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Facultad de Ciencias Agropecuarias

Universidad Nacional de Trujillo

RESEARCH ARTICLE

Use of purple corn (*Zea mays* L.) cob in the formulation of functional teas developed using Flash Profile and CATA methods

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Received: 28 January 2025. Accepted: 3 August 2025. Published: 18 August 2025.

Abstract

Purple corn (*Zea mays L.)* is a superfood native to Peru, highly regarded for its functional properties and commonly used in the preparation of traditional beverages and desserts, such as *chicha morada* and *mazamorra morada*. Following processing, the corn cobs remaining as a byproduct retain significant amounts of bioactive compounds with potential for utilization. This study proposes their use as a primary component in the production of teas. To ensure product safety, the moisture content, total ash, and counts of enterobacteria and aflatoxins in the raw materials were first evaluated. Fourteen formulations were developed, varying in the proportions of corn cobs, quince, stevia, cinnamon, and cloves, as well as extraction times (5 and 10 minutes at 100 °C) with hot water. Two rapid sensory evaluation methods using consumer panels were applied sequentially: Flash Profile (FP) and Check-All-That-Apply (CATA), External preference mapping was then conducted, and the most acceptable teas were subjected to instrumental characterization. The FP methodology generated 400 sensory descriptors, classified semantically, from which 12 key descriptors were selected for the CATA test: sweet, stevia flavor, quince flavor, fruity flavor, fruity smell, astringent, bitter, cinnamon smell, reddish color, acid, purple and "*Chicha morada*" flavor. The confidence ellipses in the FP Multiple Factor Analysis (MFA) space allowed to identify six groups of formulations for the CATA test. This test revealed that the characteristics that improve consumer acceptability are: "*Chicha morada*" flavor, fruity flavor, sweet and fruity smell. The External Preference Mapping allowed to determine the formulations, with 90% preference among consumers, despite not being the ones with the highest concentrations of total polyphenols, antioxidant activity and monomeric anthocyanins. In conclusion, the sensory methodologies applied in this study help to elucidate the sensory characteristics that influence consumer acceptability, representing valuable tools for the development of new functional products from purple corn by-products.

Keywords: purple corn; consumer-based sensory evaluation; sensory development; functional foods.

DOI: https://doi.org/10.17268/sci.agropecu.2025.044

Cite this article:
Mora-Velit, J., Puma-Isuiza, G., Liñan-Pérez, J., Salvá-Ruiz, B. K., & Silva-Jaimes, M. I. (2025). Use of purple corn (*Zea mays* L.) cob in the formulation of functional teas developed using Flash Profile and CATA methods. *Scientia Agropecuaria*, *16*(4), 577-590.

1. Introduction

Purple corn (*Zea mays L.*) is a superfood native of Peru that is also grown in other countries such as Ecuador, Bolivia, and Argentina (Jing et al., 2007). This cereal has gained interest due to its functional properties, acting mainly as an antioxidant and hypoglycemic agent (Salvador-Reyes et al., 2022; Lao et al., 2017; Xu et al., 2021; Díaz-García et al., 2021). The most important compounds present in purple corn are anthocyanins like: cyanidin-3-glucoside, pelargonidin-3-glucoside, peonidin-3-glucoside and their respective acylated derivatives (Mohammadalinejhad et al., 2023; Yang & Zhai, 2010; Lao & Giusti, 2018; Pedreschi & Cisneros-Zevallos, 2007). In addition, purple corn also contains several phenolic compounds such as vanillic acid, p-coumaric acid, protocatechuic acid, quercetin and hesperetin derivatives (Pedreschi & Cisneros-Zevallos, 2007). These compounds are known to reduce blood pressure by increasing the total antioxidant capacity of the blood. In addition, they reduce cholesterol and prevent various types of cancer, as they counteract the harmful effects of free radicals, oxidative stress and carcinogenesis; therefore, their regular intake is useful even for people who do not suffer from any disease (Guillen-Sánchez et al., 2010; Lao et al., 2017).

Over the years, purple corn has been used as an important component in the preparation of typical Peruvian drinks and desserts, such as *chicha morada*, which is a non-carbonated drink obtained by cooking corn together with other fruits and spices; and mazamorra morada, which is a dessert made from concentrated of *chicha morada* with the addition of thickeners (Ramos-Escudero et al., 2012; Salvador-Reyes et al., 2022; Ramos-Guerrero et al., 2021). Purple corn cobs are generally considered by-products or agricultural waste; however, they contain significant amounts of polyphenolic compounds (Díaz-García et al., 2021; Lao & Giusti, 2018; Yang & Zhai, 2010). For this reason, they have been studied as raw materials for the development of extrudates (Rolandelli et al., 2023), tea (Díaz-García et al., 2021), and even bioactive films (Chavez-Marquez et al., 2023). Although their use in tea production has not been widely explored, they represent a promising alternative due to their ease of application and health-promoting properties, particularly their high content of anthocyanins and phenolic compounds, which make them a valuable source of natural antioxidants (Ramos-Escudero et al., 2012; Lao et al., 2017). This is because the highest concentration of the aforementioned bioactive compounds is found in the purple corn cob (Rojas et al., 2025), thanks to the biosynthesis of nitrogen, necessary for grain growth, which accumulates in the cob in the form of phenolic acids and anthocyanins (Seebauer et al., 2004).

In Peru, the purple corn variety INIA-601, developed by the National Institute of Agrarian Innovation (INIA) of the Ministry of Agrarian Development and Irrigation (MIDAGRI), has gained interest because it contains a higher concentration of anthocyanins (6.34% and 3.03% in the cob and husk, respectively) (INIA, 2019). Díaz-García et al. (2021) studied the optimization of a low-calorie natural antioxidant tea prepared from purple corn cobs, obtaining important results of antioxidant activity measured by ORAC (9.09 ± 0.29 µmol TE/mL) and monomeric anthocyanins (97.19 ± 4.40 mg C3GE/L), evidencing its potential use as a functional tea. However, no optimization or validation was carried out considering the sensory perception of consumers.

Tea is the second most popular non-alcoholic beverage in the world after water, due to its mild stimulating effects, nutritional and functional properties, and pleasant taste (Wang et al., 2022). Since ancient times, tea has been the most common form of dietary supplement used by the Peruvian population for health care and the treatment of common ailments; this practice has become established as an integral part of daily life in the country (Wang et al., 2017). Consequently, per capita consumption of herbal teas in Peru reaches 35.8 cups per year, ranking it fifth in Latin America with the highest consumption. Aromatic infusions, such as anise, chamomile, tea, cinnamon, and clove, are the most popular, showing a sustained average annual growth of 4% (Euromonitor International, 2024). The growing consumption of herbal teas in Peru boosts the local economy by stimulating the cultivation of aromatic and medicinal plants, generating income for small producers. It also fosters the development of value-added products and promotes the creation of sustainable businesses. Generally, tea extracts have a unique sweet aftertaste (Zhang et al., 2020) and a representative floral flavor (Su et al., 2022); however, they may cause undesirable sensory perceptions, due to bitterness and astringency (Zhang et al., 2020) that directly influence tea quality and consumer preference (Li et al., 2019, Yang et al., 2013). For this reason, in the present development a natural and healthy component has been included that provides sweetness to the developed tea, which is stevia, because, on the one hand, there is a wide tendency to consume low-calorie sweeteners as alternatives to saccharose (Guggisberg et al., 2011) and, on the other hand, the aim is to develop an instant food preparation that is quick to consume, in accordance with food trends.

Most published sensory studies on tea use highly trained panelists who are instructed to compare the various sensory attributes with a standard tea (Deng et al., 2023, Han et al., 2022, Zeng et al., 2023, Cao et al., 2021). It is known that during the evaluation some subjective factors may be present, such as the environment where the evaluation is carried out, personal preferences, mood, degree of specialization and idiosyncrasy of the panelists (Zhu et al., 2017; Li et al., 2019). So, it is of great interest to include strategies that are more flexible and include the voice of the consumer in the design and development of the product (Liñan-Pérez et al., 2023), since consumer panels capture real-world perceptions and preferences, this improves external validity compared to trained panels. Flash Profile (FP) and Check-All-That-Apply (CATA) are alternative and rapid methods compared to conventional methods that can be used for specific purposes (Lee et al., 2021). FP is a verbal method where relative intensity is assessed on an ordinal scale, while CATA generates a binary response (presence/absence) (Lee et al., 2021). One of the main challenges of the CATA method lies in the careful design and selection of terms, ensuring that consumers can easily tick those they find appropriate to describe the sensory attributes of the samples (Bruzzone et al., 2015; Dooley et al., 2010). Since the CATA method is limited by the generation of sensory vocabulary, applying a complementary method such as the Flash Profile allows consumers to be included throughout the development process, as they generate their own vocabulary. Furthermore, CATA allows for the introduction of hedonic responses that provide an understanding of product acceptance and its approximation to the ideal consumer profile, which is a limitation of the Flash Profile. In general, complementing consumer-based sensory methods with each other allows for greater insights into the potential impact of products on the market by analyzing consumer perception (Galarreta-Morales 2025; Liñan-Pérez 2023).

There are no previous studies in which these sensory techniques are used simultaneously and complementarily for the development of foods with a focus on the consumer. Furthermore, there is no application for a rapid sensory profile adopted as a sample of purple corn cob teas. Therefore, the objectives of this research were: (1) to generate a lexicon for the sensory description of tea products using Flash Profile (2) to use the sensory profiles generated by CATA and Flash Profile methodologies in the sensory development of tea, and (3) to identify the best formulation using External Preference Mapping.

2. Methodology

The development of purple corn cob-based teas was carried out in 3 stages: (1) preparation of the tea, (2) sensory development of the formulations and (3) evaluation of the sensory preference by consumers. The tea was prepared according to the procedure of Díaz-García et al. (2021) with some modifications. To do this, the selection and cleaning of the purple corn cob (variety INIA 601), quince (*Cydonia oblonga*), stevia (*Stevia reaudiana Bertoni*), cinnamon (*Cinnamomum verum*) and clove (*Syzygium aromaticum*) was carried out. Then, they were washed and disinfected by immersion in sodium hypochlorite (70 ppm) for 5 minutes. They were rinsed and allowed to drain naturally. The corn cob and quince were cut (2 mm) and dried (Reter, DRR-200) at 60 and 56 ºC, respectively, until obtaining a moisture less than 5%. Afterwards, grinding (Robot Coupe® R5VV) and sieving were carried out to obtain an average particle size of 2000 µm. The raw materials were blended according to the formulations presented in Table 1. The optimal formulation (C) from a previous study by Díaz-García et al. (2021) was used, which maximized the antioxidant activity (ORAC) and total monomeric anthocyanin content (TMAC) of a purple corn cob-based tea using a D-optimal design. A control (A) containing only purple corn cob was included. B was obtained by maximizing L* (L* = 58.94), C by minimizing L* (L* = 42.75), and D by establishing a mean L* value (L* = 50.84) from the study by Díaz-García et al. (2021) (data not reported). Interestingly, C was similar to the optimal formulation by Díaz-García et al. (2021). In addition, formulations E, F, and G, which did not contain stevia, were included. The goodness of fit of the model was checked with the lack of fit ($p > 0.05$), the coefficient of determination (R^2) and the $R^2_{adjusted}$. Cinnamon and clove fractions were fixed relative to the sum of the other materials according to the percentages of 3.33, for cinnamon and 0.25 for clove based on preliminary tests. Then, they were packaged in corn fiber tea bags (6x8 cm) and irradiated (Gammabean 127 IR194) at the facilities of the Servicio Nacional de Sanidad Agraria (SENASA) at 8 kGy for 30 minutes to ensure their microbial stability.

Table 1
Percentage formulations of purple corn cob-based tea and extraction parameters for sensory evaluation

Encode of formulas	Purple corn cob (%)	Quince (%)	Stevia (%)	Cinnamon (%)	Clove (%)	Extraction parameters
A	100	0.0	0.0	0.0	0.0	100 °C x 10 min (250 mL)
B	48.9	39.2	8.3	3.3	0.3	
C	83.6	4.5	8.3	3.3	0.3	
D	63.3	24.8	8.3	3.3	0.3	
E	53.4	42.7	0.0	3.6	0.3	
F	91.2	4.9	0.0	3.6	0.3	
G	69.1	27.0	0.0	3.6	0.3	
H	100	0.00	0.0	0.0	0.0	100 °C x 5 min (250 mL)
I	48.9	39.2	8.3	3.3	0.3	
J	83.6	4.5	8.3	3.3	0.3	
K	63.3	24.8	8.3	3.3	0.3	
L	53.4	42.7	0.0	3.6	0.3	
M	91.2	4.9	0.0	3.6	0.3	
N	69.1	27.0	0.0	3.6	0.3	

2.1. Physicochemical analysis

The tea raw materials (purple corn, quince, stevia, cinnamon, and clove) were characterized by their moisture and ashes content using the method 984.25 (AOAC, 2019) and the Mexican Standard NMX-F-527 (NMX, 1992), respectively. The tea formulations with the highest acceptability, identified by external preference mapping, were characterized by their moisture content (AOAC, 2019), pH (method 918.12, AOAC, 2019), total solids content (NMX, 1992) and L*a*b* values using a colorimeter Konica Minolta CM-5 (Díaz-García et al., 2021). All analyses were performed in triplicate.

2.2. Total Polyphenol Content (TPC)

The total polyphenol content (TPC) was determined according to the modified Folin-Ciocalteu method of Singleton & Rossi (1965). For this purpose, 50 µL of tea extracts were mixed with 50 µL of Folin-Ciocalteu reagent (1:5, v/v) in a 96-well plate and left to stand for 2 min. Then, 100 µL of NaOH (0.3 M) was added and placed in the Multi-Mode microplate reader (Biotek Instruments Inc., Synergy HTX), where it stood for 5 min and then the absorbance was measured at 760 nm for 60 min. The results were expressed in mg GAE/L of extract. The analysis was performed in triplicate.

2.3. Total monomeric anthocyanins

Total anthocyanin monomeric (TAM) content was determined by the slightly modified pH differential method (Giusti & Wrolstad, 1996). Extracts were centrifuged (10,000 RPM for 10 min at 4 ºC) and mixed with buffers (1:40) at pH = 1 (potassium chloride) and pH = 4.5 (sodium acetate) in a 96-well plate, where absorbance was read at 520 and 700 nm. TAM content was determined using equation 1 and expressed as mg of cyanidin-3-glucoside/L of extract (mg C3GE/L). The analysis was performed in triplicate.

$$TAM\left(mg\frac{C3GE}{L}\right)=\frac{(A)(MW)(DF)1000}{\varepsilon(1)}\ldots\ldots Eq.1$$

Where: A (absorbance) = $(A_{520} - A_{700})_{pH=1.0} - (A_{520} - A_{700})_{pH=4.5}$, MW (molecular weight) = 449.2 g/mol de cyanidin-3-glucoside, DF = dilution factor; 1000 = conversion of g to mg; ε (molar absorptivity coefficient in L/mol/cm for cyanidin-3-glucoside) = 26.900; 1 = length of the path in cm.

2.4. Oxygen Radical Absorbance Capacity (ORAC) assay

The ORAC method was applied according to the recommendations of Díaz-García et al. (2021). The extracts were centrifuged (Labortechnik GmbH, Z216MK) at 10,000 RPM for 10 min at 4 °C and the supernatant was recovered. Then, extraction was performed with acetone:water (70:30, v/v) at room temperature and centrifuged again at the same parameters to finally recover the supernatant. Then, 150 µL of fluorescein solution (111.2 nM) was placed in each well of a 96-well black microplate and 25 µL of the supernatant was added (phosphate buffer at pH 7.4 and 75 mM was used as diluent). The plates were then incubated at 37 °C for 30 min and 25 µL of 2,2'-azobis (2-amidinopropane) dihydrochloride (153 mM) was added to all wells to make a final volume of 200 µL. The fluorescence intensity was measured using a multimode microplate reader (Biotek Instruments Inc., Synergy HTX) with an excitation and emission wavelength of 485 nm and 520 nm, respectively. The results were expressed in µmol TE/mL of extract. The analysis was performed in triplicate.

2.5. Enterobacteria count

Enterobacteria counts were performed on the raw materials (purple corn cob-INIA 601, quince, stevia, cinnamon and cloves) and on the tea after irradiation, according to the ICMSF (2000). The sample (10 g) was weighed with 90 mL of 0.1% peptone water and shaken for 5 minutes. Serial dilutions were made with 1 mL of each dilution and 9 mL of the diluent, generating a battery of 5 consecutive dilutions. Subsequently, 1 mL of each dilution was added to the Petri plates and liquefied malt extract agar cooled to 45 ºC was added. Finally, when it solidified it was incubated at room temperature for 5 days alternating light/darkness 12 hours at 37 °C for 24-48 hours. After the incubation process, the count of present colonies was performed.

2.6. Aflatoxin determination

The total aflatoxins (B1, B2, G1, and G2) in the raw materials were also determined according to the AOAC methodology (2019). A total of 12.5 g of homogenized sample was weighed and mixed with 50 mL of an extraction solution composed of acetonitrile:water (84:16, v/v). The extract was filtered and 8mL of the filtrate were transferred into glass tubes and purified by passing through Mycosep 226 AflaZon+ cartridges. The resulting solution was further filtered through 0.22 µm PTFE syringe filters. After purification, separation of aflatoxins [AFB1 (B2a), AFB2, AFG1 (G2a), and AFG2] was carried out using a reverse-phase C18 chromatographic column (100 mm × 2.1 mm, 1.7 µm). The mobile phase consisted of 10 mmol ammonium acetate (A) and methanol (B) in a 95:5 (v/v) ratio, with a flow rate of 0.3 mL/min. The injection volume was set to 2µL, and the column temperature was maintained at 40 °C ±1°C. Detection and quantification were performed using a fluorescence spectrophotometer coupled to an integrator grapher, following the standard calibration curve approach.

2.7. Identification of attributes and sensory characterization of tea formulations

The sensory development consisted of the application of the Flash Profile (FP) and Check all that apply (CATA) methods in a complementary manner. First, the FP was used in order to obtain the list of sensory characteristics of the purple corn cob-based formulations; in addition, it served to identify those samples that were different from each other and that served as a basis for the application of the CATA methodology, which allowed obtaining the sensory profile of the samples and the external preference mapping.

2.7.1. Consumer recruitment

For each method, 100 consumers, with ages between 20 and 50 years old, signed free and informed consent to participate in the study. They were asked to fill out a prior exploratory survey, where the main selection criteria were the interest, the availability to participate in the study and the frequency of consumption of non-alcoholic beverages such as *chicha morada* or similar products (Esmerino et al., 2017; Wang et al., 2023).

2.7.2. Preparation of tea formulations

To carry out the sensory test, the extracts were obtained according to the recommendations of Castañeda-Saucedo et al. (2020). To do this, a tea bag was placed in each cup and then water at 100 °C was added until completing 250 mL. Two resting times (5 and 10 min) were considered for each formulation (Table 1), making a total of 14 treatments. Subsequently, the tea bags were removed, and the extracts were allowed to cool to room temperature (approximately 25 °C). Each tea extract was prepared instantly before each session and was supplied to the consumer in 50 mL containers. Additionally, 150 mL of table water was provided for participants to rinse their mouths between each sample, to avoid saturation of flavors (Kemp et al., 2018).

2.7.3. Flash Profile (FP)

FP was applied in two sessions: in the first 45-minute session, consumers freely generated sensory characteristics for the 14 formulations provided in sequential monadic order, and they were also asked to define each term in their own words (Heo et al., 2023); in the second 75-minute session, all samples were provided simultaneously to rank them, with ties allowed, according to the intensity of each sensory characteristic generated in the first session. Scores were coded according to the rank order of each sample for each sensory descriptor (from 1: very weak to 14: very strong). In case of a tie, samples were coded as the mean of their respective ranks (Delarue & Sieffermann, 2004).

2.7.4. Check All That Apply (CATA)

For the CATA methodology, the presentation of the samples was monadic, according to a balanced random design. As recommended by Ares & Jaeger (2013), the order of presentation of the terms in the evaluation booklet was balanced between the samples and between the consumers, so that each consumer evaluated each of the samples with the terms grouped in a different order. Each sample was initially coded with three-digit random numbers. However, for consistency and clarity in the presentation of results, the sample codes from the Flash Profile methodology (labeled A to N) were adopted throughout the manuscript. Sensory characterization of the formulations by CATA was performed using the sensory terms collected from the FP related to appearance, aroma, flavor, texture, aftertaste, and mouthfeel. The order in which the terms of the CATA list were presented was different for each product and each participant (Ares et al., 2014). For the evaluation, consumers were asked to taste the sample and select all the terms that apply or describe the sample they are evaluating (Vidal et al., 2018).

2.7.5. External Preference Mapping (EPM)

Sensory acceptability was obtained by applying a hedonic scale test in which the participant was asked about their degree of acceptability with the evaluated sample using a nine-point scale where: 1= I do not like it very much and 9= I like it very much (Jaeger et al., 2018). EPM was performed using the consensus space obtained from the Correspondence Analysis (CA) of the CATA data. A circular preference model was then fitted, following the proposal by Varela and Ares (2014) and Dooley et al. (2010) which considers consumer preference to be radially distributed around an ideal point in the sensory map. This model allows for the identification of regions of greatest acceptance using the Euclidean distance between the samples and said ideal point.

2.5. Statistical analysis

2.5.1. Analysis of instrumental data

The data obtained from the instrumental characterization were processed using one-way analysis of variance, after verifying the assumptions (normality of residuals, homoscedasticity, and independence). Finally, Tukey's multiple comparison test was used. A significance level of $p < 0.05$ was applied to all statistical analyses.

2.5.2. Sensory data analysis

a. Flash Profile data analysis

FP data were processed with Multiple Factor Analysis (MFA), where confidence ellipses were constructed using the truncated total bootstrap to elucidate cluster formation. This approach allowed the simultaneous analysis of both panelist and product variability, enabling the identification of significant perceptual differences between samples. The use of bootstrapped ellipses provides a robust visualization of sample grouping, offering statistical support for the consistency of sensory profiles across replicates or assessors (Pagès, 2005).

b. CATA data analysis and external preference mapping

CATA data were decoded (0/1) and a contingency table was constructed, on which a CA was performed, previously Cochran's Q test was used to assess whether consumers detected significant differences between the samples for each of the terms of the CATA questionnaire. Cochran's Q test, based on a permutation approach, yielded more precise p-values. It involved generating 1,000 random permutations of the characteristic-formulation matrix under the null hypothesis, recalculating the Q statistic for each permutation to construct an empirical distribution of the statistic. The p-value was estimated as the proportion of permutations whose Q value was equal to or greater than the observed Q value, allowing for a more robust assessment of statistical significance.

Coordinate and penalty analysis were performed to obtain the ideal profile along with taste ratings measured on the hedonic scale (Varela & Ares, 2014). The consensus space of the Correspondence Analysis of the CATA test was used in order to obtain the External Preference Map with the PREFMAP function (Varela & Ares, 2014).

All statistical analyses for the sensory data were performed using the FactoMineR (Lê et al., 2008), SensoMineR (Lê & Husson, 2008), Agricolae (De Mendiburu & De Mendiburu, 2019) and R language packages (R Core Team, 2024).

3. Results and discussion

3.1. Characterization of raw material

Table 2 shows the results of the physicochemical characterization of the raw materials used to make the tea formulations.

It can be observed that they had a moisture below 9.18 ± 1.68 % and a total ash content that varied between 0.47 ± 0.17 (quince) and 5.00 ± 0.26 (clove). Enterobacteria count values ensured the safety of the tea (<10 CFU/g); in addition, the presence of aflatoxins was not detected in any of the inputs. The moisture content of the five samples was less than 10% to ensure their stability during the production process. Enterobacteria count is a very important parameter in the production of tea media to ensure their safety. The results, shown in Table 2, are within the range established by RM Nº 591-98-SA of the Ministerio de Salud del Perú (MINSA, 2008), whose value corresponds to maximum levels of 10^3 CFU/g.

Aflatoxins are known to be secondary metabolites produced by fungi of the genera Aspergillus and Penicillium. The pathophysiological effects of aflatoxins in humans include liver cancer, cirrhosis, and accumulation in human tissues (Rojas et al. 2021); therefore, their study or identification is important. Some authors such as Windham et al. (1998) reported aflatoxin values between 70 and 11,936 ppm; they also found 6 inputs and foods that had values higher than the permitted 20 ppm, including mote corn (*Zea corn*) (33.20 ppb ± 0.66), showing that these compounds can persist despite the preparation of food since they are thermostable molecules, and can cause cumulative damage to the body. However, in this study the presence of aflatoxins was not detected, ensuring the safety of the formulations.

Table 2
Moisture, total ash (mean ± SD), enterobacteria and aflatoxins (B1, B2, G1, and G2) of the main tea raw materials

Raw material	Moisture (%, b.s.)	Total ashes (%, b.s.)	Enterobacteria (CFU/ g)	Total Aflatoxins (B1, B2, G1 and G2)
Purple corn cob	4.93 ± 0.62	2.57 ± 1.14	< 10	No detected
Quince	3.03 ± 0.98	0.47 ± 0.17	< 10	No detected
Stevia	9.18 ± 1.68	1.79 ± 0.92	< 10	No detected
Cinnamon	3.96 ± 0.96	4.25 ± 1.13	< 10	No detected
Clove	8.52 ± 1.15	5.00 ± 0.26	< 10	No detected

3.2. Development of tea using Flash Profile and CATA

3.2.1. Generation of sensory descriptors

The Flash Profile methodology allowed generating 400 sensory descriptors divided into color (148), flavor (199), smell (43) and texture (10), which were grouped according to their semantics, the number of times they were repeated and their correlation (r > 0.6) with the first 2 dimensions of the MFA, as shown in Table 3.

Table 3
Sensory descriptors generated using the Flash Profile methodology

Dimension	Correlation	Sensory descriptor
1	+	sweet (31), stevia flavor (18), quince flavor (7), fruity flavor (10), fruity smell (9)
	-	astringent (7), bitter (11), smell of cinnamon (8)
2	+	reddish color (10), acid (20)
	-	purple color (22), "*chicha morada*" flavor (6)

Values in parentheses represent the number of times the sample was repeated.

The 12 sensory descriptors obtained for the purple corncob tea samples can be grouped according to flavor (stevia flavor, quince flavor, fruity flavor, fruity smell, "*chicha morada*" flavor, smell of cinnamon); basic tastes (sweet, bitter, acid); appearance (reddish color, purple color) and texture (astringent). These sensory characteristics are similar to those obtained by Zheng et al. (2024) who, through a panel of trained judges, determined the sensory profile in pickled tea samples, whose characteristics were: acidic, floral, fruity, sweet, woody, rancid, bitter, astringent, sweet and umami flavor. Regarding the term "stevia flavor," it is important to note that consumers were able to distinguish this flavor, as many of them indicated in the recruitment survey that they included stevia as a natural sweetener in their daily diet. In fact, Saharudin (2020) mentions that the inclusion of stevia in high concentrations produces a licorice-like flavor and a bitter aftertaste. About the number of descriptors, in the present research a greater number was obtained because, when using the FP, the number of terms generated is based on the number of evaluators and the descriptive capacity they possess (Puma-Isuiza, 2020). Likewise, Dairou & Sieffermann (2002) used two different panels to compare the efficiency of the FP with the conventional profile in red fruit jams, where they found that the two procedures produced similar information. However, the FP proved to be faster than the conventional profile but less self-explanatory from a semantic point of view. From the information generated in Table 3, twelve sensory descriptors were generated which were subsequently used to construct the evaluation sheet used in the CATA test.

Furthermore, the confidence ellipses drawn on the MFA space (Figure 1) allowed the formation of 6 groups: where teas E, G, L, and N form one group because they present no perceived significant difference (the ellipses intersect); teas A, F, H, and M form the second group; teas C, K, and J form the third group; and teas B, D, and I each form a group because their confidence ellipses do not intersect.

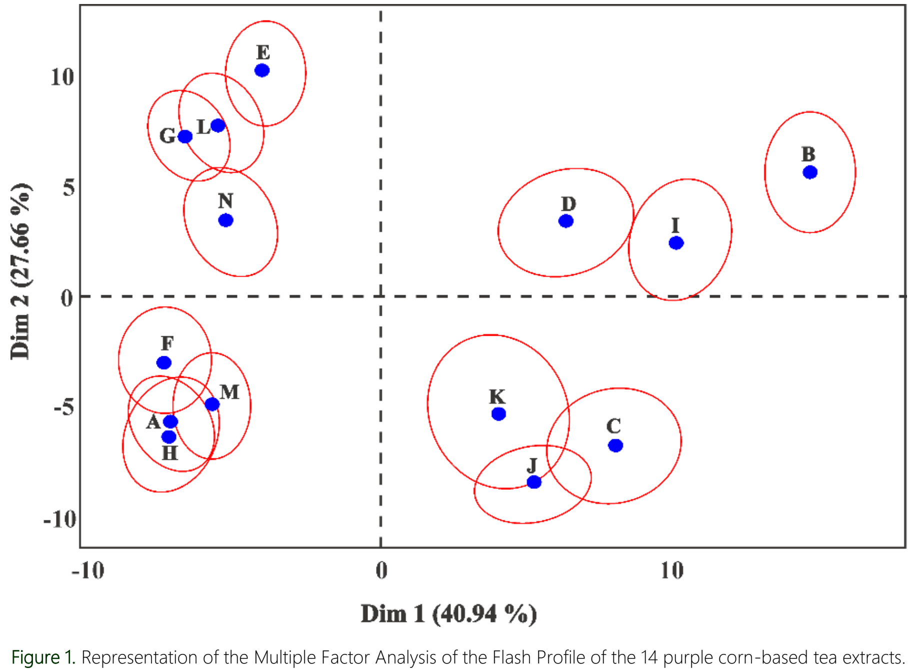

Figure 1. Representation of the Multiple Factor Analysis of the Flash Profile of the 14 purple corn-based tea extracts.

Considering the degree of differentiation perceived by consumers, it was decided to include samples B, D, and I in the subsequent stage of the evaluation using the CATA methodology; and it was decided to include representative samples of each group formed, taking into account that, in a preliminary study (data not shown) where acceptability was evaluated with a 9-point hedonic scale (1 = I don't like it very much and 9 = I like it very much) of the 14 formulations, it was observed that teas formulated without stevia obtained a very low score in terms of acceptance (A, E, F, G, H, L, M, and N), so they were not considered in the next stage of the study; however, despite the fact that samples H and M obtained low hedonic scores, it was decided to include them as negative controls, since sample H only contained purple corn cob and sample M contained all the inputs except stevia. Finally, from the group consisting of teas C, K, and J, formulation K was chosen, which was distinguished from the other 3 by its formulation. Among samples K and C, which had the same formulation but different preparation times, the one with the shortest preparation time was chosen (K). In this regard, the following samples were considered for evaluation in the next stage: B, D, H, I, J, K, and M.

3.2.2. Sensory characterization by CATA

The final CATA assessment (Table 4) was evaluated with Cochran's Q statistical test, which managed to identify 12 sensory attributes which were statistically different ($p < 0.05$) between the formulations under study.

Table 4 shows the Cochran's Q test results in significant differences ($p \leq 0.05$) of the 12 terms of the CATA questions, which were used to describe the tea formulations, suggesting that consumers perceived differences in the sensory characteristics of the extracts evaluated, justifying their inclusion in the report card.

The correspondence analysis of the frequency table of the sensory descriptors evaluated by CATA (Figure 2A) allowed us to better understand how the formulation affected the sensory profile of the purple corn cob-based extracts. It is possible to observe that samples H and M, which did not contain stevia, are far from the projection of the "ideal" vector, corroborating the criterion of removing the other similar formulations from our study. On the other hand, samples D and K are associated with the presence of reddish color, and samples I and B with a fruity smell, and Stevia flavor that is associated with the sweet taste. Sample J is mainly associated with the "*Chicha morada*" flavor and quince flavor and is the sample that is closest to the ideal vector.

Figure 2A shows the representation of the samples and the sensory descriptors in the first two coordinates of the correspondence analysis using $\chi 2$ distances. The first and second dimensions explained 90.47 percent of the variance of the experimental data. According to Liñan (2019), methodologies with consumers naturally have intrinsic variability. The distance between the points corresponding to the samples is a measure of their similarity.

On the other hand, Figure 2B allowed us to elucidate the sensory descriptors that influence consumer acceptability, the most relevant being the "*Chicha morada*" flavor, fruity flavor, sweet and fruity smell. Saldaña et al. (2018) evaluated samples of *mazamorra morada* with the incorporation of extracts of purple corn, quince and spices; and determined that the perception of the fruity flavor characteristic of purple corn must be present in the dessert to increase consumer acceptability. Likewise, Zapata et al. (2019) determined that the addition of quince during beer maceration increased the concentration of volatile compounds related to fruity and floral sensory descriptors, which increased product acceptance.

Table 4
Cochran's test for each of the sensory descriptors used in the CATA questionnaire. Sensory descriptors with p-value < 0.05 are considered to have statistically differentiated the samples

Descriptors	p-value	B	D	H	I	J	K	M
Purple color	0.0000	0.140 (a)	0.220 (a)	0.880 (d)	0.340 (ab)	0.780 (cd)	0.520 (bc)	0.800 (cd)
Reddish color	0.0000	0.540 (cd)	0.760 (d)	0.100 (a)	0.340 (abc)	0.200 (ab)	0.460 (bc)	0.160 (a)
Sweet	0.0000	0.900 (b)	0.760 (b)	0.000 (a)	0.920 (b)	0.840 (b)	0.760 (b)	0.040 (a)
Stevia flavor	0.0000	0.820 (b)	0.660 (b)	0.000 (a)	0.780 (b)	0.780 (b)	0.740 (b)	0.020 (a)
Bitter	0.0000	0.040 (a)	0.040 (a)	0.260 (b)	0.000 (a)	0.040 (a)	0.040 (a)	0.420 (b)
Astringent	0.0044	0.040 (a)	0.100 (a)	0.200 (a)	0.040 (a)	0.080 (a)	0.060 (a)	0.220 (b)
Acid	0.0019	0.260 (b)	0.060 (a)	0.060 (a)	0.080 (a)	0.140 (ab)	0.060 (a)	0.080 (a)
"*Chicha morada*" flavor	0.0000	0.680 (b)	0.620 (b)	0.160 (a)	0.680 (b)	0.760 (b)	0.740 (b)	0.220 (a)
Quince flavor	0.0000	0.440 (b)	0.320 (ab)	0.100 (a)	0.420 (b)	0.320 (ab)	0.200 (ab)	0.100 (a)
Fruity flavor	0.0000	0.600 (b)	0.540 (b)	0.200 (a)	0.580 (b)	0.640 (b)	0.640 (b)	0.240 (a)
Smell of cinnamon	0.0017	0.140 (a)	0.220 (ab)	0.280 (ab)	0.080 (a)	0.280 (ab)	0.220 (ab)	0.420 (b)
Fruity smell	0.0000	0.660 (b)	0.580 (b)	0.160 (a)	0.660 (b)	0.620 (b)	0.600 (b)	0.040 (a)

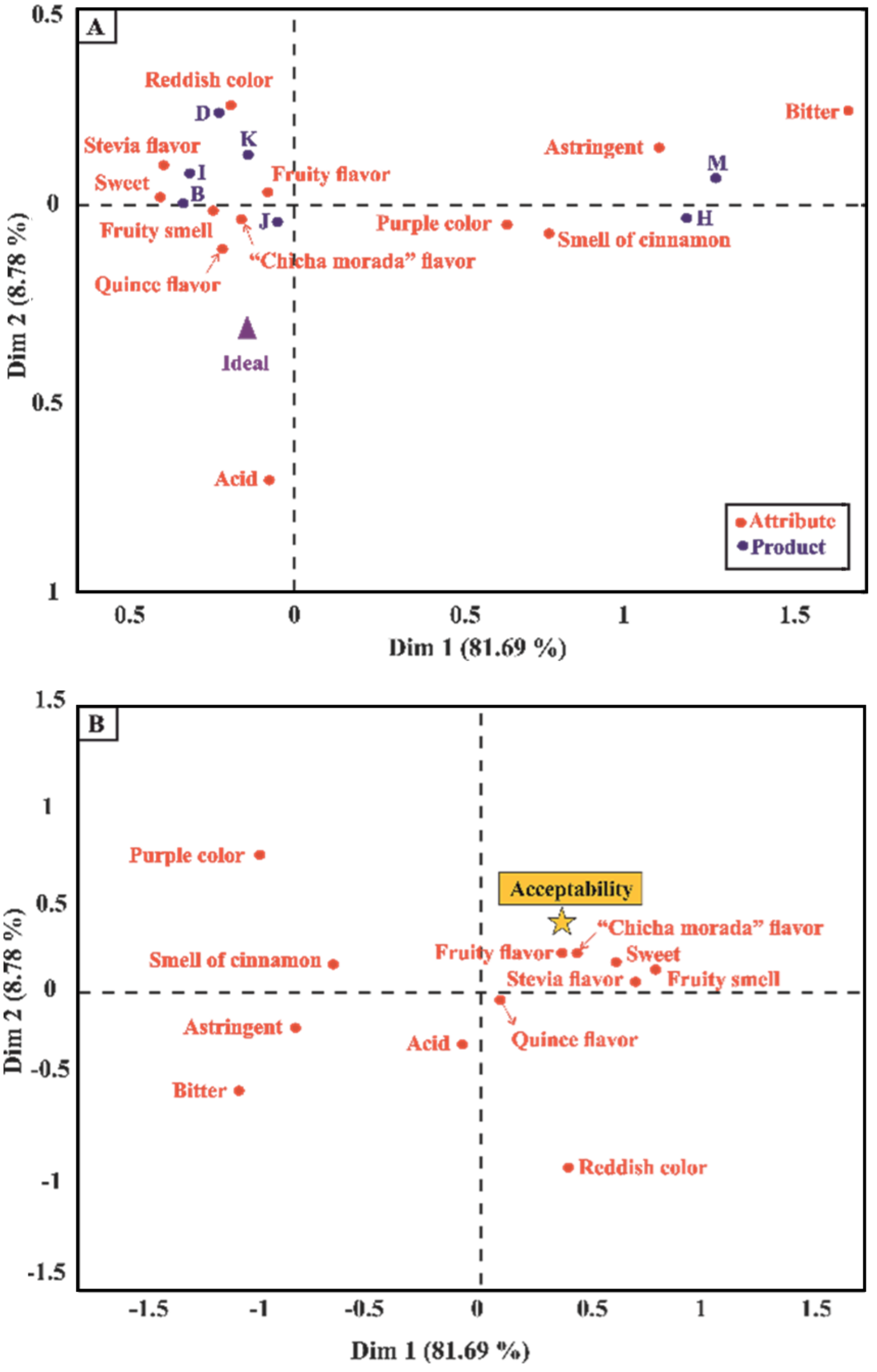

Figure 2. Representation of the tea formulations, the ideal product and the terms in the first and second dimensions of the correspondence analysis of the CATA counts (A) and (B) Representation of the influence of the sensory terms on consumer acceptability.

The penalty analysis (Figure 3) shows the effect of drops in the mean of overall liking in relation to the fraction of consumers who perceived a sensory descriptor differently depending on the ideal product compared to the formulations under study. That is, the positive connotations show a need to increase this attribute to meet consumer expectations, considering ideal parameters in product development. Regarding the colors of each attribute, blue means too low and red means too high. The dotted vertical line represents the minimum of 20%, indicating that percentages lower than this value are likely inconsequential for the purpose of the evaluation (Marketo & Moskowitz, 2004).

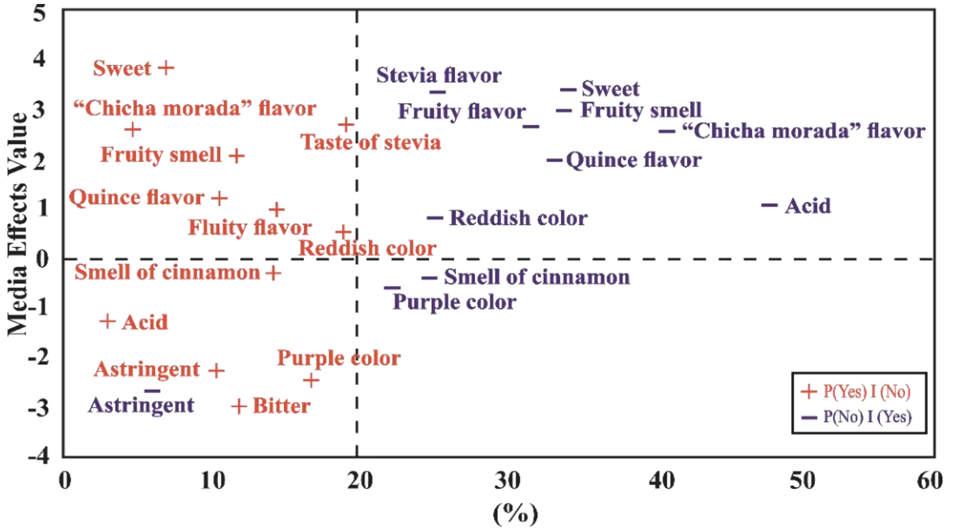

Figure 3. Average drops in overall liking of tea extracts according to penalty analysis.

Figure 3 shows that the characteristics rated too high (red) are located before the dotted line, so these attributes are inconsequential for the purpose of this evaluation, as they will not negatively influence consumer perception. The characteristics stevia flavor, fruity smell, sweet, fruity smell, "*chicha morada*" flavor and quince flavor are located beyond the dotted line, and each shows average drops greater than 1. Varela & Ares (2014) mention that when a nine-point liking scale is used and the average drop is 1, this value is considered a reference for indicating a significant decrease in a product's liking. Therefore, the reddish color and acidic characteristics, perceived as too low, generated a significant decrease in the acceptability of the formulations evaluated. So, the characteristics that are necessary to be present in the formulations are: sweet, stevia flavor, "*Chicha morada*" flavor, fruity flavor and smell, quince flavor.

3.2.3. External preference mapping

Figure 4 shows the external preference mapping using the PREFMAP technique based on the first 2 dimensions of the CATA Correspondence Analysis based on the evaluation carried out using a hedonic scale. The contour lines correspond to different percentages of consumers who rated their overall liking for the seven tea formulations under study, which allows us to observe the clusters that have a preference above the average in each region of the preference map. Samples M and H are in an area where the percentage of consumers who liked them was 40 and 50 percent, respectively. On the other hand, the samples that were most liked were I, B, D, K and J; these were located near areas where the percentage of consumers who rated their overall liking highly was 90, 90, 80, 80 and 80 percent, respectively.

Figure 4 shows that samples B and I are highly accepted by 90% of the consumers who participated in the test. They have the same formulation and differ only in the preparation time, which apparently would be indifferent to consumer acceptability. On the other hand, these samples, B and I, have a lower percentage of corn cob in their formulation compared to samples D, K and J (which were highly accepted by 80% of consumers); this could be affecting the taste of the teas due to the presence of phenolic compounds such as: vanillic acid, p-coumaric acid, protocatechuic acid, quercetin and hesperetin derivatives (Pedreschi & Cisneros-Zevallos, 2007) which can contribute a bitter taste and astringency (Oliveira et al., 2014). Likewise, samples B and I have a higher quince content, which provides a fruity sensory profile given by the following compounds: ethyl octanoate (pear flavor), butyl acetate (banana flavor), 1-hexanol (herbaceous flavor) and ethyl hexanoate (apple and pineapple flavor) (Griñán et al., 2019), resulting in increased acceptability in the samples evaluated.

Based on external preference mapping, formulations B, I, and D were selected because they were the most accepted by the majority of consumers, as shown in Figure 4; in the case of formulations K and J, since they were perceived as statistically similar (Figure 1), sample J was chosen because it was positioned closer to the ideal product for the consumer (Figure 2). These four samples (B, D, I, and J) were evaluated according to their physicochemical properties in the final stage of the research.

3.3. Instrumental characterization of tea

The physicochemical characterization of the 4 extracts obtained from purple corn cob-based tea formulations (B, J, I, and D) is shown in Table 5. It can be observed that the pH varied between 3.8 ± 0.26 (sample I) and 4.5 ± 0.70 (sample J), and there was no significant difference ($p > 0.05$) between the moisture of all the samples. Regarding the total solids in dry extract, values below 4.26 ± 0.95 were obtained. Sample J obtained the highest values of antioxidant activity (9.09 ± 0.29), total polyphenol content (278.17 ± 10.77) and total monomeric anthocyanins (97.19 ± 4.40) compared to the other 3 selected samples; also, lower luminosity values (44.45 ± 1.01), possibly due to the higher AMT content.

In Table 5, sample J obtained the highest values in terms of its antioxidant activity ($p < 0.05$) evaluated by the ORAC method (9.09 ± 0.29 µmol TE/mL), total polyphenol content ($p < 0.05$) (278.17 ± 10.77 mg GAE/L) and monomeric anthocyanin content (97.19 ± 4.40 mg C3GE/L), compared to samples B and D (Table 5), possibly because it had less exposure time (5 minutes) to 100 °C during preparation and there could have been a degradation of its bioactive compounds decreasing its functional properties. On the other hand, sample J was the prototype that contained a higher content of purple corn cob (83.6%) giving it these high contents of antioxidant activity.

On the other hand, it is known that in natural products made with plant extracts, the main problem of deterioration is microbial growth, because factors such as pH, CO_2 rate, low amount of nitrogenous substances and sugar concentration, constitute a favorable environment for their growth (Pascual & Calderon, 2000). The pH range found in the samples oscillated between 3.8 and 4.5, which would prevent microbial growth, because most bacteria are inhibited by low pH values. However, molds, yeasts and some bacteria, such as lactic acid and acetic acid, are acid uric organisms capable of developing and deteriorating highly acidic foods, because they tolerate and find their substrate in acidic environments (Gómez 2004).

Table 5
pH, moisture (%, DW), total solids (%, DW), antioxidant activity (ORAC, µmol TE/mL), Total Polyphenol Content (TPC, mg GAE/L), Total Monomeric Anthocyanins (TMA, mg C3GE/L) and colorimetric coordinates (L*, a*, b*)

Characteristics	Samples			
	B	J	I	D
pH	3.8 ± 0.62^{b}	4.5 ± 0.70^{a}	3.8 ± 0.26^{b}	4.0 ± 0.75^{b}
Total solids (%, DW)	4.26 ± 0.95^{a}	4.13 ± 1.84^{b}	4.22 ± 2.29^{a}	4.10 ± 1.95^{b}
ORAC (µmol TE/mL)	7.14 ± 1.56^{c}	9.09 ± 0.29*^{a}	7.07 ± 1.56^{c}	8.70 ± 0.18^{b}
TPC (mg GAE/L)	226.20 ± 30.20^{c}	278.17 ± 10.7*^{a}	228.12 ± 26.12^{c}	242.45 ± 27.90^{b}
TMA (mg C3GE/L)	70.53 ± 4.85^{b}	97.19 ± 4.40^{*a}	70.62 ± 4.25^{b}	78.06 ± 2.19^{b}
L*	53.54 ± 1.26^{a}	44.45 ± 1.01^{*b}	53.46 ± 1.18^{a}	45.85 ± 2.60^{b}
a*	55.75 ± 0.92^{b}	55.29 ± 0.58^{*b}	55.32 ± 0.82^{b}	58.18 ± 0.98^{a}
b*	20.23 ± 1.52^{b}	21.02 ± 0.78*^{b}	20.28 ± 1.22^{b}	25.25 ± 2.00^{a}

*Díaz-García et al. (2021). Different letters in each row present significant difference ($p < 0.05$).

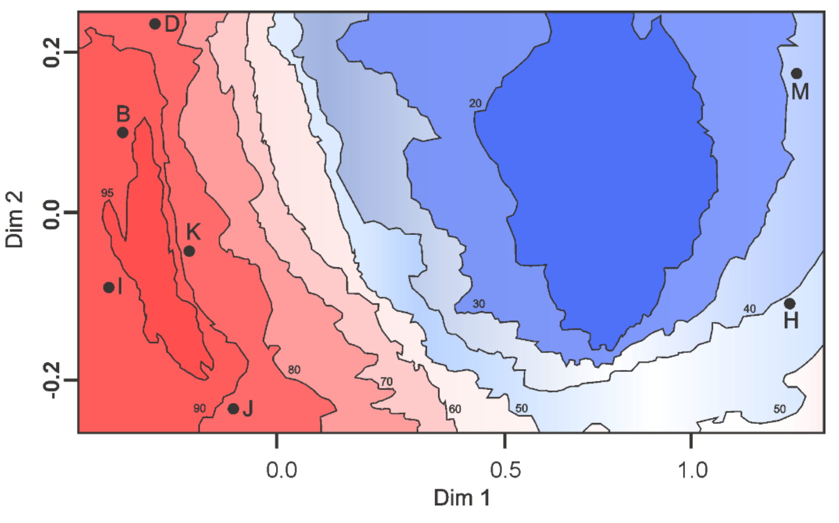

Figure 4. External preference mapping of tea formulations.

4. Conclusions

Using Flash Profile, the sensory lexicon describing the tea samples developed from purple corn cob was obtained, which were: purple, reddish color, sweet, stevia flavor, bitter, astringent, acid, "*chicha morada*" flavor, quince flavor, fruity taste, smell of cinnamon, and fruity smell. It was also determined that Flash Profile remains an important methodology not only for the sensory characterization of various products, but also as a strategy for the generation of sensory characteristics that can be successfully included in the evaluation report of the CATA questions, which not only allows obtaining the descriptive profile of the analyzed samples, but also provides notions about the characteristics with the greatest impact on consumer acceptability and those that consumers expect to find in their ideal product. It was observed that samples B and I presented a higher percentage of consumers who had a high degree of acceptability through the application of external preference mapping. These samples were not necessarily those that presented the highest values of total polyphenol content, antioxidant activity and total monomeric anthocyanins (sample J); which would show that the use of the two sensory methodologies under study allows elucidating the sensory characteristics that influence consumer acceptability, constituting potential tools in the development of new functional products.

Author contribution

J. Mora-Velit: Methodology, Formal analysis, Investigation, Writing – original draft, Visualization. G. Puma-Isuiza: Data curation, Investigation, Writing – original draft, Resources. J. Liñan-Pérez: Investigation, Writing – original draft, Resources. B. K. Salvá-Ruiz: Conceptualization, Methodology, Writing – review & editing, Funding acquisition. M. I. Silva-Jaimes: Conceptualization, Methodology, Validation, Formal analysis, Resources, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors acknowledge INNOVATE-PERU for funding the project "Development of purple corn tea with quince and stevia leaves as a proposal for a fruit infusion with high antioxidant capacity, naturally sweetened and with a high level of pleasure in LECOLE PRODUITS S.A.C.'': contract 027-INNOVATEPERU-PIEC1-2019.

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