (QDA) is a sensory profile method and has been widely used in studies that seek to identify the sensory profile of food products (Melo, Bolini, & Efraim, 2009; Rocha, Deliza, Corrêa, do Carmo, & Abboud, 2013). The application of QDA demand time, since it involves sessions to generate the descriptors, extensive training with the panel working with the references for each attribute and the statistical selection of these individuals, in order to arrive at a sensory panel capable to evaluate a product (Stone & Sidel, 2004). Some studies

* Corresponding author at: Faculty of Food Engineering, Food and Nutrition Department, University of Campinas, R. Monteiro Lobato 80, 6121 Campinas, Brazil. Tel.: +55 598 99933484.
E-mail address: rafaelcadena@gmail.com (R.S. Cadena).

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have searched for alternatives to the use of the QDA and have presented satisfactory results (Albert, Varela, Salvador, Hough, & Fiszman, 2011), but it is premature to affirm that these methods generate data with the same degree of reliability. Therefore, QDA is still the most used method for sensory characterization and studies involving food replacers.

Sucrose can be substituted by high intensity sweeteners (Cadena & Bolini, 2011). The substitution of sucrose by another sweetening agent is a challenge for researchers and industry alike, since in addition to the sweet taste, other sensory attributes may be modified. High intensity sweeteners are being more and more used by consumers who search for products with reduced sucrose contents, either for their reduced energy content or due to the demands of *diabetes mellitus* sufferers (Cadena & Bolini, 2011; Scheurer, Brauch, & Lange, 2009; Weihrauch & Diehl, 2004). Sucralose has been considered as the sweetener that best substitutes sucrose, since it provokes less sensory alterations in the product (Brito & Bolini, 2010; Cardoso & Bolini, 2008; De Marchi, McDaniel, & Bolini, 2009).

New high intensity sweeteners are being developed and perfected, such as neotame, thaumatin and stevia (Cardoso & Bolini, 2007; Moraes & Bolini, 2010). Neotame is an artificial sweetener while thaumatin and stevia are natural sweeteners. Neotame is derivative of aspartame and is 6000–10,000 times sweeter than sucrose, so its relative cost is expected to be lower than that of sucrose or aspartame at the equivalent sweetness (Nofre & Tinti, 2000). Thaumatin is obtained from a fruit (*Thaumatococcus daniellii*) native to Sudan (Africa) and stevia is extracted from leaves of the plant *Stevia rebaudiana* (Cardello-Bolini, Silva, & Damasio, 1999; Shah, Jones, & Vasiljevic, 2010). Stevia is a better known sweetener and it was suggested that to reduce the bitter taste, common to many Stevia species, it is important to obtain stevia with more rebaudioside. Neotame, developed recently, and thaumatin, although is not a new sweetener, presented only a few studies in literature. De Souza et al. (2013) used both sweeteners in mixed fruit jam and showed similar acceptance in relation to control sample. Esmerino et al. (2013) studied the influence of neotame and stevia (90% of rebaudioside) on the viability of the starter and probiotic cultures used in the production of strawberry-flavored and these sweeteners were able to obtain a probiotic, functional food with reduced calorie content. Even as De Souza et al. (2013) and other authors (Cadena & Bolini, 2012; Palazzo, Carvalho, Efraim, & Bolini, 2011) studied the isosweetness of neotame and thaumatin, however there are no studies involving the application and stability in food product.

Thus, more researchers are required to determine possible applications involving these food additives and the objective of this study was to determine the physicochemical characteristics and sensory profile of mango nectar sweetened with traditional and new high-intensity sweeteners and their relationship with consumer acceptance, throughout the 120 days of storage.

2. Material & methods

2.1. Mango nectar samples

The mango nectar samples were prepared using frozen pasteurized mango pulp (DeMarchi®) and water (1:1). The samples were sweetened with their respective sweeteners: 0.27% of the acesulfame-K/sucralose/neotame blend (100:50:1); 0.052% stevia with 97% rebaudioside; 0.0011% neotame; 0.011% sucralose and 0.013% of the thaumatin/sucralose blend (1:1). A control sample was also formulated with 7% sucrose. The ideal sucrose concentration and the relative sweetness of each of the sweeteners, values used to determine the concentration of each to be used in the nectars, were determined in a previous study (Cadena & Bolini, 2012). The samples were pasteurized at 98°/15 s, packaged in flexible multilayer plastic packs constituting of polyolefins for heat-sealing of the pack, an oxygen barrier copolymer and an internal black layer as the protective element against light and ultraviolet radiation (Walter, Faria, & Cruz, 2010), and stored at light in a room temperature (25 ± 2 °C). The mango nectar samples were analyzed after their elaboration (Day zero) and after sixty (Day 60) and one hundred and twenty days (Day 120) of storage.

2.2. Physicochemical analyses

Sample color (L*, a*, b*) was determined in a Hunterlab Colorquest II model colorimeter. The apparatus was calibrated with the D65 illuminant (6900 K), the reading being carried out using a 10 mm quartz cuvette, illuminant C and hue of 10°, with Regular Transmission (RTRAN) at the moment of reading and a white reference plate (C6299 Hunter Color Standard). The pH of the samples was determined using an Orion Expandable Ion Analyzer EA 940 pH meter. The total titratable acidity was measured using AOAC. Official Methods of Analysis of AOAC International (1997) and expressed as % citric acid. The percentage of soluble solids in terms of °Brix was determined using a Carl Zeiss 844976 Jena refractometer with AOAC. Official Methods of Analysis of AOAC International (1997). Finally the ratio was calculated as the ratio of total soluble solids (°Brix) to titratable acidity (Sabato et al., 2009).

2.3. Sensory analysis

2.3.1. Sensory profile

The candidates were preselected using Wald's sequential analysis (Amerine, Pangborn, & Roessler, 1965; Meilgaard, Civille, & Carr, 2007). Two mango nectar samples were prepared in the laboratory with different sucrose contents, previously tested to give a significant level of difference equal to 1%. Triangular tests were applied with 28 judges using these mango nectar samples (Cardoso & Bolini, 2007; Cavallini & Bolini, 2005). Thirteen judges with a mean age of 25 were chosen at the end of the pre-selection, all non-smokers and with sufficient time available to take part in the sensory profile analysis.

The pre-selected candidates chose the descriptive sensory terms for the mango nectar samples separately using the Repertory Grid method (Moskowitz, 1983), and 16 descriptive terms were generated. The definitions and references for the maximum and minimum intensity of each attribute were determined with the aid of the trained panel (Table 1). Training was carried out in nine 1-hour sessions such that each panel member had the same sensory memory in relation to the anchors (minimum and maximum) of the intensity scale for each attribute. After training, 13 judges were selected according to their discriminatory power between the samples ($p < 0.50$), repeatability ($p > 0.05$) and consensus between them (Damasio & Costell, 1991). The samples were served to the judges in plastic cups coded with three digit numbers. A 9 cm non-structured scale was used for each descriptor term, anchored at the extremes by "none" or "weak" to the left and "strong" to the right (Meilgaard et al., 2007; Stone & Sidel, 2004). The samples were evaluated in triplicate using complete balanced blocks (Walkeling & MacFie, 1995) and in monadic way with the aid of the FIZZ Sensory Software (2009).

Since the samples were evaluated throughout the storage time, the judges were re-trained in three 1-hour sessions and reevaluated for their discriminative power ($p < 0.50$), repeatability ($p > 0.05$) and consensus. They were also asked to reevaluate the references to check if they were adequate, and the samples to analyze if any change had occurred in the descriptive terms. No modification with regard to the references was found necessary during these training sessions and selection of the judges.

2.3.2. Consumers test

The acceptance tests were carried out using 120 individuals in each evaluation time (Day zero, Day 60 and Day 120) which liked and consumed mango nectar. Since this was a widely consumed product,

Table 1
List of definitions and references for each descriptive term of mango nectar samples.

Descriptor	Definition	References
Appearance		
Yellow color	Light yellow to dark yellow under white light	Weak: mustard Purity® Strong: 10 g mustard Purity® and 3.5 g spicy brown mustard Cepera®
Viscosity appearance	Velocity which the mango nectar runs down the wall of the wine glass	Weak: mango nectar Fruthos® Strong: mango concentrated juice Dafruta®
Brightness	The degree to which the sample reflects light in one direction	Weak: defrosted mango pulp DeMarchi® Strong: orange nectar Caseira®
Presence of particles	Particles that remain on the wall of the wine glass	Weak: orange nectar Caseira® Strong: Mango pulp DeMarchi® and water (1:2)
Aroma		
Mango	Refers to aroma of mango in natura	None: deionized water Strong: mango in natura
Sweet	Refers to the presence of sugars allowing the release of a sweet aroma	Weak: cooked mango — 5 min Strong: mango nectar Fruthos®
Cooked mango	Aroma of mango after a thermal process	Weak: mango nectar Fruthos® Strong: cooked mango — 12 min
Acid	Acid aroma from oxidation	None: deionized water Strong: concentrated mango juice Dafruta®
Flavor		
Mango	Flavor of mango in natura	Weak: mango pulp DeMarchi® and water (1:2) Strong: mango in natura
Sweet taste	Refers to sucrose in aqueous solution	Weak: defrosted mango pulp DeMarchi® Strong: mango nectar Fruthos® and 8 g of sucrose
Cooked mango	Flavor of mango after a thermal process	Weak: mango pulp DeMarchi® and water (1:2) Strong: cooked mango pulp DeMarchi® — 8 min
Acid taste	Refers to acid citric in aqueous solution	None: deionized water Strong: concentrated mango juice Dafruta®
Sweet aftertaste	Sugar taste residue after swallowing	None: deionized water Strong: aqueous solution of aspartame 0.2%
Bitter aftertaste	Bitter taste residue after swallowing	None: deionized water Strong: aqueous solution of acesulfame-K 0.2%
Texture		
Viscosity	Degree to which the sample resists flow under an applied force in the mouth	Weak: peach nectar Del Valle® Strong: strawberry yoghurt Activia®
Astringency	Sensation of drying-out	None: deionized water Strong: cashew concentrated juice Maguary® and water (1:9)

there was no need to establish any filter for age, sex or income of the participants. The consumers were recruited at the University of Campinas and were between 18 and 65 years of age and 60% being women.

The tests were carried out in individual, aroma-free booths with controlled temperature (22 ± 2 °C). The samples were served in plastic cups coded with 3-digit algorithms. The acceptance was determined using a linear, 9 cm hedonic scale (Stone & Sidel, 2004), anchored in “disliked extremely” to the left and “liked extremely” to the right. All the samples were presented using complete balanced blocks (Walkeling & MacFie, 1995) and in monadic way. No additional information concerning the samples was provided to the consumers, in order to prevent errors (Thompson, Chambers, & Chambers, 2009). In this study, only the data of overall liking was analyzed and related with sensory profile and physicochemical data using statistical analyses.

2.4. Statistical analyses

The training of the panel of assessors was validated for each descriptive term analyzed, applying the analysis of variance (ANOVA) to determine discriminative ability ($p < 0.50$), repeatability ($p > 0.05$) and consensus between the judges (Damasio & Costell, 1991).

The data obtained in the physicochemical analyses, QDA and acceptance test were also analyzed by ANOVA. For both analyses, when a significant difference ($p < 0.05$) was detected in some variable, Tukey's means test was applied to evaluate the difference between the samples. The results were analyzed with the aid of the software SAS System for Windows (Statistical Analysis System) (2008).

The sensory profile data were also analyzed by Multiple Factor Analysis (MFA). Each time that the respective mean table was separated as a group (Day zero, Day 60 and Day 120), the MFA was applied (Escofier & Pagès, 1994). The MFA constructs sensory map in two dimensions which allows to analyze the variation among samples and evaluation time. The agreement between each evaluation time was evaluated by computing the regression vector (RV) coefficient (Abdi, 2010). The RV coefficient has been used as a tool to assess the global similarity between factorial configurations (De Saldamando, Delgado, Herencia, Giménez, & Ares, 2013). This coefficient takes the value of 0 if the configurations are uncorrelated and the value of 1 if the configurations are homothetic. It depends on the relative position of the points in the configuration and therefore is independent of rotation and translation (Robert & Escoufier, 1976). In this study the RV coefficient was applied to measure the agreement between each evaluation time. The MFA and RV coefficient were performed with R language (R Development Core Team, 2007) using FactoMineR (Lê, Josse, & Husson, 2008).

The physicochemical analyses, QDA and overall impression data were correlated by way of the partial least square (PLS) regression analysis (Tenenhaus, Pagès, Ambroisine, & Guinot, 2005). The overall impression was the dependent variable (Y-matrix) whereas the physicochemical parameters and QDA descriptive terms were the independent variables (X-matrix). The PLS regression has been widely used in sensory studies (Bayarri et al., 2012; Cadena, Cruz, Faria, & Bolini, 2012; Cruz et al., 2011). In the external preference map (PREFMAP) (Cadena et al., 2012; Kaaki, Baghdadi, Najm, & Olabi, 2012) the consumers are represented by points, and a greater concentration of these close to a particular attribute indicates that this descriptive term is important for acceptance of the mango nectar samples. The PLS-R model was carried out using the XLStat (2007).

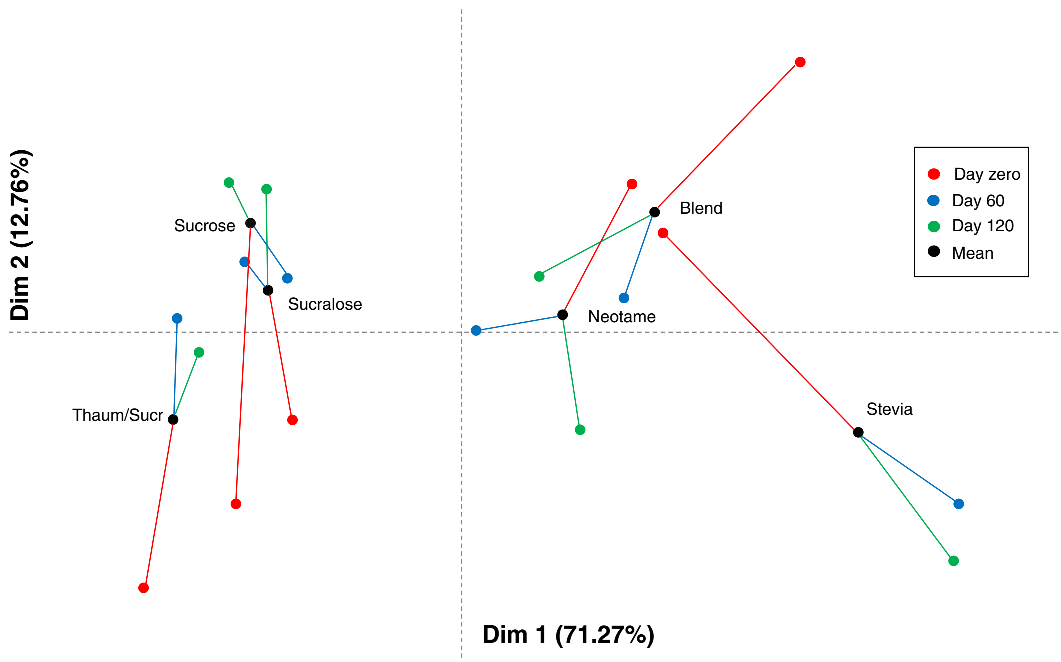

Fig. 1. Multiple Factor Analysis performed on data of sensory profile of mango nectar samples over storage time.

3. Results & discussion

3.1. Physicochemical analyses

With respect to the pH values and titratable acidity of the mango nectars (Table 2), there were no significant differences ($p > 0.05$) between the different samples, and, as also for the soluble solid content (°Brix), the values did not change during the shelf life. Since sucrose is a soluble solid (Etxeberria & Gonzalez, 2005), this showed a significant influence, with a higher °Brix in this sample (control). Thus the control mango nectar sample, sweetened with sucrose, showed a much higher ratio than the other samples, due to the increase in soluble solids in this sample. In their respective studies with prebiotic mango nectar and orange juice, respectively, Amiri and Niakousari (2008) and Renuka et al. (2009) also found no significant differences ($p > 0.05$) in these parameters during the storage time.

Table 2
Physicochemical characteristics of mango nectar samples throughout storage time.

	Blend[a]	Sucrose	Stevia	Neotame	Sucralose	Thaum/sucra[b]
Day zero						
pH	4.12^{aA}	4.13^{aA}	4.10^{aA}	4.11^{aA}	4.13^{aA}	4.11^{aA}
°Brix	7.50^{bA}	14.00^{aA}	7.83^{bA}	7.50^{bA}	7.50^{bA}	7.33^{bA}
Titratable acidity (%)	0.1501^{aA}	0.1499^{aA}	0.1538^{aA}	0.1542^{aA}	0.1565^{aA}	0.1479^{aA}
Ratio[c]	49.97	93.40	50.91	48.64	47.92	49.56
L*	50.62^{cdA}	50.17^{dA}	51.06^{cA}	52.09^{bA}	51.75^{bcA}	53.70^{aA}
a*	3.96^{bcB}	3.95^{bcB}	4.29^{abB}	3.98^{bcB}	4.50^{aB}	3.79^{cB}
b*	15.75^{cC}	16.03^{cC}	17.16^{bC}	17.19^{abC}	17.71^{aC}	17.35^{abC}
Day 60						
pH	4.12^{aA}	4.13^{aA}	4.10^{aA}	4.11^{aA}	4.13^{aA}	4.11^{aA}
°Brix	7.50^{bA}	14.00^{aA}	7.83^{bA}	7.50^{bA}	7.50^{bA}	7.33^{bA}
Titratable acidity (%)	0.1497^{aA}	0.1481^{aA}	0.1558^{aA}	0.1550^{aA}	0.1560^{aA}	0.1486^{aA}
Ratio[c]	50.10	94.53	50.26	48.39	48.08	49.33
L*	47.92^{dB}	47.81^{dB}	48.22^{cdB}	49.68^{aB}	48.78^{bcB}	49.23^{abB}
a*	4.21^{cAB}	4.57^{bcAB}	4.98^{abAB}	4.62^{bcAB}	5.27^{aAB}	$4\ 22^{cAB}$
b*	21.62^{cB}	21.09^{cB}	21.42^{cB}	22.88^{bB}	25.58^{aB}	22.65^{bB}
Day 120						
pH	4.11^{aA}	4.12^{aA}	4.08^{aA}	4.09^{aA}	4.12^{aA}	4.09^{aA}
°Brix	7.50^{bA}	14.00^{aA}	7.83^{bA}	7.50^{bA}	7.33^{bA}	7.50^{bA}
Titratable acidity (%)	0.1485^{aA}	0.1487^{aA}	0.1544^{aA}	0.1583^{aA}	0.1547^{aA}	0.1482^{aA}
Ratio[c]	50.51	94.15	50.71	47.38	47.38	50.61
L*	43.88^{dC}	43.56^{dC}	45.71^{bcC}	46.49^{abC}	44.95^{cC}	47.04^{aC}
a*	4.76^{bcA}	5.25^{bcA}	5.42^{bA}	5.52^{bA}	6.01^{aA}	4.68^{cA}
b*	26.34^{cA}	26.11^{cA}	26.25^{cA}	28.04^{bA}	31.65^{aA}	27.60^{bA}

Means with same letters (lowercase) in a same line and means with the same letters (uppercase) in the same column of each parameter indicate that samples do not have statistical difference at a significance level of 5% by Tukey's means test.
*L = luminosity; +a = red −a = green; +b = yellow −b = blue.
[a] Acesulfame-K/sucralose/neotame (100:50:1).
[b] Thaumatin/sucralose (1:1).
[c] Ratio of °Brix and titratable acidity (%).

The color parameters (L*, a*, b*) underwent significant ($p < 0.05$) alterations throughout the shelf life. The mango nectar samples darkened, the values for the parameter of luminosity (L) retracting and the intensity of the yellow color (b) increasing. In a study with passion fruit juice, Saron, Dantas, Menezes, Soares, and Nunes (2007) also found a significant ($p < 0.05$) rise in the values for luminosity. These browning alterations could be associated with non-enzymatic processes with the formation of caramel colored pigments (Damasceno, Fernandes, Magalhães, & Brito, 2008; Fennema, 2008). The possibility of enzymatic browning by polyphenoloxidase and peroxidase as a causal agent can be discarded since, in addition to using frozen pasteurized pulps, the samples suffered further heat processing during elaboration of the mango nectars, which would also help inactivate enzymes responsible for browning (Freitas, Francelin, Hirata, Clemente, & Schmidt, 2008; Khan & Robinson, 1993; Valderrama, Marangoni, & Clemente, 2001).

3.2. Sensory profile

3.2.1. Appearance & aroma

The mango nectar samples (Table 3) only showed significant ($p < 0.05$) differences in relation to the presence of particles at zero time, and after 60 days such a difference was not reported by the judges. The attribute that most suffered alteration with time was the color yellow. After 120 days, all the samples showed a darker yellow color, differing ($p < 0.05$) from the original tone. As explained above, this darkening of the samples occurred due to non-enzymatic action with the formation of caramel-colored pigments (Fennema, 2008).

As with appearance, there was little variation between the mango nectar samples with respect to the attribute of aroma (Table 3), although a greater variation occurred during the shelf life on an individual basis. As from Day 60, the mango nectar samples presented significant ($p<0.05$) increases in acid aroma, accentuating this attribute at the end of the analysis. On Day 120 the samples with sucrose and sucralose showed a smaller intensity of acid aroma ($p<0.05$) than the samples with stevia and thaumatin/sucralose. The tasters probably identified a greater intensity ($p<0.05$) of sweet aroma in the samples with sucrose and sucralose as a result of the reduced intensity of acid aroma.

3.2.2. Flavor & texture

Table 4 shows the results obtained for the descriptive terms of flavor and texture in the QDA. The Blend and Neotame samples showed the lowest intensity ($p<0.05$) of mango flavor as compared to the other samples, probably influenced by the greater intensity of sweet taste ($p<0.05$) in relation to the Sucrose sample (control).

The descriptive terms of sweet aftertaste and bitter aftertaste were influenced by the substitution of sucrose by sweeteners. The samples Blend, Stevia and Neotame showed a greater intensity of residual sweetness ($p<0.05$) than the samples Sucrose, Sucralose and Thaumatin/Sucralose. The latter sample, influenced by the addition of thaumatin, together with the other samples Blend, Stevia and Neotame, presented a greater degree of residual bitterness than the samples Sucrose and Sucralose. The occurrence of residual bitterness was reported in other studies that used acesulfame-K (Brito & Bolini, 2010) and stevia (Melo et al., 2009; Prakash, DuBois, Clos, Wilkens, & Fosdick, 2008). Cardoso and Bolini (2008) identified an herbal flavor related to the use of stevia in peach nectar, but due to the increase in the percentage of rebaudioside, this off flavor was not identified in the samples of mango nectar analyzed in the present study.

The intensity of acid taste of the mango nectar samples increased ($p<0.05$) during the shelf life as from the 60th day of storage, probably due to the production of CO_2 and acids by heat resistant microorganisms (Corrêa-Neto & Faria, 1999; Vitali & Rao, 1984; Worobo & Splittstoesser, 2005). The sample Stevia presented the greatest intensity of residual bitterness and decrease in mango flavor ($p<0.05$) as from the 60th day.

The samples showed no significant differences ($p>0.05$) in relation to texture and there was no variation in the attribute of viscosity during

Table 3
Means for the descriptive sensory attributes of appearance and aroma during the storage time.

	Blend[a]	Sucrose	Stevia	Neotame	Sucralose	Thaum/sucra[b]
Day zero						
Yellow color	4.86^{aB}	4.81^{aB}	4.98^{aB}	4.84^{aB}	4.80^{aB}	4.96^{aB}
Viscosity appearance	3.96^{aA}	4.27^{aA}	4.36^{aA}	3.93^{aA}	3.81^{aA}	3.74^{aA}
Brightness	3.85^{aA}	4.09^{aA}	4.03^{aA}	3.88^{aA}	3.62^{aA}	3.88^{aA}
Presence of particles	3.10^{abA}	3.03^{abA}	3.28^{aA}	2.65^{bcA}	2.46^{cA}	2.54^{bcA}
Mango	4.25^{aB}	4.55^{aB}	4.35^{aA}	4.53^{aA}	4.74^{aA}	4.38^{aA}
Sweet	5.36^{aA}	4.94^{abA}	4.88^{abA}	4.89^{abA}	4.82^{abB}	4.49^{bA}
Cooked mango	4.43^{aA}	4.33^{aA}	4.18^{aA}	4.19^{aA}	4.19^{aA}	4.29^{aA}
Acid	0.96^{aA}	0.77^{aB}	0.98^{aB}	0.66^{aB}	0.80^{aB}	0.93^{aB}
Day 60						
Yellow color	5.29^{aAB}	4.95^{abB}	4.90^{abB}	5.23^{aB}	4.25^{cB}	4.49^{bcB}
Viscosity appearance	3.43^{aA}	3.69^{aA}	3.68^{aA}	3.98^{aA}	4.07^{aA}	3.85^{aA}
Brightness	3.53^{aA}	3.51^{aA}	3.46^{aA}	3.57^{aA}	3.76^{aA}	3.51^{aA}
Presence of particles	2.62^{aA}	2.91^{aA}	2.65^{aA}	2.87^{aA}	2.70^{aA}	2.87^{aA}
Mango	5.02^{aA}	4.49^{bAB}	4.44^{bA}	4.59^{abA}	5.04^{aA}	4.44^{bA}
Sweet	4.42^{aA}	4.47^{aA}	4.88^{aA}	4.92^{aA}	5.01^{aB}	4.30^{bA}
Cooked mango	4.16^{aA}	4.58^{aA}	4.56^{aA}	4.69^{aA}	4.39^{aA}	4.49^{aA}
Acid	1.92^{aB}	1.41^{aA}	1.99^{aA}	1.67^{aA}	1.38^{aA}	1.84^{aA}
Day 120						
Yellow color	5.54^{aA}	5.27^{aA}	5.82^{aA}	5.78^{aA}	5.62^{aA}	5.46^{aA}
Viscosity appearance	3.63^{aA}	3.79^{aA}	3.96^{aA}	3.72^{aA}	4.01^{aA}	3.72^{aA}
Brightness	4.06^{aA}	3.51^{aA}	3.24^{bA}	3.85^{aA}	3.86^{aA}	3.83^{aA}
Presence of particles	3.35^{aA}	2.91^{aA}	3.79^{aA}	3.23^{aA}	3.14^{aA}	3.26^{aA}
Mango	5.05^{aA}	4.98^{aA}	3.99^{bcA}	4.03^{bcB}	4.61^{abA}	3.90^{cA}
Sweet	4.80^{bA}	5.37^{aA}	4.51^{bA}	4.31^{bA}	5.71^{aA}	4.31^{bA}
Cooked mango	4.53^{aA}	4.71^{aA}	4.87^{aA}	4.64^{aA}	4.35^{aA}	4.58^{aA}
Acid	2.15^{abB}	1.67^{bA}	2.68^{aA}	2.30^{abA}	1.64^{bA}	2.50^{aA}

Means with same letters (lowercase) in a same line and means with the same letters (uppercase) in the same column of each parameter indicate that samples do not have statistical difference at a significance level of 5% by Tukey's means test.

[a] Acesulfame-K/sucralose/neotame (100:50:1).

[b] Thaumatin/sucralose (1:1).

Table 4
Means for the descriptive sensory attributes of flavor and texture obtained during the storage time and the overall impression of consumers test.

	Blend[a]	Sucrose	Stevia	Neotame	Sucralose	Thaum/sucra[b]
Day zero						
Mango	4.40^{bA}	5.30^{aA}	5.09^{aA}	4.32^{bA}	5.48^{aA}	5.23^{aA}
Sweet	6.89^{aA}	5.80^{cA}	6.43^{abcB}	6.50^{abA}	6.01^{bcA}	4.93^{dA}
Cooked mango	3.72^{aA}	4.08^{aB}	4.04^{aB}	3.63^{aB}	3.59^{aB}	3.35^{aA}
Acid	1.86^{aB}	1.54^{aB}	1.86^{aB}	1.55^{aB}	1.57^{aB}	1.53^{aC}
Sweet aftertaste	5.04^{aA}	2.50^{bA}	4.62^{aB}	4.53^{aA}	2.96^{bA}	2.35^{bA}
Bitter aftertaste	1.56^{aA}	0.60^{bA}	1.33^{aB}	1.26^{aA}	0.68^{bA}	1.19^{aA}
Viscosity	3.78^{aA}	3.38^{aA}	3.57^{aA}	3.20^{aA}	3.26^{aA}	3.51^{aA}
Astringency	1.97^{aB}	0.78^{cB}	1.46^{bC}	1.49^{bB}	1.39^{bB}	1.10^{bcB}
Overall impression	5.57^{bA}	6.53^{aA}	5.55^{bA}	5.63^{bA}	6.65^{aA}	6.16^{abA}
Day 60						
Mango	5.18^{aA}	4.97^{abA}	4.37^{cB}	5.01^{abA}	5.46^{aA}	4.54^{bcA}
Sweet	6.37^{aA}	5.13^{bA}	6.96^{aA}	5.46^{bB}	4.93^{bB}	3.90^{cB}
Cooked mango	4.22^{aA}	4.73^{aA}	4.27^{aAB}	4.27^{aA}	4.17^{aA}	4.02^{aA}
Acid	2.24^{abAB}	1.88^{bAB}	2.76^{aA}	2.27^{abAB}	1.80^{bB}	2.14^{abB}
Sweet aftertaste	4.55^{bA}	2.24^{cA}	5.96^{aA}	3.45^{bA}	2.04^{cA}	1.75^{cA}
Bitter aftertaste	1.75^{bcA}	1.02^{cdA}	4.39^{aA}	1.81^{bA}	1.04^{cdA}	0.97^{dA}
Viscosity	3.09^{bA}	3.66^{abA}	3.74^{abA}	3.60^{abA}	4.19^{aA}	3.21^{aA}
Astringency	1.89^{aB}	1.89^{aAB}	2.34^{aB}	1.97^{aB}	1.72^{aB}	1.87^{aB}
Overall impression	4.43^{bB}	6.22^{aA}	4.47^{bB}	5.33^{bA}	6.61^{aA}	5.12^{bB}
Day 120						
Mango	5.12^{aA}	5.07^{aA}	4.38^{bB}	4.51^{bA}	5.17^{aA}	4.45^{bA}
Sweet	6.39^{aA}	5.23^{bA}	6.84^{aA}	5.40^{bB}	5.47^{bAB}	4.19^{cB}
Cooked mango	4.62^{aA}	4.76^{aA}	4.87^{aA}	4.79^{aA}	4.46^{aA}	4.44^{aA}
Acid	2.48^{aA}	1.77^{bA}	2.64^{aA}	2.55^{aA}	2.42^{aA}	2.96^{aA}
Sweet aftertaste	3.84^{bB}	2.12^{cA}	6.27^{aA}	4.43^{bA}	2.38^{cA}	1.75^{cA}
Bitter aftertaste	1.93^{bA}	1.06^{cA}	3.58^{aA}	1.98^{bA}	1.08^{cA}	1.33^{bcA}
Viscosity	3.36^{aA}	3.72^{aA}	3.66^{aA}	3.60^{aA}	3.78^{aA}	3.41^{aA}
Astringency	2.82^{abA}	2.89^{abA}	3.46^{abC}	3.56^{aA}	2.70^{bA}	3.40^{abA}
Overall impression	3.77^{cC}	6.01^{aB}	3.65^{cC}	4.42^{bB}	6.04^{aB}	4.48^{bC}

Means with same letters (lowercase) in a same line and means with the same letters (uppercase) in the same column of each parameter indicate that samples do not have statistical difference at a significance level of 5% by Tukey's means test.
[a] Acesulfame-K/sucralose/neotame (100:50:1).
[b] Thaumatin/sucralose (1:1).

the storage time. However the attribute of astringency was identified with greater intensity ($p < 0.05$) in the Blend sample at zero time, and in general this attribute increased with storage time, differing significantly ($p < 0.05$) after 120 days of storage, associated with the deterioration of the samples and consequent production of the acids that give rise to astringency.

The Stevia mango nectar was the sample presenting the greatest number of attributes (brightness, mango aroma and flavor, sweet aroma and taste, acid taste, bitterness aftertaste and sweetness aftertaste) showing significant differences ($p < 0.05$) in relation to the Sucrose sample after 120 day of storage while mango nectar sweetened with sucralose presented significant difference ($p < 0.05$) only in acid taste.

3.3. Multiple Factor Analysis

The MFA allows a quick analysis of the behavior of the samples over the storage time using a two dimensional map (Fig. 1). Each colored point represents a distinct moment of evaluation (Day zero, Day 60 and Day 120) and the black one is a mean point. The distance between each point enables to evaluate similarities and differences among each sample and each evaluation time, i.e. if a sample is distant from another, this represents that these two samples are different and if the scenery is the opposite and the samples are very close, this represents that the samples are similar.

The dimension 1 of MFA explains 71.3% of the variation among samples and separated them in two groups: a group with control sample (Sucrose) and samples that used sucralose to sweeten the mango nectar and other group that used Stevia, Neotame and Blend. The dimension 2 explains 12.8% and separated the samples Thaum/Sucr and Stevia of their first group. The less distance between Sucrose and Sucralose represents more degree of similarities in sensory profile among these samples while the greater distance between Sucrose and Stevia represents that these samples are very different.

The colored points, as mentioned, represent each evaluation time. The red point represents Day zero, i.e. the day of sample elaboration. In all samples that were noted the red point (Day zero) is far from blue (Day 60) and green points (Day 120) and these two points are close together. The changes in sensory profile of the mango nectar samples were higher among Day zero and Day 60 than Day 60 and Day 120. The greater distance between Day zero and Day 60 represents that the sensory characteristics of all mango nectar samples suffered changes in storage. In addition, these changes in sensory perception were lower after the 60th day of storage and that was showed in MFA by the proximity of the points that represent Day 60 and Day 120.

The Rv coefficient measures the agreement between each evaluation time, i.e. a greater value of RV means that the configuration of this evaluation time is similar than one another. The RV coefficient of the sample configurations in Day 60 and Day 120 was 0.90 and was the higher agreement between configurations. While the RV coefficient of Day zero–Day 60 and Day zero–Day 120 was 0.55 and 0.48, respectively. This confirms what were observed in MFA, that the changes in sensory profile were higher in the first half of the research (Day 0 to 60th) than in the second half (Day 60th to 120th).

3.4. Relationship between physicochemical parameters, sensory profile data and consumer data

The correlation of the physicochemical and descriptive data with the overall impression of consumer test by way of the Partial least square (PLS) regression allows for elucidation of which attributes contributed positively and negatively to acceptance of the mango nectar samples and verify their degree of influence (Fig. 2).

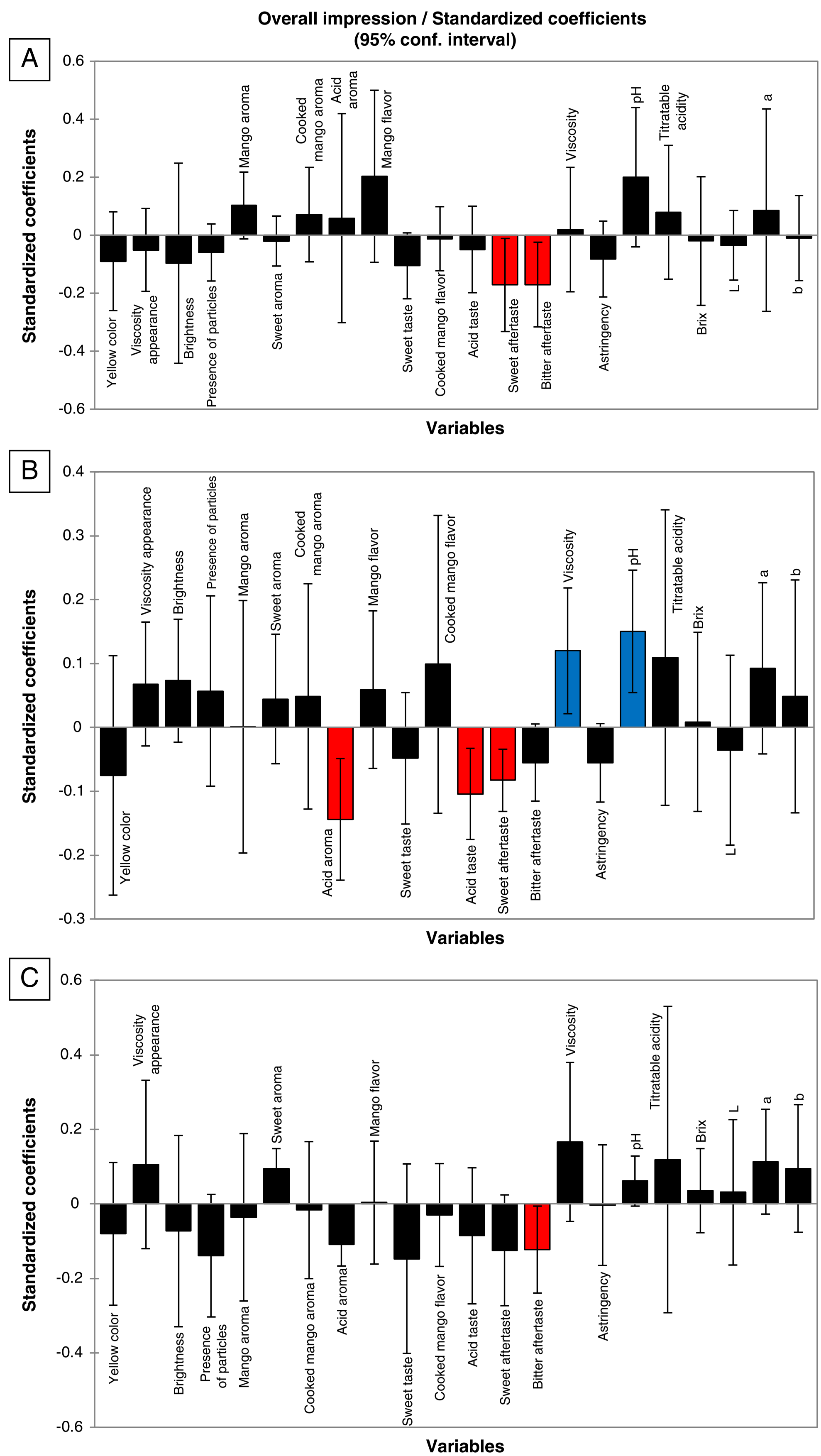

Fig. 2. 95% jackknife confidence intervals of the PLS regression coefficients. (A) Day zero; (B) Day 60; (C) Day 120.

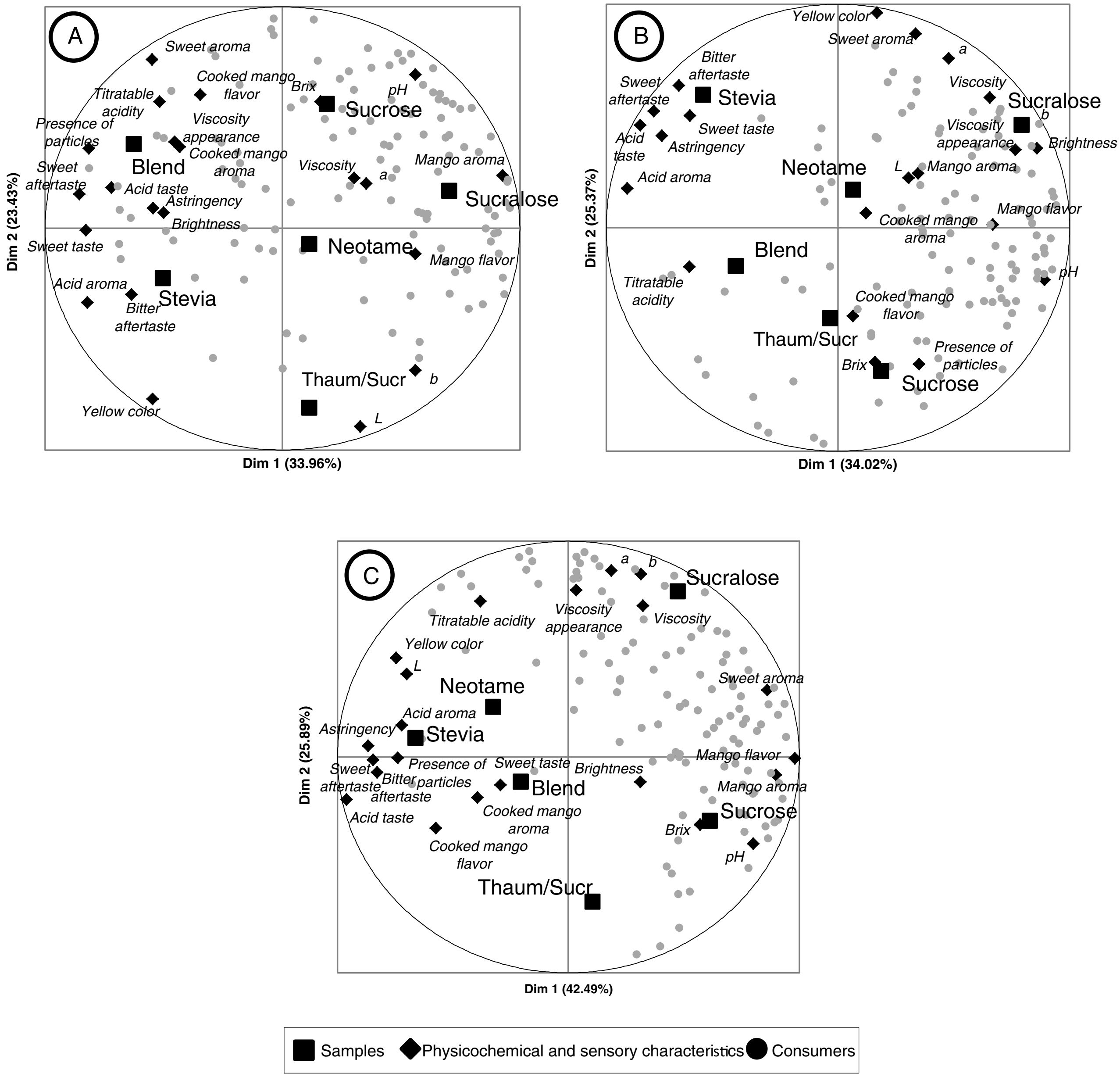

Fig. 3. External preference map obtained by partial least square regression of the sensory profile and physicochemical data and responses for overall impression of the mango nectar samples. (A) Day zero; (B) Day 60; (C) Day 120.

The columns of descriptive terms found in the positive part of the Y axis or Standardized Coefficients axis are considered positively important for acceptance of the mango nectar, whereas columns found in the negative part of the Y axis represent attributes whose presence and intensity were negative for sample acceptance.

The size of the columns represents the influence of the attribute in acceptance of the sample, both positively and negatively. Thus the larger the column the greater the influence of the descriptive term on the result for acceptance of that mango nectar sample. In addition it should be observed that if the standard deviation crosses the Y axis, this indicates that the influence of the attribute cannot be considered with an interval of confidence of 95% (black columns). The columns of attributes that affect the acceptance positively are colored in blue and the columns of attributes that affect the acceptance negatively are colored in red.

The PLS regression of data allows for the identification of which attributes, in the intensities presented, influenced acceptance of the mango nectar samples positively or negatively in an interval of confidence of 95% in each evaluation time. Sweet aftertaste and bitter aftertaste affect the acceptance negatively in Day zero. Those attributes are not expected in mango nectar but are common when sucrose replacers are used (Cadena & Bolini, 2011). At 60th day of storage, acid aroma and acid taste, attributes related to the deterioration of the samples, affect the acceptance negatively, even as sweet aftertaste. At the end of the study, at 120th day, only bitter aftertaste affected the sample acceptance negatively. Probably with the increase in all samples, sensory attributes related to sample deterioration did not influence the sample acceptance with an interval of confidence of 95%.

Fig. 3 shows the results obtained in the PREFMAP in each evaluation time. The consumers (circles) were close to the samples (squares) that had the largest acceptance means. Initially at Day zero (Fig. 3a), Sucrose (control sample), Sucralose and Neotame were the samples with the largest concentration of consumers around. However, over the PREFMAP at Day zero, it was noted that some consumers are close to samples Blend and Stevia suggesting that these people preferred the mango nectar samples sweetened with these sweeteners. In addition, the proximity of consumers to certain attributes (lozenges) shows that these attributes were important to establish a greater degree of acceptance of the samples. Thus, the attributes of mango aroma and mango flavor characterized the more accepted samples and the intensities found in these samples influenced the acceptance of these samples by consumers. On the other hand the samples Blend and Stevia were close to attributes that could reveal defects. The former (Blend) was characterized by astringency and sweet aftertaste, whereas the second was characterized by the presence of cooked mango flavor and bitter aftertaste. These attributes, associated with a reduced intensity of those attributes that contribute to sample acceptance, probably influenced the fact that the samples Blend and Stevia received lower mean scores for acceptance than the other mango nectar samples. Over storage time at Day 60 (Fig. 3b), the concentration of consumers close to samples Sucrose, Sucralose, Neotame and, now, Thaum/Sucr increased. In contrast, the number of consumers that accepted more sample Stevia and Blend decreased. Furthermore, at this point of storage, it was clearly noted by PREFMAP that attributes not expected by consumers in a mango nectar sample and peculiar when high intensity sweeteners are used (sweet aftertaste and bitter aftertaste) and attributes related to the deterioration of the product (acid aroma, acid taste and astringency) were close to the sample Stevia, which was the less accepted by consumers at Day 60. Fig. 3c shows the PREFMAP after 120 day of storage. Consumers that concentrated around samples Sucrose and Sucralose increased again and attributes mango aroma and mango nectar were responsible in separating these samples, as well as astringency, acid taste and other off flavors contributed to separate Stevia, Neotame and Blend.

4. Conclusions

The search for new sweeteners and the improvement of already existing and regulated ones will always present new possibilities for researchers and industry. The present study confirmed sucralose as the best substitute for sucrose when compared with other high intensity sweeteners at zero time and after 120 days of storage. However, it is interesting to note that stevia with 97% rebaudioside, a sweetener of natural origin, and the blend thaumatin/sucralose (1:1) of which thaumatin is also of natural origin, were also highly similar to sucrose at zero time. After 120 days of storage, the thaumatin/sucralose (1:1) blend showed a sensory profile closer to that of sucrose than the sample with stevia. The high intensity sweeteners used in this study presented a good stability in mango nectar. According to the MFA, after the 60th day of storage was found sensory alterations linked with nectar deterioration (acid aroma and acid taste).

The appearance of undesirable attributes according to the consumer, such as sweet aftertaste and bitter aftertaste is still a constant problem when dealing with high intensity sweeteners. These attributes, according PREFMAP and PLS regression collaborated to the less acceptance of samples with more intensity of them. Thus, more studies are required aimed at developing new sweeteners and, especially, the discovery and improvement of those of natural origin.

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