

Production and sensory attributes of a fermented beverage based on coffee pulp

Producción y atributos sensoriales de una bebida fermentada a base de pulpa de café

Alejandro Molano-Castañeda¹, Carolina Navarro-Sepúlveda¹, Karina Cruz-Castillo¹, Lined Cristina Henao-Marín¹, Esteban Largo-Ávila¹, Carlos Hernán Suárez-Rodríguez¹, Diego Fernando Castro-Vargas¹, Alba Mery Garzón-García¹

¹ Vicerrectoría de Regionalización, Universidad del Valle, Regional Caicedonia. Carrera 14 # 4-48, Valle del Cauca, Colombia. CP. 762540.

ABSTRACT

Coffee pulp is obtained as the most voluminous by-product of coffee bean processing. The objective of this research was to utilize fresh coffee pulp cv. Castillo[®] for the production of a fermented beverage. The pulp was washed and scalded twice. Anaerobic fermentation was conducted using saccharose (33.33 g/L) and different concentrations of commercial yeast (0.175, 0.245, and 1.050 g/L) for 20 days, with water from the second scalding stage as medium. Subsequently, the microorganisms were inactivated, and the fermentation product was refrigerated for 8 days. The fermented beverage was characterized by measuring physicochemical parameters (pH, density, alcohol content, and titratable acidity), color by CIELab system, antioxidant capacity by ferric reducing antioxidant power (FRAP) assay, and sensory attributes (appearance, aroma, taste, and overall acceptance). The beverage produced with a yeast concentration of 1.050 g/L conserved the red hues of coffee cherries, presented the highest antioxidant capacity (24.525 mg EAG/L), as well as high consumer acceptance. However, the taste was the sensory attribute with the lowest ratings due to the presence of sour notes in the beverage (≈ 6). This preliminary study allowed to know a potential use of coffee pulp for health beneficial fermented beverages.

Keywords: *Coffea arabica* L.; liquid-state fermentation; physicochemical parameters; antioxidant capacity; sensory attributes.

RESUMEN

La pulpa de café se obtiene como el subproducto más voluminoso del procesamiento del grano de café. El objetivo de esta investigación fue utilizar pulpa fresca de café cv. Castillo[®] para producir una bebida fermentada. La pulpa se lavó y escaldó dos veces. La fermentación anaeróbica se realizó utilizando sacarosa (33.33 g/L) y diferentes concentraciones de levadura comercial (0.175, 0.245 y 1.050 g/L) durante 20 días, con agua de la segunda etapa de escaldado como medio. Posteriormente, los microorganismos se inactivaron y el producto de la fermentación se refrigeró durante 8 días. La bebida fermentada se caracterizó midiendo parámetros

fisicoquímicos (pH, densidad, contenido de alcohol y acidez titulable), color por el sistema CIELab, capacidad antioxidante por el ensayo de poder antioxidante reductor férrico (FRAP) y atributos sensoriales (apariencia, aroma, sabor y aceptación general). La bebida producida con una concentración de levadura de 1.050 g/L conservó los tonos rojos de las cerezas de café, presentó la mayor capacidad antioxidante (24.525 mg EAG/L) y una alta aceptación por parte del consumidor. Sin embargo, el sabor fue el atributo sensorial con menor calificación debido a la presencia de notas ácidas en la bebida (≈ 6). Este estudio preliminar permitió determinar el uso potencial de la pulpa de café en bebidas fermentadas beneficiosas para la salud.

Palabras clave: *Coffea arabica* L.; fermentación en medio líquido; parámetros fisicoquímicos; capacidad antioxidante; atributos sensoriales.

INTRODUCTION

Coffee is one of the most widely consumed beverages worldwide, with consumption reaching nearly 2 billion cups between 2021 and 2022, equivalent to 170.3 million 60 kg bags (Colcafé, 2023). According to FAOSTAT (2025), Colombia was the fourth-largest producer of green coffee in 2023, exceeding 680,000 tons, following Brazil, Vietnam, and Indonesia. One of the main cultivars grown in Colombia is Castillo[®], developed by the National Coffee Research Center (Cenicafé). This variety is recognized for its high yield potential, desirable cup quality, and resistance to coffee leaf rust and berry disease (Figueroa-Varela and Duque-Dussán, 2025).

During coffee processing, only 9.5% of the total fruit weight is utilized, corresponding to the roasted bean. As a result, coffee pulp is the most abundant by-product, accounting for approximately 40–50% of the fresh fruit's weight (Durán-Aranguren *et al.*, 2021). Research on the chemical and microbiological composition of coffee pulp has explored its potential for producing value-added products, including yeasts, alcohol, colorants, pectin, honey, and intermediate compounds (Hu *et al.*, 2023; Serna-Jiménez *et al.*, 2018). Nevertheless, limited research has focused on its application in the development of functional foods and beverages.

*Author for correspondence: Alba Mery Garzón García
e-mail: garzon.alba@correounivale.edu.co

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Previously, coffee cherry pulp of various cultivars (Bourbon, Caturra, Catuai, and Maragogype), as well as a beverage called Cascara made with 65.6 g of dry coffee pulp, 71 g of sugar, and 57 mL of lemon juice per liter of water, were found to contain high levels of phenolic compounds and caffeine (Heeger *et al.*, 2016). Cascara tea is commercialized worldwide and sold as a superfood, containing Brain-Derived Neurotrophic Factor (BDNF) (Iriondo-DeHond *et al.*, 2020). Patil *et al.* (2022) developed a beverage by infusing 100 g of dried coffee pulp in 1 L of distilled water at 90 °C for 10 min, with 80 g of sugar and 5.5 mL of lemon juice. To boost its functional food value, they inoculated the beverage with kefir grains (2% w/v). This beverage received positive feedback from consumers and exhibited high antioxidant activity. Additionally, dried coffee pulp from cv. Gayo Arabica was used to produce kombucha through fermentation with a mix of acetic acid bacteria and yeast. Fermenting this kombucha for 12 days improved its taste (Muzaifa and Rahmi, 2021). Arabica husk coffee was also used to prepare kombucha with a sucrose concentration of 10 g/L for fermentation with SCOBY (Symbiotic Colony of Bacteria and Yeast) microorganisms. The optimal fermentation time for kombucha was determined to be 14 days, at which point the beverage reached a pH of 2.69. This fermentation process enhanced the beverage's antioxidant, antimicrobial, and prebiotic activities (Le *et al.*, 2023).

The industrial processing of coffee cherries generates a substantial amount of fresh pulp, rich in sugars and nutrients that can be transformed into value-added products through microbial processes (Lopes *et al.*, 2020). Fermentation is one approach that has been explored to create products with biological activity. This method has previously led to changes and the release of phenols, as well as an increase in antioxidant activity, when a mixture of coffee pulp, water, and sugar was inoculated with *Lactobacillus plantarum* (Myo *et al.*, 2021). However, further research is necessary, as past studies have primarily focused on fermented products made from dried coffee pulp and fermentation with lactic acid bacteria. Therefore, this study aimed to analyze the production process and assess the chemical and sensory attributes of a beverage produced through the fermentation of fresh coffee pulp using commercial yeast.

MATERIAL AND METHODS

Vegetal material

Approximately 2 kg of coffee pulp (*Coffea arabica* L. cv. Castillo[®]) were obtained from ripe cherries (Figure 1) at the Buenavista farm in Génova, Quindío, Colombia, located at 4°17'02.4" N, 75°46'05.8" W.

Reagents

Absolute ethanol (95%) was purchased locally from San Jorge (Cali, Valle del Cauca, Colombia). We obtained sodium acetate buffer and gallic acid from Alpha Chemika (Mumbai, MH, India), and 2,4,6-tris(2-pyridyl)-s-triazine (TPTZ) from Sigma-Aldrich (St. Louis, MO, USA). FeCl₃ was obtained from Millipore Corporation (Darmstadt, Hesse, Germany). We sour-



Figure 1. Coffee plant (a) and pulp (b) cv. Castillo[®].

Figura 1. Planta (a) y pulpa (b) de café de la variedad Castillo[®].

ced hydrochloric acid from Panreac AppliChem (Castellar del Vallés, Barcelona, Spain).

Reception and characterization of the raw material

The pulp was washed to remove impurities such as branches and leaves. During this stage, water activity (*a_w*; AQUALAB 3, Addium, Pullman, WA, US), pH (HI 991001, HANNA Instruments, Woonsocket, RI, US), total soluble solid content (TSS; PAL-1, ATAGO CO., TYO, JP), moisture content (AOAC 934.06 method), titratable acidity (TA) considering citric acid as predominant and following the AOAC 942.15 method (AOAC, 2012), and color of the coffee pulp were also assessed (3NS800 spectrophotometer, 3NH, Zengcheng District, GZ, CN). Color evaluation was conducted using CIELab coordinates (L* or lightness: white(+)/black(-), a*: red(+)/green(-), b*: yellow(+)/blue(-)), C* (chromaticity), and hue (h*; 0° or 360°: red, 90°: yellow, 180°: green, and 270°: blue) (Pathare *et al.*, 2013).

Production of the beverage by liquid-state fermentation

The production of a fermented beverage from coffee pulp followed traditional methods shared by farmers in Génova, Quindío, Colombia. Initially, 1 kg of coffee pulp was combined with 3 L of potable water and heated to approximately 90 °C. Afterward the water was filtered with a strainer and discarded. The scalded pulp was then mixed with an additional 3 L of potable water and heated to 60 °C in a conventional batch. The water from this step was collected and used for the fermentation process.

For the fermentation process, sugar was added at a concentration of 33.33 g/L, and commercial yeast (*Saccharomyces cerevisiae*, Productos Toke Gourmet, Tuluá, Valle del Cauca, Colombia) was separately incorporated at concentrations of 0.175, 0.245, and 1.050 g/L. The samples were subjected to anaerobic fermentation at room temperature for 20 days (Figure 2). This process was performed in duplicate.

After fermentation, the yeast was inactivated by heating the samples at 60 °C. The fermented beverages were then filtered to remove impurities and stored under refrigeration at 7 °C and 70% of relative humidity for 8 days.

Physicochemical and color analysis of the fermented beverage

The pH of the fermented beverage was measured both before and after storage at refrigeration temperatures (7 °C). Additionally, the density was determined using a pycnometer, and the alcohol and total solid content were assessed by an alcohol hydrometer. Titratable acidity was evaluated following the method described by Le *et al.* (2023). For this assay, titration was performed with a 0.1 N sodium hydroxide solution, considering acetic acid as the predominant acid. Color was evaluated following the same procedure used for the pulp, using Petri dishes (5 mm thick) filled to a height of 1 cm and placed on a white background.

Antioxidant capacity of the fermented beverage by ferric reducing antioxidant power (FRAP)

The antioxidant capacity of the fermented beverage was assessed by the ferric reducing antioxidant power (FRAP) method, as the methodology proposed by Garzón-García *et al.* (2023) with some modifications. Stock solutions were prepared as follows: a 300 mM sodium acetate buffer at pH 3.6 (Alpha Chemika, Mumbai, MH, IN), a 20 mM $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ solution (Millipore Corporation, Darmstadt, HE, DEU), and a 10 mM solution of 2,4,6-tris(2-pyridyl)-s-triazine (TPTZ; Sigma-Aldrich, St. Louis, MO, USA) in 40 mM HCl (Panreac Appli-Chem, Castellar del Vallés, BCN, ES). The working solution consisted of mixing these stock solutions in a 10:1:1 (v/v/v) ratio (buffer, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, and TPTZ-HCl, respectively). For the assay, 3.5 mL of the working solution were added to 250 μL of each sample. Absorbance was measured at a wavelength of 638 nm after 30 min of rest in a UV-Vis spectrophotometer (UV-1200, MAPADA INSTRUMENTS, Songjiang District, SH, CHN). A calibration curve was plotted using gallic acid standard (Alpha Chemika, Mumbai, MH, IN), with concentrations ranging from 0.01 to 1 mg/mL ($R^2 = 0.996$). The results were expressed as mg EGA/L (mg gallic acid equivalents per liter of beverage).



Figure 2. Fermentation of the beverage based on coffee pulp.
Figura 2. Fermentación de la bebida a base de pulpa de café.

Sensory analysis

Following the methodology of Lopes *et al.* (2020), sensory analysis was conducted with 12 untrained testers aged 18 to 44, six women and six men. Each evaluator received three random samples, each containing 5 mL of the beverage, and assessed them based on appearance, aroma, taste, and overall acceptance. The evaluation used a hedonic scale from 9 to 1: (9) like extremely (8) like very much, (7) like moderately, (6) like slightly, (5) neither like or dislike, (4) dislike slightly, (3) dislike moderately, (2) dislike very much, and (1) dislike extremely. Scores higher than 5 indicated that the beverage was not rejected.

Statistical analysis

The results were expressed as the mean of triplicate measurements $\pm$ standard deviation. A one-way ANOVA and Tukey's test were conducted to assess the effect of different yeast concentrations (0.175, 0.245, and 1.050 g/L of beverage) on the physicochemical parameters, antioxidant capacity by FRAP assay, and sensory attributes of the fermented beverage ($p < 0.05$).

RESULTS AND DISCUSSION

Characterization of the raw material

Table 1 indicates that coffee pulp is a highly perishable by-product due to its water activity exceeding 1, and moisture content surpassing 80%. It exhibited a neutral pH and high titratable acidity, with similar pH values reported by Romauli *et al.* (2023) for Arabica, Robusta, and Liberica pulp coffees cultivars. This suggests that coffee pulp contains a significant amount of free acids, making it highly susceptible to microbial and enzymatic activity. Therefore, prompt processing under stable conditions is essential.

The coffee pulp cv. Castillo[®] exhibited a low total soluble solid content of approximately 3 °Brix, a value comparable to that reported by Fierro-Cabrales *et al.* (2018) for coffee pulp cv. Costa Rica. These authors also found a high fiber content on a wet basis in coffee pulp, approximately 30.63%. Consequently, the fermentation process facilitated the extraction of antioxidant phenolics primarily from fiber and some bio-

Table 1. Characterization of the coffee pulp cv. Castillo[®].

Tabla 1. Caracterización de la pulpa de café de la variedad Castillo[®].

Parameter	Value
<i>Physicochemical analysis</i>	
Aw	>1
Moisture content (%)	88.281 $\pm$ 0.425
pH	5.050 $\pm$ 0.020
TSS	3.367 $\pm$ 0.058
TA (%)	0.794 $\pm$ 0.126
<i>Color evaluation</i>	
L*	26.174 $\pm$ 0.006
a*	14.662 $\pm$ 0.008
b*	8.101 $\pm$ 0.018
C*	16.751 $\pm$ 0.014
h*	28.921 $\pm$ 0.049

transformed bioactive compounds through the activity of enzymes such as pectinases, β -galactosidase, β -glucosidase, and esterases (Dey and Kuhad, 2014). During fermentation, the glycosidic bonds of large-molecular-weight polyphenols are metabolized allowing them to benefit intestinal microorganisms. This degradation increases the activity of glycosylated polyphenols (proanthocyanidins, gallic acid, ellagic acid) (Yang *et al.*, 2023).

On the other hand, the color evaluation of the pulp showed low luminosity (L^*) and chromaticity (C^*), but red hues. This was confirmed by color analysis performed by Romauli *et al.* (2023) on fresh coffee pulps. Color caption of coffee pulp cv. Castillo® can be classified as red purple, which is related to the presence of hydrophilic pigments such as anthocyanins. These pigments can impart natural color and beneficial properties to the products developed from the coffee pulp, such as high antioxidant activity (Tran *et al.*, 2022).

Physicochemical parameters and antioxidant capacity of the fermented beverage

As shown in Table 2, varying concentrations of commercial yeast (0.175, 0.245, and 1.050 g/L) significantly affected the pH ($p < 0.05$). The results showed that yeast concentrations of 0.175 and 1.050 g/L resulted in the highest pH values. However, the pH values of the beverage at different yeast concentrations were within the recommended range for lactic fermented beverages (3.5–4.5) (Alu'datt *et al.*, 2019). Regarding total soluble solids and titratable acidity, yeast concentration had no significant effect on these parameters. According to Le *et al.* (2023), sucrose acts as a substrate that supports microbial growth and metabolism, and the observed increase in organic acid concentration after fermentation may be attributed to microbial activity.

The different concentrations of commercial yeast did not affect the density of the fermented beverage ($p > 0.05$). The density values suggested that the beverage had properties similar to those of water. On the other hand, the alcohol content was measured before and after the refrigeration stage. Before refrigeration, the alcohol content was 7° for the beverage with a commercial yeast concentration of 0.175 g/L, and 6° for those with 0.245 and 1.050 g/L of yeast. After refrigeration, the alcohol content dropped to 0°. This decrease in alcohol may be attributed to the conversion of ethanol and other substrate metabolites into acetaldehyde, which is subsequently transformed into acetic acid due to temperature and the action of certain native microorganisms (Ignat *et al.*, 2020).

The fermented beverage based on coffee pulp with 1.050 g/L of commercial yeast demonstrated the highest antioxidant capacity by the FRAP assay. This suggests that the activity of microorganisms leads to the release of bioactive compounds. Moreover, the bioactive compounds released and presented in the beverage can stabilize the free radicals by electron transfer (Bibi Saader *et al.*, 2020). Heeger *et al.* (2016) assessed the antioxidant activity of the Cascara beverage (an infusion of dried coffee pulp) using the Trolox

Table 2. Physicochemical parameters and antioxidant capacity determined by FRAP assay, of fermented beverage with distinct commercial yeast concentration (0.175, 0.245, and 1.050 g/L).

Tabla 2. Parámetros fisicoquímicos y capacidad antioxidante determinados mediante ensayo FRAP, de bebida fermentada con distintas concentraciones de levadura comercial (0.175, 0.245 y 1.050 g/L).

Parameter	Yeast concentration (g/L of beverage)		
	0.175	0.245	1.050
<i>Physicochemical analysis</i>			
pH	3.817 ± 0.021 ^a	3.673 ± 0.051 ^b	3.833 ± 0.021 ^a
Density (g/mL)	0.995 ± 0.035 ^a	0.988 ± 0.008 ^a	0.980 ± 0.008 ^a
TSS (°Brix)	<2		
TA (%)	1.600 ± 0.172 ^a	1.750 ± 0.087 ^a	1.900 ± 0.173 ^a
<i>Antioxidant capacity</i>			
FRAP assay (mg EGA/L)	20.182 ± 0.984 ^b	11.350 ± 1.097 ^c	24.525 ± 1.761 ^a
<i>Color evaluation</i>			
L^*	43.540 ± 0.708 ^b	49.747 ± 2.356 ^a	39.500 ± 1.775 ^b
a^*	32.950 ± 2.252 ^{ab}	30.323 ± 3.857 ^b	38.760 ± 2.656 ^a
b^*	33.913 ± 1.911 ^{ab}	34.433 ± 2.957 ^a	28.137 ± 2.196 ^b
C^*	47.286 ± 2.926 ^a	45.906 ± 4.500 ^a	47.896 ± 3.439 ^a
h^*	59.005 ± 1.001 ^a	65.381 ± 5.382 ^a	41.574 ± 0.418 ^b

For each parameter, means that do not share the same letter are significantly different ($p < 0.05$).

Equivalent Antioxidant Capacity (TEAC) method with ABTS, the Oxygen Radical Absorbance Capacity (ORAC), and total phenolic content (TPC) assays. The Cascara beverage exhibited values of 3.02 mmol Trolox equivalent (TE)/L, 8.86 mmol TE/L, and 283 mg GAE/L, respectively. The FRAP assay results in the present study demonstrated significant biological activity in the fermented beverage, indicating an increase in the release of hydrophilic compounds following the fermentation process. Previously, there were no reports on the antioxidant capacity of hydrophilic compounds in beverages based on coffee pulp.

The color parameters of the beverages were affected by the hue of the pulp. Most of these parameters (L^* , a^* , b^* , and h^*) were also influenced by the fermentation conditions. Higher yeast concentrations were associated with a slight decrease in luminosity, likely due to the polymerization of polyphenols (Błaszczak *et al.*, 2024). In addition, the slight reductions in b^* and h^* values indicated more intense red tones in CIELab color system; color saturation (C^*) remained unchanged under the samples processed under different yeast concentrations ($p > 0.05$).

Sensory analysis of fermented beverage

The sensory analysis, using a hedonic scale, revealed no significant differences in consumer preferences related to yeast

concentration, particularly in terms of appearance, taste, aroma, and overall acceptance ($p>0.05$). However, Figure 3 indicated that beverages with yeast concentrations of 0.175 and 1.050 g/L received notably higher scores. The sensory attributes with the highest scores were appearance and aroma, with the red hues and alcohol aroma being particularly appealing to consumers. On the other hand, the attribute with the lowest scores was taste. This could be attributed to the lack of cultural familiarity with non-alcoholic fermented beverages in the area, the presence of acetic acid notes in the beverage, and the fact that most customers can distinguish sourness when the pH is below 5.0 (Makwana and Hati, 2019).

On the other hand, Le *et al.* (2023) observed that the fermentation time influenced the sweetness and acidity of fermented Cascara kombucha, which was prepared using Arabica husk coffee and kombucha starter cultures known as SCOBY. Their findings indicated that a fermentation period of 7 to 14 days enhanced the sweetness and sourness of the beverage. Thus, in the present study, the fermentation time may have contributed to the lower taste scores of the beverage.

CONCLUSIONS

The evaluation of conditions for producing a fermented beverage based on coffee pulp revealed that while yeast concentration did not significantly impact the beverage's density or sensory attributes, it did influence pH, most of color parameters, and antioxidant capacity, as determined by the FRAP assay. A yeast concentration of 1.050 g/L was found to enhance the release of bioactive compounds and achieve a pH level suitable for human consumption. Overall, consumer feedback on the fermented beverage was positive; however, the presence of sour notes led to lower ratings for taste. Further analysis may be required to optimize fermentation time and improve flavor.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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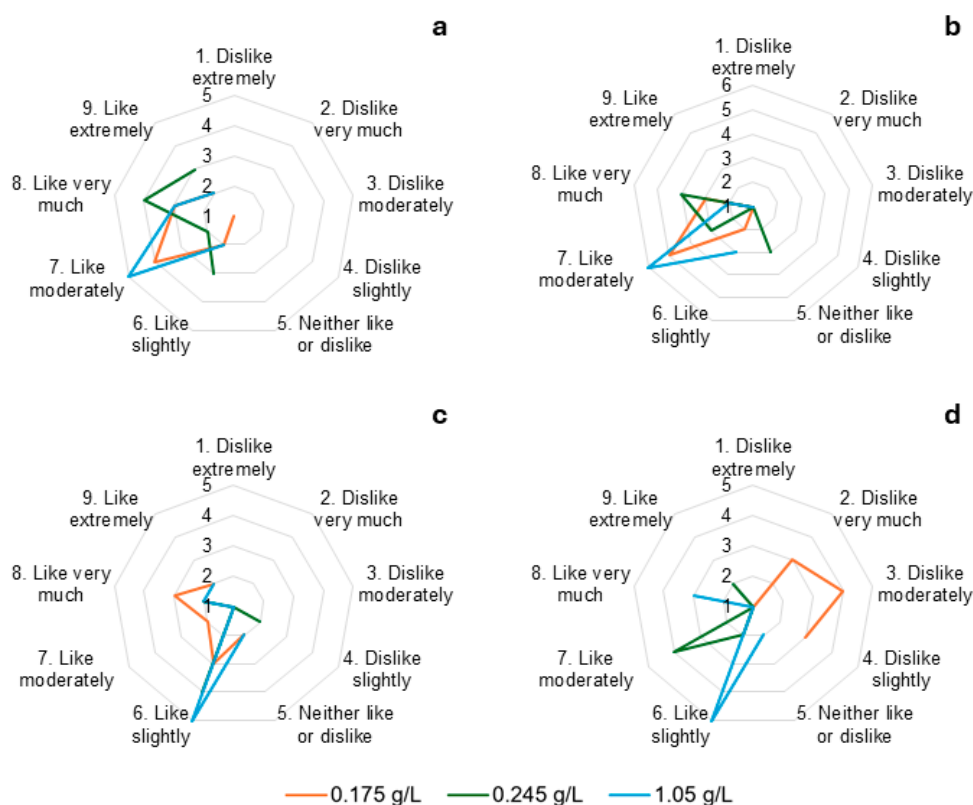


Figure 3. Sensory attributes of a fermented beverage based on coffee pulp with distinct commercial yeast concentrations (0.175, 0.245, and 1.050 g/L): (a) appearance, (b) aroma, (c) taste, and (d) overall acceptance.

Figura 3. Atributos sensoriales de una bebida fermentada a base de pulpa de café con distintas concentraciones de levadura comercial (0.175, 0.245 y 1.050 g/L): (a) apariencia, (b) aroma, (c) sabor y (d) aceptación general.

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