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Sensory characterisation, dominant attributes in time and consumer preference of industrial and artisanal Mexican chocolates

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Abstract

The objective of the present work was to determine the sensory differences, consumer preference, and dominant attributes of industrial and artisanal Mexican chocolates. This characterisation was performed by using Quantitative Descriptive Analysis. Consumer preference was analysed by using External Preference Mapping, and the dominant attributes through Temporal Dominance of Sensations. Sensory differences between chocolate types were more evident in attributes such as chocolate aroma, cocoa aroma, and cocoa flavour. Consumer preference was focused towards artisanal chocolates that showed high intensities of brown colour, cocoa aroma, chocolate aroma, fat aroma, sweet aftertaste, and dominant attributes such as bitter, fat aroma, and bitter aftertaste. Results provided a significant insight about the preference of consumers for artisanal and industrial chocolates based on their sensory attributes.

Introduction

Aztecs, Incas, and Mayas in Mesoamerica cultivated cocoa (*Theobroma cacao*) for use in rituals and ceremonies (Donadini *et al.,* 2012). In 2017, the world production of cocoa beans was 5.2 million tons. Republic of Ivory Coast is the largest producer (1.4 million tons), followed by Ghana (610,000 tons), and Indonesia (605,000 tons) (FAOSTAT, 2017). México had a production of 27,000 tons in that year. It was mainly concentrated in Tabasco, Chiapas, Oaxaca, and Guerrero states (FAOSTAT, 2017).

Chocolate is prepared by extracting, pressing, or spraying cocoa, and mixing it with or without sugar or other ingredients such as butter (NOM-186-SSA1/SCFI-2002; NOM, 2002). Chocolate contains 6% protein, 61% carbohydrates, and 3% moisture. Chocolate also has various minerals (phosphorus, calcium, and iron) and vitamins (Sol Sánchez *et al.,* 2016). Various works have shown that moderate consumption of dark chocolate results in health benefits due to its high content of polyphenols which are present in cocoa (Gámbaro and Ellis, 2012; Oberrauter *et al.,* 2018). Cocoa polyphenols have cardioprotective effects that contribute to the decrease in oxidation of low density lipoproteins (LDL), increased levels of high density lipoproteins (HDL), and anti-inflammatory properties (Gámbaro and Ellis, 2012; Oberrauter *et al.,* 2018). In addition, chocolate contains several psychoactive compounds (*e.g.,* phenyl ethanolamine and methylxanthines) that stimulate the release of dopamine, thereby leading to various positive effects such as sensory pleasure (Gámbaro and Ellis, 2012).

Chocolate is associated with the generation of different emotions (*e.g.,* joy and pleasure) in consumers, that is why it is considered as a stimulant and antidepressant food (Thamke *et al.,* 2009). In Mexico, chocolate has been considered an important food since

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pre-Hispanic times as it gives cultural identity in the places where it is produced and consumed as hot drinks, which are part of the cultural wealth of consumers from that state. Due to its high demand, chocolates have been produced artisanally and industrially. However, to date, there is no evidence that shows the sensory differences between artisanal and industrial chocolates, as most of the sensory research focuses on industrial chocolates from other countries (Pflanzer *et al.,* 2010; Donadini *et al.,* 2012; Gámbaro and Ellis, 2012). Therefore, sensory characterisation of both chocolate types would allow for the identification of the dominance of their attributes during the ingestion time and the relationship with consumer preference. This can be achieved by using External Preference Mapping (PREFMAP) and Temporal Dominance of Sensations (TDS) techniques that help explain the consumer preference based on product sensory characteristics and their dominant attributes in time (Ng *et al.,* 2012; Pineau *et al.,* 2012). The objective of the present work was therefore to determine sensory differences, consumer preference, and dominant attributes of industrial and artisanal chocolates from Mexico.

Materials and methods

Origin and preparation of chocolate samples

Eight chocolate brands were evaluated (n = 4 artisanal chocolates, and n = 4 industrial chocolates; Table 1). Due to confidentiality reasons, the chocolate brands are not disclosed. Chocolates were selected according to consumer, and acquired from the "20 de Noviembre" market from the City of Oaxaca de Juárez, México. The criteria used for the selection of artisanal chocolate were: 1) made with local raw materials; 2) prepared by hand or with the help of manual and mechanical tools; 3) made with the use of family labour, and 4) marketed in the State of Oaxaca (Domínguez-López *et al.,* 2011; Jaramillo-Villanueva *et al.,* 2018).

All chocolate bars were purchased on the same day, and from the same production batch in presentations of 80 - 120 g. A total of 3.4 kg of each brand of chocolate was used in the present work. Chocolate bars were stored in a dry, dark room at 18 ± 2°C until the sensory analysis. All chocolate samples for sensory analysis were prepared following the manufacturer's specifications as described below: 1) 200 g of chocolate were dissolved in 1 L of hot water (80 ± 2°C), 2) the solution was homogenised using a blender (Model Slope 14, Oster®, Newell Brands de México S.A de C.V); and 3) chocolate samples were cooled down to room temperature until 45 ± 2°C.

Experimental conditions of the samples for sensory analysis

Each judge was served with 30 mL of each chocolate (45 ± 2°C) in clear glasses coded with three random digits. A glass of water was also provided for the neutralisation of flavours in between samples. Ballots included the definition and the operating mode of each attribute, the scale, as well as the reference, and its respective value (Ramírez-Rivera *et al.,* 2018). All sensory tests were carried out in standard booths at the Sensory Evaluation Laboratory of the Universidad de la Sierra Sur, Mexico.

Sensory descriptive panel

The sensory panel was made up of three men and five women between the ages of 20 and 40. This panel has two years of experience in the evaluation of different chocolate-based products. The selection of the panellists was conducted according to the ISO standard 8586-1 (ISO, 1993) and ISO standard 11035 (ISO, 1994). Each panellist was interviewed in order to determine their availability, motivation, and

Table 1. Code and category of chocolates analysed.

Code	Type of chocolate	Cocoa content (%)	Ingredients
I1	Industrial	70	Cocoa, cinnamon, sugar, almond, and soy lecithin
I2	Industrial	70	Cocoa, cinnamon, sugar, and almond
I3	Industrial	50	Cocoa, almond, and sugar
I4	Industrial	50	Cocoa, almond, sugar, and soy lecithin
A1	Artisanal	60	Cocoa, cinnamon, and sugar
A2	Artisanal	80	Cocoa, cinnamon, sugar, and almond
A3	Artisanal	70	Cocoa, cinnamon, and sugar
A4	Artisanal	70	Cocoa, cinnamon, sugar, and almond

A = Artisanal chocolate, I = Industrial chocolate.

non-aversion to the product (ISO standard 8586-1, 1993). Subsequently, tests of recognition of basic flavours (sweet, salty, bitter, and acid), smell recognition applied (ISO standard 5496, 2005), triangular tests (ISO standard 4120, 2004a), and duo-trio tests (ISO standard 10399, 2004b) were performed. Finally, the results were evaluated through the application of the Sequential Analysis Technique (ISO standard 16820, 2004c). The training sessions were carried out in the Sensory Evaluation Laboratory of the Universidad de la Sierra Sur, Mexico.

Sensory procedure

The sensory profile of the chocolates was developed with the Quantitative Descriptive Analysis® (QDA®) technique (ISO standard 11035, 1994). QDA® Technique was performed in three stages. During the first stage, two sessions of 1 h were carried out in order to obtain the sensory attributes. A reduction of attributes was made by eliminating those with hedonic connotation that were not related to the product (ISO standard 11035, 1994) so that a preliminary list of sensory attributes could be obtained. The attributes of the preliminary list were evaluated on a structured five-point scale to determine the actual intensity. The maximum frequency of each attribute was determined by the number of times it was mentioned by the panellists (ISO standard 11035, 1994). Both of the actual intensity and the maximum frequency were used to determine the geometric mean value of each attribute, and thereby obtaining the final list of sensory attributes for the study: Brown colour (Brown-C), Cocoa aroma (Cocoa-A), Fat aroma (Fat-A), Chocolate aroma (Chocolate-A), Cocoa Flavour (Cacao-F), Bitter (Bitter-T), Bitter Aftertaste (Bitter-AT), and Sweet Aftertaste (Sweet-AT). During the second stage, two consensus sessions were conducted to determine the definition, the operating mode, the reference, and its value for each of the aforementioned sensory attributes (ISO standard 11035, 1994) (Table 2). In the third stage, the panel evaluated the sensory attributes progressively (appearance, smell, aromas, and after taste). A total of 21 training sessions with duration of 50 min per session were performed. The evaluation session, which included two tastings with a 2 h interval between tastings was carried out to evaluate the performance of the panel (discrimination, repetitiveness, and consensus) and validate the sensory profile (Tomic *et al.,* 2010). Chocolate samples were served to the panel in a sequential monadic, following

Table 2. Definitions and references of the attributes.

Attribute	Definition	Reference
Brown-C	Characteristic colour of cocoa bean	Coffee shade scale: 0 = light brown, 5 = medium brown, and 9 = dark brown
Cocoa-A	Characteristic aroma of cocoa	Cocoa powder in water (w/v) (Cacep® S.A de C.V.), 0 = 5%, 5 = 10%, and 9 = 20%
Chocolate-A	Characteristic smell of chocolate	Chocolate drinks (Nestlé de México S.A. de C.V.), 0 = 5%, 5 = 10%, and 9 = 20%
Fat-A	Characteristic aroma of vegetable fat	Chocolate drinks at different fat concentrations: 0 = No fat, 5 = Nestlé chocolate drink (Nestlé de México, S.A. de C.V.) with 16.18%, and 9 = Hershey's black chocolate drink (Hershey's de México S.A de C.V.) with 30.27% fat
Bitter-T	Bitter taste from cocoa	Instant coffee drink Nescafé® Clasico (Nestlé, México, S.A. de C.V.), 0 = 0%, 5 = 0.5%, and 9 = 1%
Cocoa-F	Characteristic flavour of cocoa	Cocoa powder in water (w/v) (Cacep® S.A de C.V.) at concentrations: 0 = 5.0%, 5 = 10%, and 9 = 20%
Bitter-AT	Bitter aftertaste remaining after ingesting the sample	Instant coffee drink Nescafé® Clasico (Nestlé, México, S.A. de C.V.) at concentrations: 0 = 0%, 5 = 0.5% and 9 = 1%
Sweet-AT	Sweet aftertaste remaining after ingesting the sample	Sugar solutions (Zucarmex de México S.A de C.V) at concentrations : 0 = 0%, 5 = 5.0%, and 9 = 10%

Values 0, 5, and 9 correspond to the intensity scale. C = Colour, A = Aroma, F = Flavour, and AT = Aftertaste.

an optimal Latin square experimental design and a continuous scale of 9 cm was used, where 0 was weak, and 9 was strong intensity (Ramírez-Rivera *et al.,* 2018).

Consumer study

The consumer study was carried out with 98 consumers (53 women and 45 men; 20 - 43 years old), and the level of liking in the chocolate samples was evaluated using a nine-point hedonic scale, where 1 = "I dislike it extremely" and 9 = "I like it extremely" (Ramírez-Rivera *et al.,* 2018). Consumers were selected according to chocolate consumption frequency at least twice a week. Chocolate samples were presented to each consumer in a randomised order (Ramírez-Rivera *et al.,* 2018).

Temporal Dominance of Sensation (TDS)

For the integration of the panel for TDS, 30 consumers were recruited, of which 26 were selected (12 women and 14 men between the ages of 20 and 45). Consumers were selected according to the following criteria: 1) chocolate consumption at least twice a week (Rodrigues *et al.,* 2016a), 2) no allergy to chocolate products (Rodrigues *et al.,* 2016a), 3) have good oral and general health (Rodrigues *et al.,* 2016a; 2016b), and 4) ability to discriminate triangular tests (ISO standard 4120, 2004b). The results of the triangular tests were processed by sequential analysis (the parameters set for this technique were p = 0.30; p1 = 0.70; $\alpha = 0.10$; y $\beta = 0.10$; ISO standard 16820, 2004c; Rodrigues *et al.,* 2016a). Consumers were sequentially served with randomised chocolate samples in three-digit coded plastic cups. Five sessions (2 h per session) were held to explain the concept of dominant attribute using the program SensoMaker (Pinheiro *et al.,* 2013). The test was performed as follows: the panellists took the chocolate to their mouths in a period of 2 s (delay time). Then for 20 s, each consumer selected the dominant attribute until the test concluded. Both delay time and evaluation time for TDS were determined consensually by the panel. During the entire test, each consumer was free to select an attribute several times (Pineau *et al.,* 2012). The sensory attributes evaluated were: Cocoa Flavour (Cocoa-F), Bitter Taste (Bitter-T), Sweet Taste (Sweet-T), Fat Flavour (Fat-F), Cocoa Aftertaste (Cocoa-AT), Sweet Aftertaste (Sweet-AT), and Bitter Aftertaste (Bitter-AT).

Statistical analysis

The sensory data of the trained panel were collected in a matrix with dimensions of J *M *N rows by K columns, where J = 8 sample, M = 2 repetitions, N = 8 judges, and K = 8 sensory attributes for a total of 1024 data. Preference data were collected in an array of dimensions of J *N rows by K columns, where J = 8 samples, N = 98 consumers, and K = the value of the preference assigned to each chocolate for a total of 784 data.

Sensory panel performance

The performance of the sensory panel was evaluated using a Variance Analysis (ANOVA) model with their respective interactions:

$$Y_{iks} = \mu + \alpha_i + \beta_k + \gamma_s + \alpha\beta_{ik} + \beta\gamma_{ks} + \alpha\gamma_{is} + ei_{ks} \quad \text{(Eq. 1)}$$

Where, Y_{iks} = result of a panellist, i = repetition s in the product k; μ = overall mean; α_i = panellist effect; β_k = product effect; γ_s = repetition effect; $\alpha\beta_{ik}$ = product interaction per panellist; $\beta\gamma_{ks}$ = product interaction per repetition; $\alpha\gamma_{is}$ = panellist interaction per repetition; and e_{ijk} = error term of the model with $e_{iks} \approx N(0, \sigma^2)$ (Tomic *et al.,* 2010). All the F-tests were carried out using the residual variance as denominator (Ramírez-Rivera *et al.,* 2018).

Representation and stability of the sensory profile

The sensory profile of chocolates was represented using a biplot constructed with data from the Principal Component Analysis Technique (PCA). The stability of the sensory profile was determined by the test of Hotelling T^2 and confidence ellipses (Cadoret and Husson, 2013). Each confidence ellipse contained 95% of the representations of each product obtained by the generation of virtual panels randomly selected from the real panel with 500 resamples (Cadoret and Husson, 2013).

Preference analysis via PREFMAP and dominant attributes by TDS curves

The statistical strategy for the analysis of the preference of chocolate consumers was carried out in three stages. In the first stage, the evaluation of the hedonic data was performed using a one-way ANOVA (α = 0.05). In the second stage, consumer classes (which were classified according to their similarity in hedonic results) were generated by using the Hierarchical Ascendant Classification (HAC) technique (Ward method). In the third stage, the classes of consumers and the QDA® sensory profile were related to generate the different PREFMAP models (Ramírez-Rivera *et al.,* 2018):

$$\text{Vector model: } Y_i = \alpha + \beta_1 X_1 + b_2 X_2 + \varepsilon \quad \text{(Eq. 2)}$$

Circular model: $Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + c(X_1^2 + X_2^2) + \varepsilon$ (Eq. 3)

Elliptical model: $Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + c X_1^2 + c X_2^2 + \varepsilon$ (Eq. 4)

Quadratic model: $Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + c X_1^2 + c X_2^2 + dX_1X_2 + \varepsilon$ (Eq. 5)

Where, X and Y = coordinates of chocolate in the first and second principal component, Y_i = hedonic result assigned by a consumer class to a chocolate, α and β_1 = coefficients of the model, and ε = error term of the model. The best PREFMAP model was determined by the Fisher test (*F*) associated with a probability value (*p*) and the coefficient of determination R^2 (Ramírez-Rivera *et al.,* 2018).

Finally, the TDS curves of the three chocolate bars were most preferably constructed based on the PREFMAP results. The construction of the TDS curves was developed according to Pineau *et al.* (2012). In each TDS curve, two lines were drawn, one indicates the "chance level" (dominance rate which may have an attribute by chance) and another one indicates "significance level" which is defined as the minimum value that the dominance rate should be considered as significant. The level of significance was calculated by using the confidence interval of a binomial proportion based on a normal approximation (Pineau *et al.,* 2012):

$$Ps = Po + 1.645\sqrt{\frac{Po\,(1-Po)}{n}} \quad \text{(Eq. 6)}$$

Where, *Ps* = the lowest significant proportion value (α = 0.05) at any point in time for the TDS curve, *Po* = 1/*p*, with *p* being the number of attributes, and *n* = number of subjects per replication. In the present work, *Po* = 0.14, so the minimum number of observation should be $n = 5/(0.14 \times (1\text{-}0.14)) = 41.5 \sim 41$. That was the reason why each of the 26 consumers performed two replications of each product. The number of evaluations carried out met the minimum value from the 30 suggested by Pineau *et al.* (2012).

ANOVA was performed using the software STATGRAPHIC PLUS® version 5.2 (Statistical Graphics Corp, USA). PCA, HAC, PREFMAP, *F* test, and R^2 were made using the software XLSTAT® (Addinsoft, New York, NY, USA) for Microsoft Excel® version 2009. The confidence ellipses and the Hotelling T^2 test were performed with the program SensoMineR (Le and Husson, 2008). The TDS curves were built using SensoMaker version 1.91 software (Pinheiro *et al.,* 2013).

Results and discussion

Sensory panel performance

Results of panel performance analysed by ANOVA are described below. The product factor indicated that the panel was discriminant ($p \leq 0.05$) in 100% of the evaluated attributes. This result is consistent with the study of Le and Husson (2008) and Leite *et al.* (2013) who observed that attributes of milk aroma, cocoa aroma, bitter, brown, and chocolate smell make it possible to discriminate against chocolates. Results from the panellist factor showed that the panel was consensual in five (Cocoa-F, Cocoa-A, Chocolate-A, Fat-A, and Sweet-AT) out of eight evaluated attributes. This represents 62.5% of panel consensus. This result is higher than that of Pflanzer *et al.* (2010) who reported a panel consensus effectiveness of 41.66% in the evaluation of 12 sensory attributes of chocolates. The panel showed an effectiveness of 87.5% in the consistency of the results from one repetition to another ($p \geq 0.05$) in seven of eight attributes. The Product × Panellist interaction showed discrepancies ($p \leq 0.05$) among the panellists when positioning the chocolate samples on the intensity scale for the attribute Bitter-AT. This agrees with Husson and Pagès (2003) in the values of $p \leq 0.05$ for the interaction Product × Panellist for the attribute Bitter-T. The interaction Product × Repetition did not exhibit a significant effect ($p \geq 0.05$) during the evaluation of samples from one repetition to another (100% effectiveness of the panel). A discrepancy was observed among the panellists as indicated by the Panellist × Repetition interaction in the evaluation of Brown-C attribute. In general, the performance of the sensory panel of the present work showed an efficient performance in terms of discrimination, consensus, and repetitiveness (Tomic *et al.,* 2010).

Representation and stability of the sensory profile

Figure 1A shows 75.54% from the total data variation in the first two main components. This value is similar to the one reported by Thomson *et al.* (2010) and Pflanzer *et al.* (2010) who obtained values of 73.5 and 85.3%, respectively. Sensory attributes corresponding to the principal component 1 were Brown-C, Cocoa-A, Bitter-T, Bitter-AT, and Sweet-AT; and for the principal component 2 were Cacao-F, Fat-A, and Chocolate-A. The principal component 2 opposed the I2, A3, A2, and A4 chocolates. Chocolates A2 and A4 were perceived with high intensities for Brown-C, Chocolate-A, Cocoa-A, and Cocoa-F attributes. The formation of the aforementioned sensory attributes could be the result of the processes of fermentation and roasting of cocoa which allow the release of aldehydes, ketones, and pyrazines (Rodríguez-Campos *et al.,* 2011). Chocolates I2 and A3 were identified as Fat-A and Sweet-AT. The fat aroma attribute may be due to the presence of acids such as acetic, propionic, isobutyric, and isovaleric that are formed during cocoa fermentation (Rodríguez-Campos *et al.,* 2011). The Sweet-AT attribute could be due to high contents of monosaccharides, disaccharides, and oligosaccharides in the sample (Vázquez-Ovando *et al.,* 2015). Chocolates have organic molecules such as diketopiperazine, free L-amino acids, or peptides, as well as low molecular weight molecules such as tannins and theobromine that may cause these chocolates to present Bitter and Bitter-AT flavors (chocolate A1) (Stark *et al.,* 2006; Rocha *et al.,* 2017). Intensities in the evaluated attributes for each chocolate are shown in Table 3. Confidence ellipses indicated that chocolates A2 and A4, I2 and A4, and I1 and A2 were perceived as similar (Figure 1B). This was confirmed by the *p*-values from the Hotelling T^2 test of 0.53, 0.07, and 0.55, respectively.

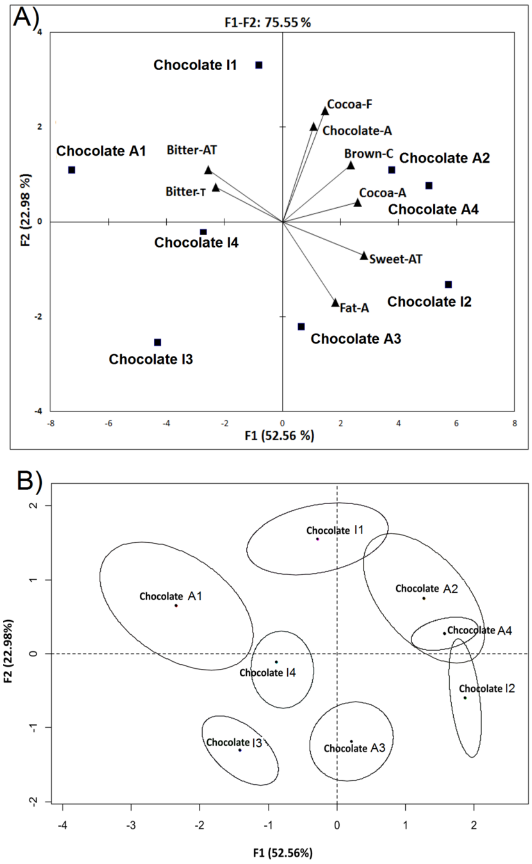

Figure 1. A) Sensory profile of artisanal and industrial chocolates from México; B) Confidence ellipses (95% with 500 resampling). (▲) = Sensory attributes, (■) = Chocolate, A = Artisanal chocolate, I = Industrial chocolate, C = Colour, A = Aroma, F = Flavour, T = Basic taste, and AT = Aftertaste.

Preference analysis via PREFMAP and dominant attributes by TDS curves

ANOVA results showed significant differences ($p \leq 0.05$) in consumer preference. According to results of each consumer, these could be classified into five classes consisting of Class 1 = 37, Class 2 = 12, Class 3 = 16, Class 4 = 22, and Class 5 = 11 consumers, respectively. Each consumer class accounted for 37.76, 12.24, 16.32, 22.45, and 11.22% of total consumers, respectively. Table 4 shows the results of the evaluation of the different PREFMAP models for each class of consumers. Therefore, Class 4 preference was determined by vector models (F = 131.55, $p \leq 0.01$), circular (F = 153.72, $p \leq 0.01$), and quadratic (F = 101.93, $p \leq 0.01$). Class 5 preference was explained by the quadratic model (F = 9.84, p = 0.09). These results could be due to the efficient performance of the sensory

Table 3. Average and standard deviation values of each sensory attribute.

Sample	Brown-C	Cocoa-F	Cocoa-A	Fat-A	Chocolate-A	Bitter-T	Bitter-AT	Sweet-AT
I1	4.8 ± 1.92^{c}	7.1 ± 2.36^{a}	3.6 ± 0.63^{b}	2.0 ± 0.17^{d}	5.7 ± 1.14^{a}	4.5 ± 1.47^{bc}	5.5 ± 1.33^{bc}	4.1 ± 2.06^{c}
I2	7.0 ± 1.77^{b}	4.7 ± 1.91^{c}	5.8 ± 0.44^{a}	6.2 ± 2.65^{a}	4.0 ± 2.79^{b}	3.6 ± 2.58^{c}	3.0 ± 2.45^{d}	6.7 ± 2.64^{a}
I3	2.4 ± 1.29^{e}	3.2 ± 1.90^{c}	2.5 ± 0.03^{b}	5.3 ± 2.71^{ab}	3.1 ± 2.47b	5.5 ± 2.37^{b}	5.5 ± 2.48^{bc}	3.6 ± 0.90^{c}
I4	3.6 ± 1.92^{d}	4.1 ± 3.34^{c}	3.3 ± 0.55^{b}	2.9 ± 1.57^{d}	3.5 ± 1.80^{b}	4.5 ± 2.87^{bc}	6.0 ± 2.70^{b}	4.7 ± 2.34^{bc}
A1	3.6 ± 1.68^{d}	3.6 ± 2.88^{c}	3.7 ± 0.58^{b}	3.3 ± 1.52^{cd}	3.7 ± 2.51^{b}	7.8 ± 2.37^{a}	8.2 ± 5.52^{a}	1.9 ± 2.57^{d}
A2	8.7 ± 1.0^{a}	6.7 ± 1.64^{ab}	5.9 ± 0.36^{a}	5.4 ± 3.27^{ab}	3.4 ± 2.31^{b}	5.0 ± 2.17^{bc}	5.4 ± 2.82^{bc}	5.9 ± 2.56^{ab}
A3	2.8 ± 2.32^{de}	3.8 ± 1.50^{c}	4.3 ± 1.65^{ab}	4.5 ± 2.66^{bc}	3.1 ± 2.59^{b}	3.4 ± 3.09^{c}	4.2 ± 3.33^{cd}	5.9 ± 1.97^{ab}
A4	7.2 ± 1.55^{b}	4.9 ± 1.36^{bc}	5.6 ± 2.85^{a}	5.6 ± 1.88^{ab}	6.0 ± 2.21^{a}	3.8 ± 2.23^{bc}	4.0 ± 1.77^{d}	6.2 ± 1.60^{a}

Different superscript letters within a column indicate significant difference at $p \leq 0.05$. A = Artisanal chocolate, I = Industrial chocolate, C = Colour, A = Aroma, F = Flavour, and AT = Aftertaste.

panel (Tomic *et al.,* 2010). But nevertheless, Masson *et al.* (2016) mentioned that the vector and quadratic models give better explanation of the preference. The PREFMAP vector and quadratic models (Figure 2) showed that chocolates I4, A1, I3, and I1 were the least preferred by consumers according to the blue contour zone (0 - 20% of consumers). This result could be associated with the presence of high intensities of the attributes Bitter and Bitter-AT. Cantini *et al.* (2018) found that consumers selected dark chocolate bars based on the presence or absence of the bitter attribute. Also, Vecchio *et al.* (2019) determined that this type of sensory attributes can be considered as the cause for rejection by consumers. The rest of chocolates were located within the orange region where 80 - 100% of consumers predominated. Consumer Classes 1 and 2 showed preference for chocolate A2 due to sensory characteristics of Brown-C, Cocoa-A, Chocolate-A, and Cocoa-F. The aforementioned sensory attributes are consistent with the attributes identified in the study conducted by Cadena *et al.* (2012) who reported that the cocoa aroma attribute is mainly related to the preference of consumers. Thomson *et al.* (2010) reported that sensory attributes such as cocoa are related to emotions such as aggressive and energetic.

The TDS curves for artisanal chocolate A2 (Figure 3A) showed that its dominant attributes were Bitter-T, Bitter-AT, and Fat-F. The Bitter-T attribute was perceived from the 16th until the 33rd s. The Bitter-AT attribute was perceived from the 26th to the 40th s, and the Fat-F attribute was perceived from the 33rd and 40th s. The bitter attributes are related to high cocoa contents, and this chocolate also shows a similarity to Brazilian chocolates made with cocoa bean blending which potentiates this sensory characteristic (Oberrauter *et al.,* 2018). Consumer Classes 3, 4 (positive ideal +), and 5 preferred I2 and A3 chocolates with high intensities of Fat-A and Sweet-AT. Additionally, the TDS chocolate curves

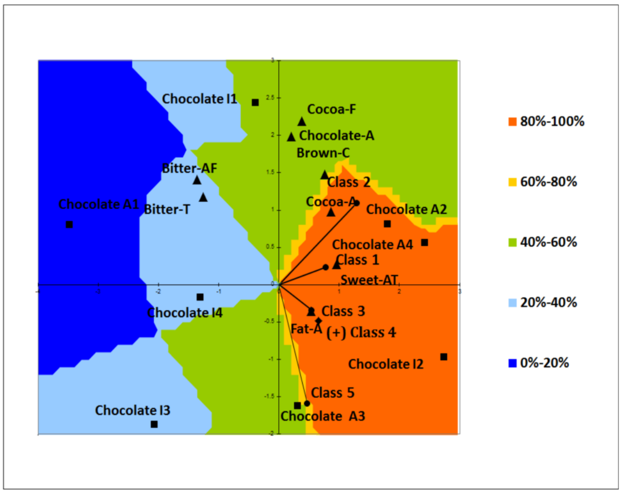

Figure 2. External Preference Mapping of chocolates. Sensory attributes (▲), Chocolate (■), Consumer class (●) and Ideal positive point (♦). Colours indicate different regions of preference. A = Artisanal chocolate, I = Industrial chocolate, C = Colour, A = Aroma, F = Flavour, T = Basic taste, and AT = Aftertaste.

I2 (Figure 3B) indicated that only the attribute Cocoa-F was dominant during the 23rd to 40th s. Thamke *et al.* (2009) evaluated chocolates using the free choice profile technique, and reported that the key sensory attributes in industrial chocolates are sweet and cocoa flavors. Thomson *et al.* (2010) showed that attributes like sweet relate to interesting, happy, and loving emotions. Ares *et al.* (2017) evaluated industrial chocolates. They indicated that sweet is a dominant attribute which is related to consumer preference. The dominant attributes of artisanal chocolate A3 (Figure 3C) were Bitter-T (15th – 40th s) and Bitter-AT (with appearances from the 24th to 29th s, and from 33rd to 40th s). These results are consistent with Rodrigues *et al.* (2016b) who used the TDS technique in chocolate samples with different cocoa concentrations (35, 53, and 63%), and reported that the dominant attribute was Bitter. The information obtained from the present work may be useful

Table 4. Evaluation of the PREFMAP'S models by consumer class.

Class	Consumers by class (*n*)	Vectorial		Circular		Elliptical		Quadratic		R^2
		F	*p*	*F*	*p*	*F*	*p*	*F*	*p*	
Class 1	37	0.52	0.62	0.00	0.96	0.68	0.50	2.48	0.26	0.17
Class 2	12	3.75	0.10	0.23	0.68	5.43	0.15	0.01	0.92	0.60
Class 3	16	0.26	0.77	0.40	0.59	1.34	0.37	2.98	0.23	0.09
Class 4	22	131.55	0.01	153.72	0.01	8.28	0.10	101.93	0.01	0.99
Class 5	11	1.39	0.32	0.00	0.98	2.60	0.25	9.94	0.09	0.35

(Models of PREFMAP'S: Vectorial, Circular, Elliptical, Quadratic)

F = Fisher test, *p* = Probability, and R^2 = Determination coefficient.

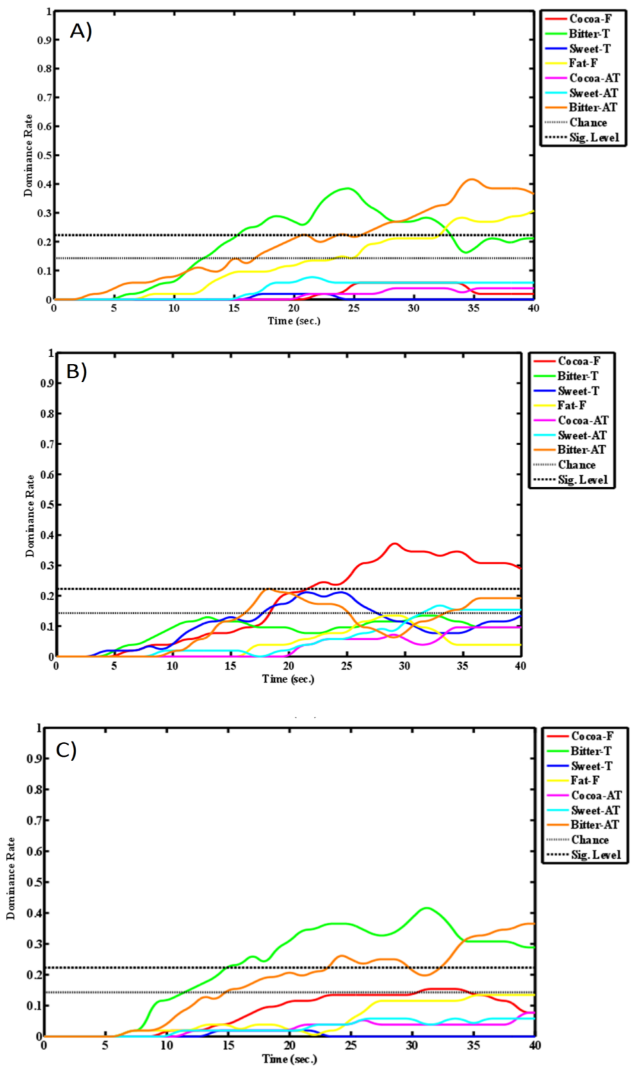

Figure 3. Curves TDS (52 evaluations). A) artisanal chocolate A2; B) Industrial chocolate I2, and C) artisanal chocolate A3. Chance = 0.15 and Sig. Level = 0.22, F = Flavour, T = Basic taste, AT = Aftertaste.

for artisanal and industrial chocolate manufacturers that seek to have greater quality control of their products, and be competitive with the local, regional, national, and international markets. This allows us to understand consumer satisfaction, maintain product quality control, and reformulate rejected products (Thamke *et al.,* 2009; Lanza *et al.,* 2011; Donadini *et al.,* 2012).

Conclusion

Artisanal chocolates exhibited diverse sensory attributes (Brown-C, Cocoa-A, Chocolate-A, Cocoa-F, Fat-A, Bitter-BT, and Bitter-AT) as compared to industrial chocolates (Sweet-AT). However, the PREFMAP results determined that consumer preference was focused towards artisan chocolates with high intensities in Brown-C, Cocoa-A, Chocolate-A, Fat-A, and Sweet-AT attributes. The TDS analysis showed that subjects perceived sensory attributes of Bitter-BT, Fat-A, and Bitter-AF for a period of 25 s in artisanal chocolates, while the Cocoa-F attribute was only perceived for 15 s in industrial chocolates. The results of the present work provide an insight about the preference of consumers of artisanal and industrial chocolates.

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