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Comparison of consumer perception of Colombian and Mexican blueberries (*Vaccinium corymbosum* L. cv. Biloxi)
Comparación de la percepción de los consumidores sobre los arándanos (*Vaccinium corymbosum* L. cv. Biloxi) colombianos y mexicanos

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ABSTRACT

Consumers often associate their flavor preferences with the origin of foods and beverages; however, these distinctions are not always considered when such products are exported. This research presents the findings of a study designed to evaluate cross-cultural differences in the perceptions of Mexican and Colombian consumers regarding the organoleptic characteristics of the biloxi blueberry variety, grown in both Mexico and Colombia. For this purpose, an experimental study was conducted based on a questionnaire in which 397 consumers from both countries assessed different sensory attributes of two samples: one grown in Mexico and the other in Colombia, both belonging to the biloxi variety. In addition, a biometric test was performed to detect facial microexpressions to complement the results of the experiment with indicators of emotional valence. The study demonstrated that certain correspondences between organoleptic properties are consistent in both cultures. Specifically, in both nationalities a significant effect is evident in acidity, bitterness, and sweetness. The Colombian blueberry was perceived as sweeter, while the Mexican blueberry was evaluated as more bitter and sour. Similarly, it was found that when the blueberry evaluated was rated as more acidic, the overall flavor rating was lower. These results are relevant for blueberry producers, traders, and exporters, knowing that the sweeter varieties will be the most accepted by Colombian and Mexican consumers.

Keywords: Emotion measurement; Country of origin; Sensory characterization by consumers; Sensory quality; Sensory science.

RESUMEN

Los consumidores suelen asociar sus preferencias con sabores específicos según la procedencia de los alimentos y bebidas; sin embargo, no siempre se consideran estas diferencias cuando se exportan dichos alimentos. Esta investigación presenta los resultados de un estudio diseñado para evaluar diferencias interculturales en la percepción de los consumidores mexicanos y colombianos de características organolépticas (gusto general, frescura, intensidad de color, intensidad de aroma, acidez) entre el arándano cultivar biloxi cultivado en México y Colombia. Se diseñó un estudio experimental basado en un cuestionario en el que 397 consumidores de ambos países (192 en México, 205 en Colombia) evaluaron distintos atributos sensoriales de dos muestras: un arándano mexicano y uno colombiano, ambos de la variedad biloxi. Adicionalmente, se realizó un análisis de microexpresiones faciales para complementar los resultados del experimento con indicadores de valencia emocional. Se demostró que ciertas correspondencias entre las propiedades organolépticas son consistentes en ambas culturas. Específicamente, en ambas nacionalidades, se evidencia un efecto significativo en los atributos acidez, amargura y dulzura. El arándano colombiano fue percibido más dulce, mientras que el arándano mexicano fue evaluado como más amargo y ácido. Cuando el arándano evaluado fue clasificado como más ácido, la calificación de gusto general fue más baja. Estos resultados son relevantes para los productores, comercializadores y exportadores de arándanos, sabiendo que aquellas variedades más dulces serán las que tendrán mayor aceptación por parte de los consumidores colombianos y mexicanos.

Palabras clave: Calidad sensorial; Caracterización sensorial por los consumidores; Ciencia sensorial; Medición de la emoción; País de origen.

INTRODUCTION

Various experts have delved into how people relate to the food and beverages they consume (Kaneda *et al.* 2000; Piqueras-Fiszman *et al.* 2012; Faye *et al.* 2013; Velasco *et al.* 2013; Reinoso Carvalho *et al.* 2015; Velasco *et al.* 2015; Wang *et al.* 2015; Spence, 2017). Although the definition of food flavor starts from a purely organoleptic perspective, it is necessary to have a broader vision of how people perceive food, considering all the associations that are assigned to flavors based on experience and learning (Gilbert *et al.* 2014). These associations undoubtedly have an emotional connotation (Cardello *et al.* 2012).

Emotions are made up of subjective feelings, cognitions, and physiological responses that assign value to an experience (Jonauskaite *et al.* 2020). Some scientists have concluded that the recognition of emotions is universal; that is, regardless of where people were born or raised, it is possible for anyone to recognize facial expressions associated with an emotional state (Ekman & Friesen, 1971; Barrett, 2017). According to Ekman's theory, there is one facial expression to reflect positive emotion (happiness), one expression for neutral emotion (surprise), and five expressions for negative emotion (fear, anger, sadness, disgust, and contempt) (Ekman, 2003).

It is possible that the universal tendencies to associate some flavors with certain emotions are more modulated by the characteristic flavors of each culture than by the sensory characteristics of foods. For example, traditional Mexican cuisine is known to have made use of edible flowers for centuries and probably even millennia (Mulík & Ozuna, 2020).

Blueberries have great potential in the food product market (Hoke *et al.* 2017) due to the increased consumption of fruits that provide vitamins, minerals, and antioxidants to improve the immune system (Yue & Wang, 2017; Lagunes-Fortiz *et al.* 2020). This fruit has several advantages, such as its low caloric content, ideal for diets, its slow maturation, and that it can be kept refrigerated (Konarska, 2015; Romo-Muñoz *et al.* 2019).

In 2016, 650 tons of blueberries were produced in Colombia; for 2018 and 2019, this figure increased to 1,850 tons, showing a growth of 185%. In Mexico, in 2016, 17,100 tons were registered, and in 2018 and 2019, it amounted to 48,600 and 53,670 tons, respectively. The most noticeable growth in Latin America was obtained by Peru, with a production of 125,404 tons in 2019; production increased 44,504.13 tons compared to 2018 (Ghezzi *et al.* 2021).

When evaluating the yield measured in metric tons per hectare, in both Mexico and Colombia, there was a significant decrease of 4.8% and 35.9%, respectively. In general, most Latin American countries suffered considerable reductions; however, in other South American countries, there was an increase from 0 to 6 tons per hectare (tm/ha), showing that more and more countries are entering the production of blueberries. In addition, the United States and Canada show favorable figures in this regard, with percentages of 22.2% and 22.5%, which is why their numbers have been significant in the other aspects already evaluated (Tinoco-Plasencia *et al.* 2023).

Sensory quality is captured by the senses and is that which makes a food palatable or rejectable; it is the first factor in selecting a food. It includes the characteristics of smell, color, taste, texture, chewing sensation, and temperature, among others (Cheng *et al.* 2020). Sensory perception is carried out by means of electrical impulses, which are transmitted from the point of reception of the stimulus to the central nervous area.

Later the impulse is sent to the brain where the sensation is correlated and defined: a) the eye checks the appearance, shape, size, density, physical deterioration, and color, mainly; b) smell is stimulated by volatile (aromatic) substances, which are perceived when they are transmitted through the air. The primary elements of odors are intensity, type, and variety. Smell helps to distinguish if a food is spoiled. An ordinary person captures around 200 different smells, while a gourmet can detect more than 5000, and c) taste is basically perceived by the mouth, specifically in the taste buds of the tongue. The tongue can detect five basic tastes (sweet, sour, salty, bitter, and umami (Motoki *et al.* 2022).

The US Food Institute (IFT) defines sensory evaluation as "the scientific discipline used to evoke, measure, analyze, and interpret the reactions to those characteristics of food and other substances, which are perceived by the senses of sight, smell, taste, touch and hearing" (Stone, 2012).

It can also be defined as the analysis of food or other materials through the senses. Another concept that is given to sensory evaluation is the characterization and analysis of acceptance or rejection of food by the taster or consumer, according to the sensations experienced from the moment they observe it and after they consume it. It is necessary to consider that these perceptions depend mainly on the individual, on space and time (Baños Ardavín *et al.* 2014).

Studies of sensory perception (organoleptic) in agribusiness are essential for international trade because they allow the evaluation of the characteristics of food products, such as flavor, aroma, texture, and appearance, factors that directly influence consumer preference and its acceptance in global markets (Greis *et al.* 2021).

This study will allow us to identify which attributes of quality control must be maintained in production to satisfy the consumer. It will also allow you to establish if there are cultural preferences in blueberry consumption and, in this way, adjust the characteristics of the blueberries to tastes (Rivera *et al.* 2022).

Sensory perception studies in agribusiness are essential to ensure the success of a product in international trade, improving its acceptance, quality, competitiveness, and ability to meet the expectations and regulations of different global markets.

Therefore, the purpose of this work was to evaluate the sensory perception of Mexican and Colombian consumers of the same blueberry variety, whose only difference is its origin (Mexico and Colombia). The results of the consumer's sensory characterization were compared with the laboratory analysis.

MATERIALS AND METHODS

The research procedure is presented in three phases. The first phase consisted of the construction of the theoretical framework that allowed clarify the concepts that were analyzed in the study. The point of view was established from the different disciplines. In the second phase, the methodology was proposed to collect and analyze the data that would serve to do the empirical research of the study.

Experiment. This research includes a cross-sectional experimental design (Hernández Sampieri *et al.* 1991). The type of study is descriptive and inferential, and the information was collected through surveys (Montero & León, 2002), with questions containing ordinal measurement levels. The selection of the sample was non-probabilistic, where the selection criteria were: (1) being between 18 and 45 years old and (2) having previously consumed blueberries. The experiment was applied to 397 people. The participants were part of the databases of two universities.

The purpose of this research is to assess if there are differences between the perception of consumers regarding Mexican and Colombian blueberries, considering variables such as smell, taste, color (criterion variable), and the origin of the blueberry (treatment factor), taking into account that the quality of the blueberry fruit varies according to the abiotic (soil, climate, water) and biotic conditions, and the cultivation practices of the two countries (Cortés-Rojas *et al.* 2016). The error control design that was proposed for this experiment is crossover so that the same consumer tests the two treatments at random. The statistical model is presented in equation 1.

$$\text{Preference}_{ijt} = \mu + \text{Blueberry}_i + \text{Lot}_j + \text{Time}_t + \varepsilon_{ijt} \quad \text{equation 1}$$

where = 1,2; = 1, ..., 397; = 1.2.

Preference_{ijt} is the rating of the attribute blueberry when applying the i-th treatment in the j-th individual.

μ is the overall mean rating preference regardless of treatment applied.

Blueberry_i is the effect of the treatment

Lot_j is the group effect

Time_t is the effect of the order in which the treatment was applied

ε_{ijt} is the random variable error associated with the j-th experimental unit of the i-th treatment. Assuming normality with zero mean, independence, and homogeneity of variance.

The data were analyzed by means of both one-way ANOVA as implemented in the SPSS v18 statistics package, with the between-subjects factors of blueberry variety (Colombian and Mexican blueberry) and the within-subjects factor of liking level of the blueberry tasted (visual analogue scale: 0 = not at all, 10 = very much).

To contrast the results of the experiment with the physical characteristics of the blueberries, a bromatological study was carried out on the blueberries consumed by the participants in the Nutrition Laboratory of the Universidad de Ciencias Aplicadas y Ambientales. The physicochemical determinations that were made in both fresh matter and dried fruit following the AOAC (2000) methods were: moisture, total protein, ethereal extract, crude fiber, ash, pH, tannins, total carbohydrates, gross energy, brix degrees. To carry out this study, a sample of 500 grams of blueberries from each region (Colombia and Mexico). The fruits used from the two countries had a similar harvest time to guarantee that the comparison of the characteristics maintained the same conditions.

Neuromarketing. Finally, a neuromarketing study was carried out to determine consumers' expressions when tasting the two types of blueberries. To collect the information, a personal survey format was used, with 36 questions, eight of which were closed questions and 28 scale questions (0 to 10) to evaluate the attributes of blueberries.

For the application of the experiment, we worked with groups of 10 people to assign the treatments randomly. The blueberries were placed in plastic jars with a sticker to identify which blueberry it was (WZP, Mexican blueberry and RTY, Colombian blueberry). Later, as the study participants entered, they were given the questionnaire and the order in which they should taste the blueberries. To clean the palate, they were offered soda crackers and water. Additionally, an analysis of facial micro-expressions was made, where the same procedure was followed, but the form was filled out on a computer.

For the facial micro-expressions experiment, 64 participants were examined (33 from Colombia and 31 from Mexico), representing a sample of university students and professors aged 18 - 44 years who agreed to participate in the experiment during the term (41 female; MAge = 24.03 years, SDAge = 7.10). The participants gave their consent to scan their faces before performing the experiment. The consent was in accordance with the guidelines established by the current Neuromarketing Science and Business Association code of ethics (NMSBA, 2022). First, the procedure was explained. Then, when the participant was in front of a computer that recorded their face, a baseline was established to determine the initial emotional state of the participant. The participant followed a sensory rinse procedure with water and crackers before tasting the two blueberries whose tasting order was established randomly. After tasting each blueberry, participants were asked to rate (1) overall liking, (2) freshness, (3) color intensity, (4) aroma intensity, (5) acidity and (6) tartness on a visual analog scale. The iMotions's Survey module (Version 8.1) was programmed for that purpose. Finally, the participant had to repeat the experiment with the next blueberry,

and then the test was finished. This study took approximately 7.7 minutes to complete for each participant.

iMotions's Emotion FACET module (Version 8.1) was used to identify the emotions that each participant experienced when tasting the blueberries (Colombian and Mexican) and to compare if there was a correlation between the emotion experienced and the assessment, they gave of how much they liked the blueberry they had just tasted. We ran iMotions on a Dell Lattitude 3550 T450s with Windows 10. Standard settings, as described in the iMotions manual, were used. iMotions provides the percentage of time each basic emotion was experienced: joy, anger, contempt, disgust, fear, sadness, and surprise. For each participant, iMotions establishes a valence parameter (pleasantness) to determine whether the subconscious reaction in relation to a positive or negative emotional state is correlated with emotional expressions on the face

that are recognizable by FACET facial analysis system. The valence time percentage allows classifying basic emotions, such as anger and disgust (negative valence) or joy and surprise (positive valence) (iMotions, 2021).

RESULTS AND DISCUSSION

Of the blueberries used for the consumption test, 500 grams of fruit from Mexican and Colombian were randomly chosen to perform laboratory tests and determine their characteristics. Table 1 shows that fresh Mexican blueberries have higher moisture, protein, and tannins compared to Colombian blueberries. Regarding pH, Colombian blueberries have a higher value, which makes them less acidic, this is consistent with the brix degrees that show that the Colombian fruit is sweeter.

Table 1. Laboratory results of the bromatology study of blueberry fruit from Colombia and Mexico (proximal, crude energy, tannins, pH).

Description: Blueberry Fruit	% FRESH FRUIT													
	No. lab	H	PT	EE	FC	C	ENN	CHO TOT	MO	EB Kcal/100 g	TAN TOT	MS	pH	Brix%
Origin: Chocontá, Colombia.	6427	82.06	0.67	0.20	0.97	0.22	15.88	16.85	17.72	77.7	188	17.94	3.89	13.8
Origin: Guadalajara, Mexico.	6428	84.71	0.84	0.17	1.25	0.31	12.72	13.97	14.98	67.9	244	15.29	3.08	12.4

Description: Blueberry Fruit	% DRY BASE (100% DRY MATTER)								
	No. lab	PT	EE	FC	C	ENN	CHO TOT	MO	EB Kcal/100 g	TAN TOT
Origin: Chocontá, Colombia.	6427	3.73	1.11	5.41	1.23	88.52	93.93	98.77	433	1048
Origin: Guadalajara, Mexico.	6428	5.49	1.11	8.18	2.03	83.19	91.37	97.97	444	1596

H = Humidity; PT = Total protein; EE = Ethereal Extract (Crude Fat); FC = Crude fiber; C = Ash; ENN = non-nitrogenous extract (Soluble carbohydrates); CHO TOT = Total carbohydrates; MO = Organic matter; EB = gross energy; TAN TOT = Total tannins; MS = Dry matter.

Experiment results. In Mexico, the experiment was carried out with 192 participants, of whom 53% were women and 43% were men, with an average age of 20 years. As can be seen in figure 1a. Mexican consumers perceive a marked difference in acidity between Colombian and Mexican blueberries. Additionally, other attributes that present relevant differences are sweetness and tartness.

In Colombia, 205 individuals participated in the experiment; 66% were women and 34% were men, with an average age of 23 years and an average consumption frequency of 3.2. As well as Mexican consumers, Colombians perceive a difference between Colombian and Mexican blueberries in terms of acidity, tartness, and sweetness, as presented in figure 1b. The results are consistent with laboratory tests performed.

Neuromarketing results. The analysis of variances was carried out with the 14 attributes. A significant effect is evidenced in the attributes of acidity, tartness, and sweetness when Mexican and Colombian blueberries are compared, and secondary attributes that may have an effect are grittiness, odor, and ripeness.

In the case of acidity, a significant difference is found by gender (p = .04), nationality (p = .0002), and variety of blueberry (p = <2e-16). Considering the laboratory analysis and the experiment, it is evident that the Mexican blueberry is more acidic than the Colombian blueberry. This is perceived by all consumers, although women notice it more easily, as presented in figure 2a.

For the tartness attribute only one level of significance is generated in the blueberry variety (p = <2e-16), and when observing figure 2b it is evident that the Mexican blueberry is rated as tarter by all consumers. When evaluating sweetness, it was found that only the blueberry variety is significant (p = <2e-16), which is consistent with the results shown in table 1 about brix degrees since it is evident that Colombian blueberries are sweeter than Mexican ones. This characteristic is identified by all consumers, as presented in figure 2c.
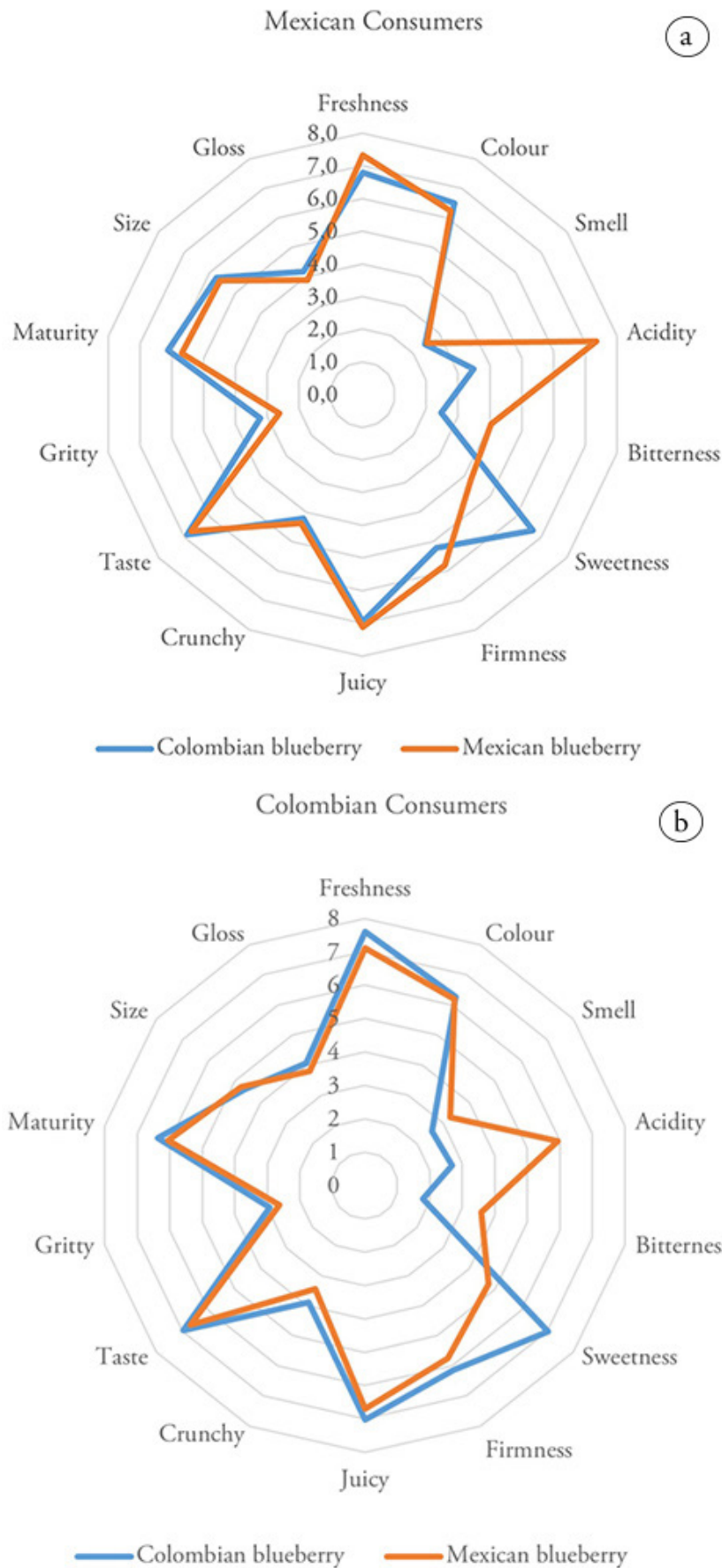
Figure 1. Rating of attributes of blueberry fruits from Mexico and Colombia. a) Mexican consumers; b) Colombian consumers
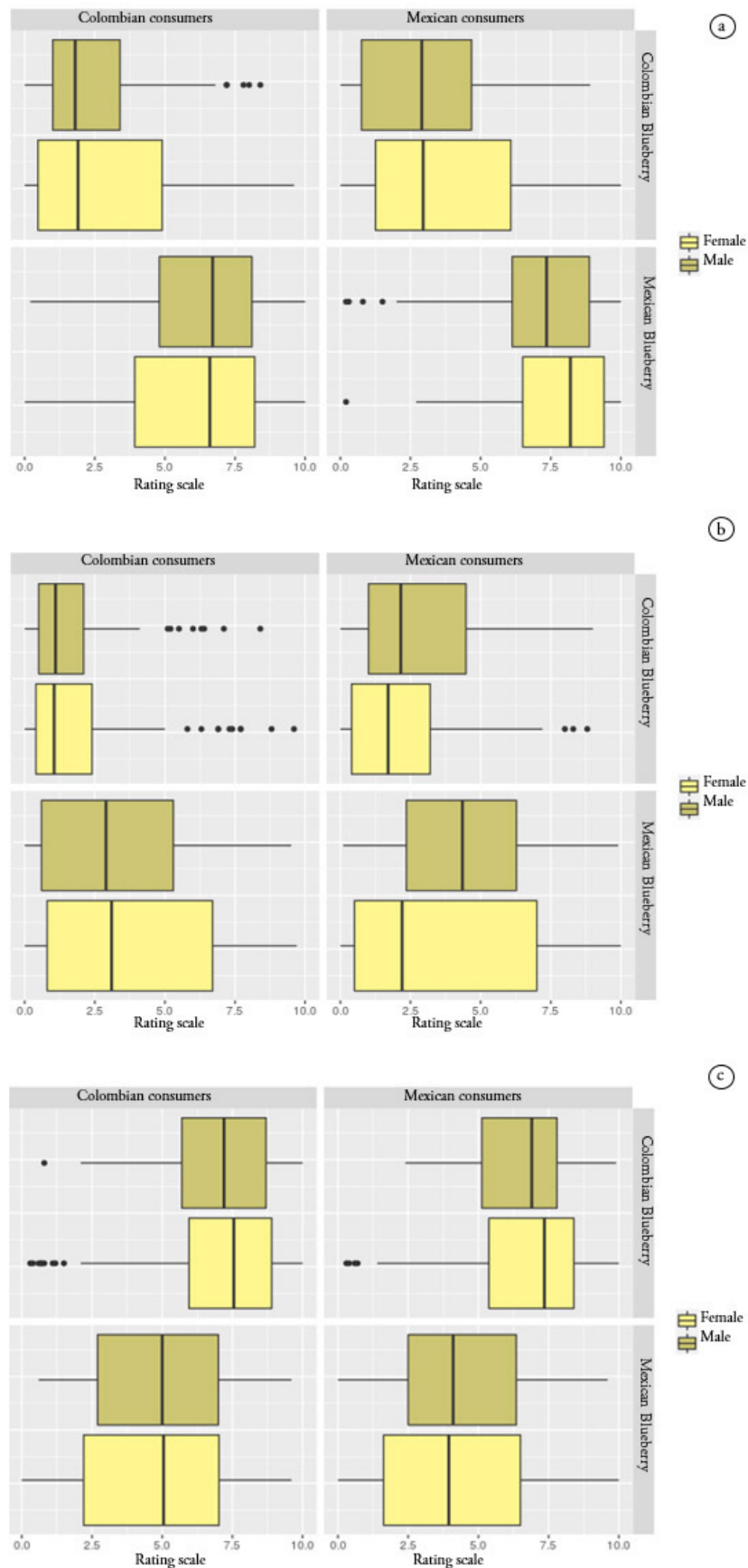
Figure 2. Rating of Colombian and Mexican blueberry by Colombian and Mexican consumers. a) acidity; b) tartness; c) sweetness.

According to this analysis (Table 2), the most valued attributes in Colombian blueberries are freshness and color intensity, while in the case of Mexican blueberries, participants recognize a higher intensity in aroma and acidity. The Colombian blueberry is the most liked. To assess any relationship between the ratings of the blueberries and the emotional valence of the facial emotional response, Pearson correlations with 2-tailed significance tests were performed. A significant positive correlation was observed between liking and acidity of the blueberries tasted (r = -.399, p = .000). This means that when the blueberry is rated as more acidic, the overall taste rating is lower (C. Similarly, a significant negative correlation was observed between freshness and negative valence (time percent) of the blueberries tasted (r = -.189, p = .032). This correlation suggests that when the blueberry was considered less fresh, the participants showed negative emotional valence expressions for a greater percentage of the time. All other correlations were non-significant and irrelevant to our hypotheses.

In general, the emotional valences were more neutral (Table 3), that is, less positive and negative when testing the Colombian blueberry than the Mexican one (41.4% vs. 39.5%), which, as previously observed, coincides with the fact that it was precisely the Colombian blueberry that was the better evaluated, considered less acidic, and with more freshness. When analyzing specific emotions (Table 4), it is observed that only the expression of surprise is more persistent when evaluating the Colombian blueberry in relation to the Mexican (28.3% vs. 26.6%), the rest of the emotional expressions are more accentuated during the Mexican blueberry test.

Table 2. Crosstabulations: Blueberry variety and analyzed emotion by attribute.

Blueberry Variety / Emotion	Liking *	Freshness *	Color intensity *	Aroma intensity *	Acidity	Tartness *
Colombia	8.0	7.4	6.9	2.4	3.0	2.4
Mexico	6.7	6.9	5.9	2.7	5.6	3.4

Mean scores, marked with *, were significantly different according to Tukey's test (confidence level of 95%).

Table 3. Crosstabulations: Blueberry variety and perception of the stimulus

Blueberry variety / Emotion valence	Positive Time Percent *	Negative Time Percent *	Neutral Time Percent *
Colombia	8.0	6.8	41.4
Mexico	8.6	8.6	39.5

Mean scores, marked with *, were significantly different according to Tukey's test (confidence level of 95%).

Table 4. Crosstabulations: Blueberry variety and rating by type of emotion

Blueberry variety / Emotion	Joy Time Percent *	Anger Time Percent *	Surprise Time Percent *	Fear Time Percent *	Contempt Time Percent *	Disgust Time Percent *	Sadness Time Percent *
Colombia	18.4	15 .5	28.3	16.3	15.1	15.1	20.2
Mexico	19.2	16.8	26.6	17.6	15.9	17.7	21.6

Mean scores, marked with *, were significantly different according to Tukey's test (confidence level of 95%).

The consumption of blueberries has been increasing in Mexico and Colombia due to their nutritional characteristics and the current situation. From this research, it can be concluded that consumers of this type of fruit can identify the attributes analyzed in the laboratory regarding flavor. It is also evident from the experiment that there are different characteristics of the fruit depending on the country of origin due to the soil, climate, and other factors of the cultivation of Biloxi variety blueberries (*Vaccinium corymbosum*) that were used in this study.

The tests showed statistically significant differences for acidity, tartness, and sweetness of the 14 attributes studied. This indicates that freshness, color, smell, firmness, juiciness, crunchiness, taste, grittiness, maturity, size, and gloss did not show statistically significant differences. This would lead to the conclusion that the origin of the blueberry is not relevant in these attributes since the homogeneous characteristics are maintained.

At the level of preferences, it is observed that Mexicans consume this fruit more frequently compared to Colombians, however, in the qualification of the attributes, only an important difference is evidenced in their perception compared to size. Previous studies show how the aftertaste aroma of foods that are culturally familiar increases the preference for these foods (Gotow *et al.* 2021). In this sense, acidic flavors are more frequently found in Mexican cuisine, so such familiarity with aromas and flavors may have influenced the rating given to blueberries.

Based on the results of the study, the following recommendations can be made to blueberry producers:

Product adjustment according to local market: Given that significant differences were observed in the perception of sourness, sweetness, and sour taste between consumers in Mexico and Colombia, it would be advisable to adapt marketing strategies and products to local flavor preferences. For example, in Mexico, where acidic flavors are more appreciated, this characteristic of blueberries could be highlighted in advertising campaigns, or products that highlight the acidic flavor could be developed.

Focus on frequency of consumption: The results show that Mexicans consume blueberries more frequently than Colombians. Entrepreneurs in Colombia could focus on increasing the frequency of consumption through campaigns that highlight the nutritional benefits and versatility of blueberries in various local recipes, promoting their use in traditional Colombian dishes.

Homogeneity of certain attributes for international markets: Since attributes such as freshness, color, firmness and texture do not show significant differences depending on the country of origin, companies can focus on standardizing these attributes to ensure consistent quality internationally. This is especially important to maintain competitiveness in global markets, where the perception of quality is key.

Diversification of supply according to variety of blueberries: Although the Biloxi variety was used in this study, the possibility of introducing other blueberry varieties into the market that respond even better to local preferences in terms of flavor or texture could be explored, especially in Colombia where consumption is lower.

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