International Journal of Food Science + Technology

Original article

High-intensity sweeteners in espresso coffee: ideal and equivalent sweetness and time–intensity analysis

Bruna M. Azevedo,[1]* Flávio L. Schmidt[2] & Helena M. A. Bolini[1]

1 Food and Nutrition Department, Faculty of Food Engineering, University of Campinas, R. Monteiro Lobato 80, 6121 Campinas, Brazil
2 Food Technology Department, Faculty of Food Engineering, University of Campinas, R. Monteiro Lobato 80, 6121 Campinas, Brazil

(Received 24 November 2014; Accepted in revised form 19 January 2015)

Summary The efficient substitution of sucrose by a sweetener in beverages requires the application of some sensory techniques. First, one must determine the concentrations of the sweeteners under study, equivalent in sweetness to the ideal sucrose concentration. In addition, it is fundamental to determine which is most similar to sucrose. The objectives of this study were to determine the ideal sweetness for espresso coffee and the equivalent concentrations in sweetness of different sweeteners, as well as characterise the time–intensity profile of each sweetener in relation to sweetness. The sweeteners evaluated were sucralose, aspartame, neotame, a cyclamate/saccharin mixture (2:1) and stevia. The sucrose concentration considered ideal by consumers was 12.5% (w/v), and the equivalent concentrations of the sweeteners were 0.0159% for sucralose, 0.0549% for aspartame, 0.0016% for neotame, 0.0359% for the cyclamate/saccharin mixture and 0.0998% for stevia. The time–intensity analysis indicated that possibly the sweeteners neotame, aspartame and sucralose would be the best substitutes for sucrose.

Keywords Equivalent sweetness, espresso coffee, ideal sweetness, sweeteners, time–intensity analysis.

Introduction

Coffee is one of the most widely consumed beverages throughout the world due to its unique sensory properties and physiological effects (Borém *et al.*, 2013). Coffee consumption has been related to many health benefits, due to its strong antioxidant activity and inhibition of lipid peroxidation (Napolitano *et al.*, 2007). Coffee also possesses protective effects against the risk of advanced liver disease and hepatocellular carcinoma (Vitaglione *et al.*, 2010).

The consumption of coffee is growing in Brazil; in 2013, it reached 4.87 kg of roasted ground coffee per inhabitant per year, representing an increase of 30.9% in relation to 2003, for example. This increase is because of factors such as improvement in the quality of the coffee offered on the internal market, consolidation of the gourmet or special coffee market, a significant improvement in the perception of coffee in relation to health benefits and, especially, the increase in consumer purchasing power and consumption (ABIC, 2014).

The discovery of espresso coffee by Brazilians follows a global trend to consume higher standard coffee, produced with fresh and selected ground coffee with high-quality and intense flavours and aromas.

Nowadays, the growing concern with health and the greater incidence of overweight, metabolic syndrome and diabetes have resulted in an increased interest in reduced calorie foods and beverages, especially those that use sweeteners as sucrose substitutes (Dabelea *et al.*, 2007). This trend is also seen when drinking the traditional Brazilian ‘demi-tasse coffee’.

Various types of high-intensity sweetener are permitted by Brazilian legislation (Brasil, 2008), for use in dietetic foods and beverages, with defined quantities of acceptable daily intake. These sweeteners have specific sensory characteristics that can also differ based on temperature, acidity, sweetener concentration and the chemical composition of the food product (Cardoso & Bolini, 2007). Paixão *et al.* (2014) showed that, in chocolate milk beverage, the temperature at the time of consumption influenced the perception of sweet taste beyond differences in the amount of fat present in the product.

To substitute sucrose successfully, one should first know the necessary sweetener concentration and its equivalent sweetness in relation to sucrose (Bolini-Cardelo *et al.*, 1999). Magnitude estimation is the most common method used to obtain the equivalent sweetness as related to sucrose (Souza *et al.*, 2011).

*Correspondent: Fax: +55-19-35214059;
e-mail: bma1703@fea.unicamp.br

doi:10.1111/ijfs.12774

Of the existing sensory methods available to determine the ideal amount of a particular compound, such as sucrose, that should be added to a food to improve consumer acceptance and preference, the just about right scale is the affective method most applied, not only because of the reliability and validity of its results, but also for its simplicity of use with groups (Vickers, 1988).

According to Bolini-Cardelo *et al.* (1999), the replacement of sucrose by alternative sweeteners can produce changes in the perception of the sweet taste. The aim of the time–intensity technique was to monitor these changes to find the sweetener that is most similar to the sensory profile of sucrose. This sensory technique has been used to analyse many food matrices such as chocolates (Palazzo & Bolini, 2014), gluten-free bread (Morais *et al.*, 2013), mixed fruit jam (Souza *et al.*, 2013) and ice creams (Cadena & Bolini, 2011), thus demonstrating the importance of such a technique in the sensory evaluation of foods.

This study aimed to analyse the ideal (sucrose) and equivalent sweetness and carry out a time–intensity analysis of the sweet taste stimulus in espresso coffee sweetened with different high-intensity sweeteners.

Material and methods

Material

The roasted gourmet coffee (100% Arabica beans) used in this study was provided by the Canecao Coffee Company Ltd. in the City of Campinas – SP, Brazil. According to information on the package, the roasted beans were of medium roast and characterised as beans producing a strictly soft beverage. A standard espresso coffee machine (Jura Impressa F50® - JURA Elektroapparate AG, Switzerland) was used to prepare the beverage. For each 100 mL of espresso coffee produced, approximately 35 g of roasted beans and 165 mL of deionised water were used.

The espresso coffee samples were sweetened with different high-intensity sweeteners and sucrose. The sweeteners used were as follows: sucralose (Pharmanostra®, Rio de Janeiro, RJ, Brazil), aspartame (All Chemistry do Brasil Ltda, Jabaquara, SP, Brazil), neotame (SweetMix, Sorocaba, SP, Brazil), cyclamate/saccharine mixture (2:1) (Tovani Benzaquen®, São Paulo, SP, Brazil, and Pharmanostra®, respectively), stevia containing 95% rebaudioside A (Stevita, Maringá, PR, Brazil) and sucrose (Sigma Chemical Co., St. Louis, MO, USA).

After preparing the espresso coffee, each sample was sweetened with its respective sweetener. Solutions of the sweeteners were prepared in deionised water so that each sample of espresso coffee could be sweetened correctly, as some of the sweeteners were used in very small amounts, which would increase the weighing error. Only aspartame was weighed separately into each thermal cup, considering its low water solubility. Sucrose was also added to each thermal cup separately.

The samples (30 mL/90 °C) were offered in disposable thermal styrofoam cups, coded with three-digit random numbers.

Methods

Sensory analysis

The tests were carried out in individual air-conditioned booths (22 °C) in the Sensory Science and Consumer Study Laboratory of the School of Food Engineering/University of Campinas, Campinas, Brazil (FEA/UNICAMP).

Ideal sweetness determination

Initially, the ideal concentration of sucrose to be added to the espresso coffee sample was determined by the acceptance test, using the just about right (JAR) scale (Meilgaard *et al.*, 2004). The test was carried out by sixty coffee consumers, recruited from the University of Campinas campus by way of posters and personal invitation. The consumers reported consuming at least one cup of coffee a day. The samples were sweetened with sucrose at five concentrations: 5.0%, 7.5%, 10.0%, 12.5% and 15.0%, that represent a good number for this analysis. Other studies with coffee used five or more coffee samples served monadically and sequentially (Albanese *et al.*, 2009; Moraes & Bolini, 2010; Varela *et al.*, 2014).

The consumers evaluated the sweetness by placing a mark in one of the boxes on a nine category scale from 'not nearly sweet enough' = −4, to 'much too sweet' at the other extreme = +4 and 'just right' in the middle (corresponding to zero) (Meilgaard *et al.*, 2004). A complete balanced block design was used (MacFie *et al.*, 1989), and the samples were presented sequentially in a monadic way.

The results were analysed by simple linear regression between the hedonic values and the sucrose concentration (Guinard *et al.*, 1997).

Selection of judges for equivalent sweetness analysis and time–intensity analysis

The judges were recruited by personal invitation and the placing of posters around the Faculty of Food Engineering/UNICAMP and around the rest of the university campus in other nearby faculties.

The selection was made using Wald's sequential method (Souza *et al.*, 2011), in which triangle tests with twenty-five judges were used to select those with good sample discriminating ability ($P = 0.45$; $P1 = 0.70$; α and $\beta = 0.05$). Two samples were sweetened to provide a significant difference of 0.1% in sweetness, predetermined by a paired comparison test with thirty judges. The concentrations used were 9% and 12% (w/v) of sucrose. Eighteen assessors were selected and trained to correctly use the magnitude scales with different sweetness intensity standards.

Of the eighteen judges selected in the equivalent sweetness test, 13 were chosen to take part in the time–intensity analysis, based on their capacity to work with a computer as well as their discriminative power, repeatability and agreement with the panel of assessors (Damásio & Costell, 1991).

Equivalent sweetness analysis

The relative sweetness of the high-intensity sweeteners was measured using the magnitude estimation method (Stone & Oliver, 1969).

The espresso coffee samples were presented according to a balanced complete block design (Wakeling & MacFie, 1995), followed by a reference sample sweetened with sucrose at the previously determined ideal concentration, with which the sweetness equivalence was evaluated.

Table 1 shows the concentrations used in these determinations, based on previous studies about equi-sweetness (Dutra & Bolini, 2013). For the data analysis, the values obtained by the assessors for the concentrations evaluated were normalised and their logarithms calculated.

A graph of concentration vs. sensory response was constructed with logarithmic coordinates. A linear regression of the points was obtained for each compound, representing the Steven's power function: $S = a \cdot C^n$ (S = intensity of the stimulus perceived, C = concentration of the stimulus, a = antilog of the Y-intercept, n = angular coefficient) (Moskowitz, 1974). The statistical analyses were carried out using the SAS statistical program version 8.2 (SAS, 2012).

The sweetener potency was calculated from the ratio between the optimal sucrose concentration (w/v) and the equivalent concentration of sweetener providing the same sweetness in the espresso coffee.

Table 1 Concentration of sucrose, sucralose, aspartame, neotame, cyclamate/saccharin blend (2:1) and stevia used for the equivalent sweetness analysis

Sweeteners	Concentrations providing equivalent sweetness*				
Sucrose	4.9	7.8	12.5	20.0	32.0
Sucralose	0.0063	0.0100	0.0160	0.0256	0.0410
Aspartame	0.0200	0.0340	0.0550	0.0880	0.1408
Neotame	0.0007	0.0010	0.0017	0.0027	0.0041
Cyclamate/saccharin blend (2:1)	0.0141	0.0225	0.0360	0.0576	0.0923
Stevia	0.0391	0.0625	0.1000	0.1600	0.2560

*Concentration in percentage (w/v).

Time–intensity analysis

The sweetness intensity was also analysed as a function of time in the six samples of espresso coffee.

The test was carried out using the computers present in the individual booths, which were equipped with the software *Time–Intensity Analysis of Food and Tastes* – TIAFT (Universidade Estadual de Campinas – UNICAMP, 2012), developed at the Laboratory of Sensory Science and Consumer Studies of the Faculty of Food Engineering, UNICAMP.

Training session

The judges determined the maximum sweetness reference for training in a consensual way. The training that aimed to form a sensory memory and equalisation amongst the judges was carried out by direct contact with the maximum intensity reference defined for the attribute of sweetness (espresso coffee with 15% sucrose w/v). Six training sessions were required, each lasting 1 h.

Evaluation of the attribute of sweetness by the time–intensity analysis

The test conditions were previously standardised on the TIAFT software: (i) initial waiting time, 10 s, (ii) time with the sample in the mouth, 10 s, (iii) time after ingestion of 1 min and 30 s, and (iv) structured linear scale from zero to nine (0 = none, 4.5 = moderate, 9 = strong) (Cadena & Bolini, 2011).

At the start of the analysis, the judges received an example of the maximum sweetness intensity reference with a concentration of 15% sucrose. Having first been instructed to place the entire sample volume (10 mL) in their mouths, the assessors followed the instructions from the programme. They evaluated the sweetness of the six espresso coffee samples by way of a monadic presentation with three repetitions using a complete balanced block design (Wakeling & MacFie, 1995), registering the intensity of the attribute as a function of time passed using the mouse, on a 10-point scale with nine numbers (0 = none, 4.5 = moderate and 9 = strong) (Cadena & Bolini, 2011).

After finishing the test, a time–intensity curve could be obtained using the TIAFT program with the following parameters: (i) maximum intensity registered by the judge (I_{max}); (ii) time during which the maximum intensity was registered (TI_{max}); (iii) time after ingestion of the sample when the attribute being evaluated was no longer perceived by the judge (T_{tot}); (iv) time–intensity graph; and (v) the area under the time–intensity curve (Area) (Palazzo & Bolini, 2009).

The parameters collected were submitted to an analysis of variance – ANOVA (sources of variation: samples, judges and the sample x judge interactions) and to Tukey's test to compare the sample means. The principal component analysis was also carried out using SAS (2012).

Results and discussion

Ideal sweetness determination

This analysis made it possible to determine the ideal concentration of sucrose to be added to the espresso coffee samples. The opinion of the sixty consumers was transformed into numerical data (−4 to +4), and the ideal sweetness corresponded to the value of 0. Means were calculated for the scores awarded by the subjects for each sucrose concentration evaluated. A linear regression of the perceived intensity values obtained for the sucrose concentrations showed that the ideal sweetness for the espresso coffee was obtained with 12.5% sucrose (Fig. 1).

Moraes & Bolini (2010) determined the ideal sweetness for roasted ground coffee and found the same result, 12.5% sucrose. Fonteles *et al*. (2010) found a very similar value of 12% for the ideal sucrose concentration in coffee. The results found for the ideal sucrose concentration in espresso coffee were different from those found for chocolate dairy dessert, 8.13% (Morais *et al*., 2014a), acerola nectar, 8% (Dutra & Bolini, 2013), mango nectar, 7% (Cadena & Bolini, 2012), and petit Suisse cheese, 17% (Souza *et al*., 2011). Based on these results, it was concluded that the ideal sucrose concentration varies with the type of product being evaluated. These differences showed the importance of carrying out a sensory analysis for each product.

Equivalent sweetness analysis and the determination of sweetener potencies

Table 2 reported values for R above 0.95 for all the sweeteners evaluated. However, the value obtained for stevia with 95% rebaudioside A in the espresso coffee was lower than that of the other sweeteners. This fact may be related to the characteristic bitter taste presented by stevia extracts, which may have influenced the perceived sweetness of the product (Dutra & Bolini, 2013).

The relationship between sweetness intensity and the concentration of each sweetener was represented graphically on log–log coordinates in Fig. 2.

The sucrose line is widely separated from the others, demonstrating that for the same sweetness perception, a much higher concentration of sucrose is required. The sweetener requiring the lowest concentration to induce the same sweetness perception was neotame, followed by sucralose. The same result was found for acerola nectar by Dutra & Bolini (2013).

The equivalent concentration of each sweetener was calculated from the power function of each one and the sweetener potency in relation to sucrose (Table 2).

As shown in Table 2, neotame was the sweetener with the highest sweetener potency equivalent to 12.5% of sucrose in espresso coffee, being 7812 times sweeter than sucrose. Thus, to substitute 12.5% sucrose with neotame in espresso coffee, 0.0016% of neotame is required. This result is similar to that found by Esmerino *et al.* (2013) for probiotic Petit Suisse cheese containing 15.2% sucrose, where neotame was 6082 times sweeter.

On the other hand stevia with 95%, rebaudioside A was the sweetener with the lowest sweetener potency in espresso coffee, being only 125 times sweeter than 12.5% sucrose. Moraes & Bolini (2010) also found stevia to be the sweetener with the lowest potency in roasted ground coffee beverages containing 12.5% sucrose, being only 75.2 times sweeter than sucrose. The bitterness of roasted ground coffee beverages was probably the factor that interfered with the perception of sweetness of stevia leaf extract, by masking the sweetness.

Sucralose was found to present a sweetness potency of 786. This value is higher than that found by Moraes

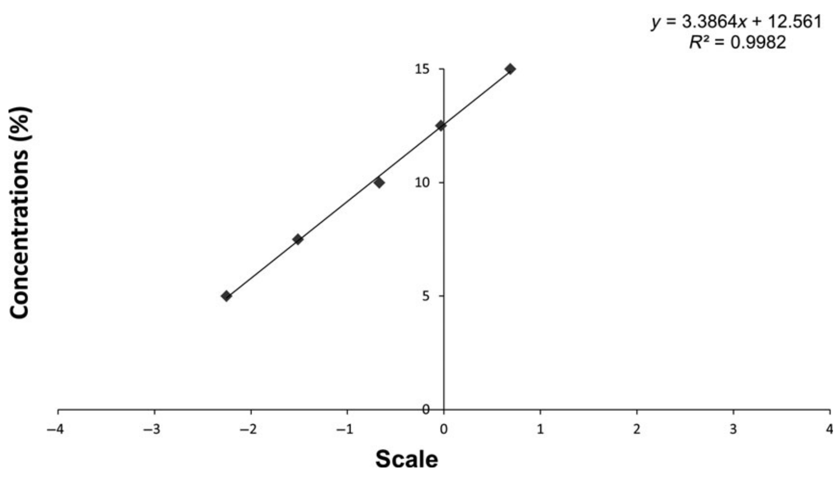

Figure 1 Ideal sucrose concentration to be added to espresso coffee, obtained with the 'just about right' scale.

Table 2 Angular coefficient, Y-intercept, linear correlation coefficient, power function of each sweetener, concentration and sweetener potency equivalent to sucrose at 12.5% (w/v)

Sweetener	Angular coefficient	*Y*-intercept	*R**	Power function	Concentration equivalent to sucrose 12.5% (w/v)	Sweetener potency at 12.5% (w/v)
Sucrose	1.2295	−1.3488	0.9899	$S = 0.04478 \cdot C^{1.2295}$	–	–
Sucralose	1.1831	2.1255	0.9937	$S = 133.517 \cdot C^{1.1831}$	0.0159	786.1
Aspartame	1.1462	1.4444	0.9779	$S = 27.8239 \cdot C^{1.1462}$	0.0549	227.7
Neotame	1.1306	3.1386	0.9943	$S = 1376.05 \cdot C^{1.1306}$	0.0016	7812.5
Cyclamate/saccharin blend (2:1)	1.0358	1.4952	0.9869	$S = 31.2774 \cdot C^{1.0358}$	0.0359	348.2
Stevia	0.9703	0.9705	0.9672	$S = 9.3440 \cdot C^{0.9703}$	0.0998	125.2

**R* = Linear correlation coefficient.

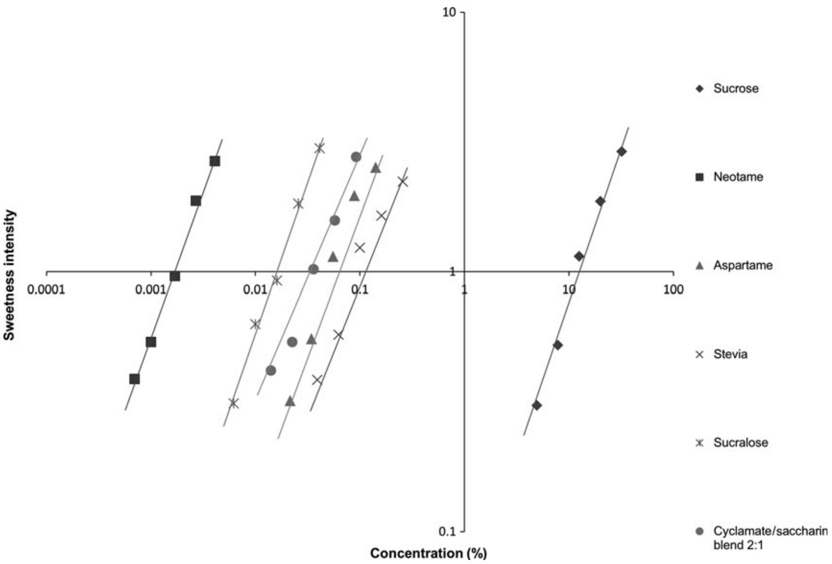

Figure 2 Relation between sweetness intensities and sweetener concentrations corresponding to 12.5% of sucrose concentration in espresso coffee.

& Bolini (2010) for the equivalence of 9.5% sucrose in instant coffee, which was 599, and that found by Souza *et al.* (2011) for the equivalence of 17% sucrose in petit Suisse cheese, which was 261.

The sweetener power of aspartame was 227 for espresso coffee, higher than the value found by Moraes & Bolini (2010) for roasted ground coffee beverages containing 12.5% sucrose, which was 172.

The cyclamate/saccharin (2:1) mixture was shown to be 348 times sweeter than sucrose, a value higher than that of 223.5 found by Cavallini *et al.* (2005) for mango juice with 8% sucrose, and of 214 found by Moraes & Bolini (2010) for roasted ground coffee beverages with 12.5% sucrose.

Varzakas (2012) and Varzakas & Chryssanthopoulos (2012) indicate generalised potencies for different sweeteners. Therefore, several studies (Moraes & Bolini, 2010; Palazzo *et al.*, 2011; Esmerino *et al.*, 2013; Morais *et al.*, 2013, 2014a; Souza *et al.*, 2013; Paixão *et al.*, 2014) showed that the sweetener potency can be modified significantly depending on the food matrix and physical and physical–chemical conditions of the matrix, without prediction of result can be obtained. For example, Cardoso *et al.* (2004), in their study with tea drink and sweeteners, found that sucralose and stevia had increase in the sweetening power with the increase in temperature. Paixão *et al.* (2014) showed that, in chocolate milk beverage, the temperature at the time of consumption influenced the perception of sweet taste beyond differences in the amount of fat present in the product.

Time–intensity analysis for the stimulus of sweetness

Table 3 shows the significance of the time–intensity results for the sweet stimulus in espresso coffee using ANOVA and Tukey's means test.

According to Table 3, there was no significant difference ($P < 0.05$) between the times taken to reach the maximum intensity (TI_{max}) in espresso coffee by the different sweeteners and the TI_{max} of the sample with sucrose. The espresso coffee sweetened with stevia

Table 3 Means of the parameters of time–intensity curves for the sweetness stimulus from espresso coffee samples

Samples	TI_{max}*	I_{max}	Area	T_{tot}*
Sucrose	14.9444[ab]	6.8925[ab]	150.919[bc]	38.392[c]
Sucralose	15.961[ab]	5.9729[c]	136.719[c]	39.029[c]
Aspartame	15.188[ab]	6.5389[b]	164.231[b]	48.364[b]
Neotame	15.0397[ab]	6.7583[ab]	162.093[b]	43.053[bc]
Cyclamate/saccharin blend (2:1)	14.1555[b]	5.0194[d]	83.709[d]	27.287[d]
Stevia	16.3288[a]	7.2115[a]	222.262[a]	54.497[a]

Means with common letters in the same column indicate that there is no significant difference between samples ($P \leq 0.05$) from Tukey's mean test.
*Time in seconds.

showed the highest mean, but only differed significantly ($P < 0.05$) from the sample containing the cyclamate/saccharin mixture. In the study carried out by Morais *et al*. (2014b) with chocolate dairy dessert using prebiotic and different high-intensity sweeteners, none of the samples showed any significant difference in relation to this parameter.

For the parameter of maximum intensity (I_{max}), only the samples containing aspartame, neotame and stevia showed no significant difference in relation to sucrose. Working with vanilla ice creams, Cadena & Bolini (2011) found that the samples sweetened with sucralose or aspartame did not differ significantly from the traditional samples (with sucrose) for this parameter. The sample containing the cyclamate/saccharin mixture exhibited the lowest mean for I_{max} and differed significantly ($P < 0.05$) from all the other samples.

The values obtained for the area under the curve and the total stimulus duration times (T_{tot}) showed similar results. The sample containing stevia showed the highest mean values for these two parameters and differed from all the other samples, suggesting that this sample presented a greater aftertaste when compared to the other sweeteners studied. The samples containing sucralose, aspartame and neotame did not present any significant difference ($P < 0.05$) for these parameters in relation to sucrose.

This result differed from that found in the study with vanilla ice cream, in which the sample sweetened with sucralose showed the highest value for T_{tot}, suggesting the presence of an aftertaste (Cadena & Bolini, 2011).

Neotame was the only sweetener that did not differ significantly ($P < 0.05$) from the sample containing sucrose for any of the four parameters evaluated. In the study of Palazzo & Bolini (2014) with milk chocolate, the addition of neotame also showed no significant difference from the addition of sucrose for any of the four parameters.

Figure 3 shows the time–intensity curves recorded for the sweet stimulus in each sample, in which the means of the parameters obtained for each sample were used to construct the curves.

The principal components analysis (PCA) was carried out for each sample and each judge from the parameters collected from the time–intensity curves (Fig. 4).

Principal components I and II explained 95.3% of the variation encountered between the samples. In general, the values for repeatability of the assessors were satisfactory in their evaluations of the samples, which can be seen from the closeness of the characteristic points for each sample.

The sample with added stevia was characterised by the four parameters evaluated (TI_{max}, I_{max}, Area and T_{tot}) as a function of their proximity to these vectors. For its part, the espresso coffee sweetened with the

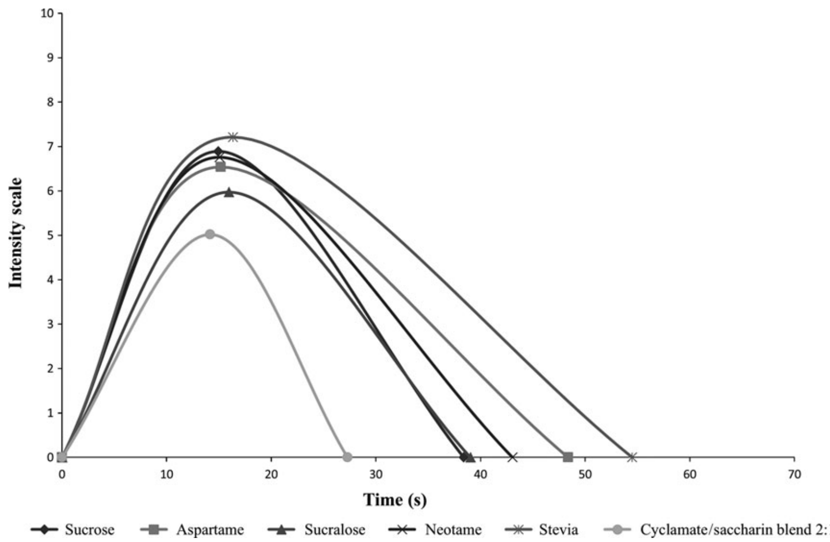

Figure 3 Time-intensity curves and characteristics of sweetness stimulus for samples of espresso coffee.

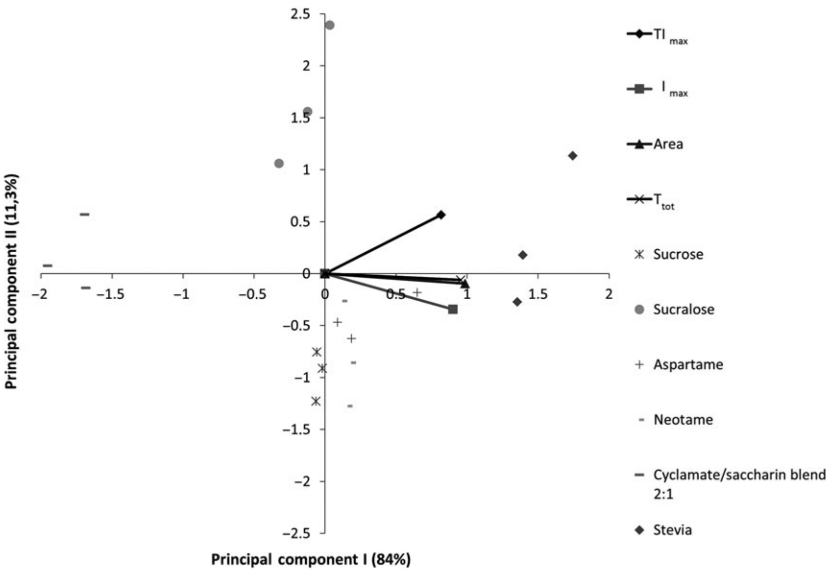

Figure 4 Principal component analysis of espresso coffee samples for the attribute sweetness.

cyclamate/saccharin mixture obtained the lowest values for all the parameters on the time–intensity curves, due to its position distant from the vectors. These results were confirmed by the ANOVA and Tukey's tests.

Proximity between samples indicates similarity in the temporal profile. Thus, the positioning of the samples containing sucrose, aspartame and neotame could indicate that these show similar temporal profiles in espresso coffee for the sweetness stimulus. The sample sweetened with the cyclamate/saccharin mixture (2:1) was distant from the others on the graph, indicating that its temporal profile was distinct from the others.

The joint analysis of the results from the ANOVA and Tukey's means tests, the time–intensity curve of each sweetener (Fig. 3) and the principal components analysis (Fig. 4) could indicate that the sweeteners neotame, aspartame and sucralose are sweeteners with temporal profiles most similar to that of sucrose in espresso coffee. On the other hand, the samples sweetened with stevia and the cyclamate/saccharin mixture (2:1) showed that the temporal profiles were most distinct from that of sucrose with respect to sweetness, so probably they would not be good substitutes for sucrose in espresso coffee.

Palazzo & Bolini (2014) studied the temporal profile of chocolate-flavoured milk sweetened with sucrose, sucralose, neotame and rebaudioside, and found that the sweetener sucralose had the temporal profile for sweetness most similar to that of sucrose.

Conclusions

The concentration of sucrose considered ideal in espresso coffee was 12.5%. The equivalent sweetness showed that neotame was the sweetener with the strongest sweetening effect in espresso coffee, as compared to the addition of 12.5% of sucrose, followed by sucralose, the cyclamate/saccharin mixture (2:1), aspartame and stevia.

It is important to consider that for each product, the ideal concentration of sucrose to be added and the equivalent concentration of each sweetener may be different, and hence, it is very important to determine the ideal sweetness and carry out the equivalent sweetness analysis. For the reasons set out above, although the studies use the same methodologies, the results provide important information for the success of products with the consumer market.

This has been the first time the time–intensity analysis of espresso coffees sweetened with different high-intensity sweeteners was carried out. This analysis indicated that the sweeteners neotame, aspartame and sucralose had the temporal profiles most similar to that of sucrose in espresso coffee in relation to sweetness and would therefore be good options for use at home and in cafeterias as alternatives to the use of sucrose.

Acknowledgments

This study was carried out with the support of the Coordination for the Improvement of Higher Level or Education Personnel (CAPES).

References

Albanese, D., Matteo, M.Di., Poiana, M. & Spagnamusso, S. (2009). Espresso coffee (EC) by POD: study of thermal profile during extraction process and influence of water temperature on chemical–physical and sensorial properties. *Food Research International*, **42**, 727–732.

Associação Brasileira de Indústria do Café – ABIC. (2014). Disponível em: http://www.abic.com.br/publique/cgi/cgilua.exe/sys/start.htm?sid = 61#1910 (accessed 04 January 2015).

Bolini-Cardelo, H.M.A., Silva, M.A.A.P. & Damasio, M.H. (1999). Measurement of the relative sweetness of stevia extract. aspartame and cyclamate/saccharin blend as compared to sucrose at different concentrations. *Plant Foods for Human Nutrition*, **54**, 119–130.

Borém, F.M., Ribeiro, F.C., Figueiredo, L.P., Giomo, G.S., Fortunato, V.A. & Isquierdo, E.P. (2013). Evaluation of the sensory and color quality of coffee beans stored in hermetic packaging. *Journal of Stored Products Research*, **52**, 1–6.

Brasil, Agência Nacional de Vigilância Sanitária – ANVISA. (2008). Resolução RDC no. 18, de 24 de março de 2008: Regulamento Técnico que autoriza o uso de aditivos edulcorantes em alimentos, com seus respectivos limites máximos. *Diário Oficial da União*, 2008.

Cadena, R.S. & Bolini, H.M.A. (2011). Time–intensity analysis and acceptance test for traditional and light vanilla ice cream. *Food Research International*, **44**, 677–683.

Cadena, R.S. & Bolini, H.M.A. (2012). Ideal and relative sweetness of high intensity sweeteners in mango nectar. *International Journal of Food Science and Technology*, **47**, 991–996.

Cardoso, J.M.P. & Bolini, H.M.A. (2007). Different sweeteners in peach nectar: ideal and equivalent sweetness. *Food Research International*, **40**, 1249–1253.

Cardoso, J.M.P., Battochio, J.R. & Cardello, H.M.A.B. (2004). Equi-sweetness and sweetening power of different sweetening agents in differents temperatures of consumption of tea drink in soluble power. *Ciência e Tecnologia de Alimentos*, **24**, 448–452.

Cavallini, D.C.U., Garcia, D.C. & Bolini, H.M.A. (2005). Determination of the relative sweetness and acceptability of cyclamate/saccharin blend, aspartame, sucralose and stevia extract as compared to sucrose in mango juice. *Alimentaria*, **368**, 106–110.

Dabelea, D., Bell, R.A. & D'Agostino, R.B. (2007). Incidence of diabetes in youth in the United States. *Journal of the American Medical Association*, **297**, 2716–2724.

Damásio, M.H. & Costell, E. (1991). Análisis sensorial descriptivo: generación de descriptores y selección de catadores. *Revista Agroquímica de Tecnologia de Alimentos*, **31**, 165–178.

Dutra, M.B.L. & Bolini, H.M.A. (2013). Acerola nectar sweetened with different sweeteners: ideal and equivalent sweetness. *CyTA – Journal of Food*, **12**, 277–281.

Esmerino, E.A., Cruz, A.G., Pereira, E.P.R., Rodrigues, J.B., Faria, J.F.A. & Bolini, H.M.A. (2013). The influence of sweeteners in probiotic Petit Suisse cheese in concentrations equivalent to that of sucrose. *Journal of Dairy Science*, **96**, 5512–5521.

Fonteles, T.V., Faheina, G.S. Jr, Oliveira, S.L.R. & Rodrigues, M.C.P. (2010). Avaliação do uso de adoçantes alternativos na aceitabilidade da bebida de café. *Alimentos e Nutrição*, **21**, 391–397.

Guinard, J.-X., Zoumas-Morse, C., Mori, L., Uatoni, B., Panyam, D. & Kilara, A. (1997). Sugar and fat effects on sensory properties of ice cream. *Journal of Food Science*, **62**, 1087–1094.

MacFie, H.J., Bratchell, N., Greenhoff, K. & Vallis, L.V. (1989). Designs to balance the effect of order of presentation and first-order carry-over effect in hall tests. *Journal of Sensory Studies*, **4**, 129–148.

Meilgaard, M., Civille, G.V. & Carr, B.T. (2004). *Sensory Evaluation Techniques*, 3rd edn. Pp. 387. New York: CRC Press.

Moraes, P.C.B.T. & Bolini, H.M.A. (2010). Different sweeteners in beverages prepared with instant and roasted ground coffee: ideal and equivalent sweetness. *Journal of Sensory Studies*, **25**, 215–225.

Morais, E.C., Cruz, A.G. & Bolini, H.M.A. (2013). Gluten-free bread: multiple time–intensity analysis, physical characterisation and acceptance test. *International Journal of Food Science and Technology*, **48**, 2176–2184.

Morais, E.C., Morais, A.R., Cruz, A.G. & Bolini, H.M.A. (2014a). Development of chocolate dairy dessert with addition of prebiotics and replacement of sucrose with different high-intensity sweeteners. *Journal of Dairy Science*, **97**, 2600–2609.

Morais, E.C., Pinheiro, A.C.M., Nunes, C.A. & Bolini, H.M.A. (2014b). Multiple time-intensity analysis and temporal dominance of sensations of chocolate dairy dessert using prebiotic and different high-intensity sweeteners. *Journal of Sensory Studies*, **29**, 339–350.

Moskowitz, H.R. (1974). *Sensation and Measurement: Papers in Honor of S.S. Stevens*. Dordrecht: Reidel Press.

Napolitano, A., Fogliano, V., Tafuri, A. & Ritieni, A. (2007). Natural occurrence of ochratoxin A and antioxidant activity of green and roasted coffees and corresponding byproducts. *Journal of Agricultural and Food Chemistry*, **55**, 10499–10504.

Paixão, J.A., Rodrigues, J.B., Esmerino, E.A., Cruz, A.G. & Bolini, H.M.A. (2014). Influence of temperature and fat content on ideal sucrose concentration, sweetening power, and sweetness equivalence of different sweeteners in chocolate milk beverage. *Journal of Dairy Science*, **97**, 7344–7353.

Palazzo, A.B. & Bolini, H.M.A. (2009). Multiple time-intensity analysis and acceptance of raspberry-flavored gelatin. *Journal of Sensory Studies*, **24**, 648–663.

Palazzo, A.B. & Bolini, H.M.A. (2014). Multiple time-intensity analysis: sweetness, bitterness, chocolate flavor and melting rate of chocolate with sucralose, rebaudioside and neotame. *Journal of Sensory Studies*, **29**, 21–32.

Palazzo, A.B., Carvalho, M.A.R., Efraim, P. & Bolini, H.M.A. (2011). The determination of equi-sweet concentrations of sucralose, stevioside and neotame as sucrose substitutes in new diet/light chocolate formulations using the time intensity analysis. *Journal of Sensory Studies*, **26**, 291–297.

SAS (Statistical Analysis System). (2012). *SAS for Windows Version 9.1.3 Service Pack 3*. Cary, NC: SAS Institute, Inc.

Souza, V.R., Pinheiro, A.C.M., Carneiro, J.D.S., Pinto, S.M., Abreu, L.R. & Menezes, C.C. (2011). Analysis of various sweeteners in petit Suisse cheese: determination of the ideal and equivalent sweetness. *Journal of Sensory Studies*, **26**, 339–345.

Souza, V.R., Pereira, P.A.P., Pinheiro, A.C.M., Bolini, H.M.A., Borges, S.V. & Queiroz, F. (2013). Analysis of various sweeteners in low-sugar mixed fruit jam: equivalent sweetness, time-intensity analysis and acceptance test. *International Journal of Food Science and Technology*, **48**, 1541–1548.

Stone, H. & Oliver, S.M. (1969). Measurement of the relative sweetness of selected sweeteners and sweetener mixtures. *Journal of Food Science*, **34**, 215–222.

Universidade Estadual de Campinas – UNICAMP. (2012). *Helena Maria André Bolini. Time-Intensity Analysis of Flavors and Tastes – TIAF: Software*. Registro no 12445-5, 03 January 2012. Pp. 178. Rio de Janeiro: Revista da Propriedade Industrial, 2151.

Varela, P., Beltrán, J. & Fiszman, S. (2014). An alternative way to uncover drivers of coffee liking: preference mapping based on consumers' preference ranking and open comments. *Food Quality and Preference*, **32**, 152–159.

Varzakas, T. (2012). Chapter 9. Quality control of sweeteners: production, handling and storage. In: *Sweeteners: Nutritional Aspects, Applications and Production Technology* (edited by T. Varzakas, A. Labropoulos & S. Anestis). Pp. 255–298. Boca Raton, FL: CRC Press, Taylor and Francis Group.

Varzakas, T. & Chryssanthopoulos, C. (2012). Chapter 11. Nutritional and health aspects of sweeteners. In: *Sweeteners: Nutritional Aspects, Applications and Production Technology* (edited by T. Varzakas, A. Labropoulos & S. Anestis). Pp. 329–366. Boca Raton, FL: CRC Press, Taylor and Francis Group.

Vickers, Z. (1988). Sensory specific satiety in lemonade a just right scale for sweetness. *Journal of Sensory Studies*, **3**, 1–8.

Vitaglione, P., Morisco, F., Mazzone, G., Amoruso, D.C., Ribecco, M.T. & Romano, A. (2010). Coffee reduces liver damage in a rat model of steatohepatitis: the underlying mechanism and the role of polyphenols and melanoidins. *Hepatology*, **52**, 1652–1661.

Wakeling, I.N. & MacFie, H.J.H. (1995). Designing consumer trials balanced for first and higher orders of carry-over effect when only a subset of samples from may be tested. *Food Quality and Preference*, **6**, 299–308.