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Physicochemical and organoleptic profile of the native fine aroma cocoa from northeastern area of Peru

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Abstract

Peru is one of the main cocoa exporters worldwide, being the Amazonas region home of the native fine aroma cocoa (CNFA). The objective of this work was to evaluate the physicochemical and organoleptic properties of the CNFA grown in Utcubamba province, Amazonas. The cocoa samples were collected in four areas (Cajaruro, Naranjos Alto, Llunchicate, and La Palma) in which farmers carry out the same postharvest handling practices. Samples underwent a six-day fermentation process and dried in full sun. The physical and chemical parameters of dried beans were evaluated. Then, chocolate pastes were evaluated through a sensory test. We found that the CNFA beans presented optimal physical characteristics to be used at an industrial level. In terms of chemical parameters there was no difference between the percentage of fat. The Cajaruro and Llunchicate samples had lower acidity values and adequate pH, which reflected on their greater acceptance in the sensory test. Therefore, CNFA beans from the Amazonas region, Peru, can be used as raw material to produce *gourmet* chocolates.

Keywords: *Theobroma cacao*; physical quality; fermentation; sensorial test.

Practical Application: Our results show that the native cocoa from the northeastern region of Peru have a promisor physicochemical and organoleptic profile suitable for being used in the chocolate industry.

1 Introduction

The cocoa (*Theobroma cacao* L.) crop is native to the Amazon region, but it currently has a pantropical distribution. It grows from sea level to approximately 1200 m a.s.l., with an average temperature between 20 to 30 °C and a relative humidity (RH) between 70 to 80% (Romero & Urrego Vargas, 2016). The cocoa tree can reach up to 10 m in height, with fruits that measure between 15 and 25 cm, containing approximately 30 to 40 beans, which after fermentation and drying are used in the manufacture of chocolate (Romero & Urrego Vargas, 2016). The traditional cocoa genetic groups are *Criollo*, *Forastero* and *Trinitario. Criollo* cocoa is characterized by having a sweet taste, good quality chocolate and an intense aroma. The *Forastero* cocoa is characterized by its bitter and little acid taste, despite of this it is widely cultivated due to its higher yield and resistance to pests. The *Trinitario* cocoa is a hybrid cocoa (*Criollo* + *Forastero*). One of the main *Trinitario* cultivars is CCN-51, widely cultivated because it is a species adaptable to different tropical regions, resistant to pests and diseases and because it has attributes of both *Criollo* and *Forastero* cocoa, highlighting an acid and astringent flavor (Romero & Urrego Vargas, 2016).

Peru has 60% of the cocoa biodiversity registered in the world, is the second exporting country of organic cocoa, and it stands out as producer and supplier of fine aroma cocoa. It has been reported that cocoa production in Peru reached 120,058 tons in 130,000 hectares in 2017 and increasing to 199,000 hectares of cocoa cultivation in 2018 (Perú, 2018). The varieties of cocoa grown in the country are *Trinitario* 53.3% (in Junín region), *Forastero amazónico* 37.3% (Cusco and Ayacucho) and Criollo 9.4% (northern area of San Martín, Amazonas, and Cajamarca), being San Martín the region with 84% of the national production with 48.4 thousand tons, followed by the Junín with 25.5 thousand tons (18.8%), Ucayali with 17 thousand tons (12.5%), and Huánuco and Cusco with 13 and 10 thousand tons, respectively (RedAgrícola, 2020).

Commercially, cocoa is classified into conventional and fine aroma cocoa. *Forastero* and CCN-51 cocoa is of the conventional type. Their beans are used to make cocoa butter and cocoa powder. The fine aroma cocoa is used to make gourmet chocolates. For this reason, the production of high-quality chocolate products has generated an increase in the demand of proper post-harvest handling practices (fermented, dried, and roasted) and the taking care of environmental factors (soil, climate and pre-harvest management), parameters that influence cocoa quality (Chía Wong et al., 2017).

Peru is a producer of fine aroma cocoa, recognized worldwide for its sensory quality. The Amazonas region, and specifically the provinces of Bagua and Utcubamba present a great variety of fine aroma cocoa genotypes, which have unique sensory attributes, different from beans from other regions, which is why it has the denomination of origin "Cacao Amazonas Perú" (Leiva et al., 2020; Oliva et al., 2020). During the chemical processes in

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fermentation, drying and roasting (Maillard reaction), the different flavors and aroma characteristics develop, which favor the organoleptic properties of the final product (Apriyanto & Umanailo, 2019; Koffi et al., 2017; Urbańska et al., 2021; Van Durme et al., 2016). The objective of this research was to evaluate the physicochemical and organoleptic properties of the native fine aroma cocoa (CNFA) from different altitudes of the Amazon Region, Utcubamba Province.

2 Material and methods

2.1 Material

The CNFA samples were collected at four different areas in the Utcubamba province in the Cajaruro district: Cajaruro (679 m a.s.l. approx.), Naranjos Alto (670 m a.s.l. approx.), Llunchicate (835 m a.s.l. approx.), and La Palma (1100 m a.s.l. approx.). The cocoa fruits were collected in optimal state of maturation in July 2021. On the same day of harvest, the cocoa pods were cut and uncooked, the cocoa beans were placed to ferment for six days, and after 48 hours, removals were made every 24 hours. Once fermentation was completed, the cocoa beans were dried in full sun, until they reached a relative humidity of 7.5%.

2.2 Physical parameters

For the determination of the physical parameters, 100 dried beans were selected. These were weighed to determine the bean index and the number of beans per 100 g, as well as the yield and dimensions of the cocoa beans. Subsequently, the shell was separated from the *nibs* with a sharp knife and the shells and *nibs* were weighed separately. The percentages of shell and *nibs* were determined. All analyzes were performed by triplicate and reported as the mean of the values. Moisture was determined by using the cereal moisture meter (Draminski). For this, four repetitions were performed per sample and the final result was calculated as the mean of the repetitions.

2.3 Chemical parameters

The pH, titratable acidity, ash, and fat content were determined following according to the procedures of the AOAC, methods 970.21 (Association of Official Analysis Chemists International, 2010), 942.15A (Association of Official Analysis Chemists International, 2019), 972.15 y 963.15 (Association of Official Analysis Chemists International, 2005), respectively. The degree of fermentation was determined by the cut test, according to the NTP-ISO 1114, 2006 Standard (Comisión de Reglamentos Técnicos y Comerciales, 2006). For this, 100 cocoa beans were taken at random, and a longitudinal cut was made, and the two halves of each grain were observed. Moldy, insect damaged, germinated, multiple, flat, broken, slaty, violet, fermented kernels were counted separately.

The fermentation index (FI) was performed according to the method described by Gourieva & Tserevitinov (1979). For this, 0.5 g of previously ground cocoa beans were weighed and added to 50 mL of a methanol: hydrochloric acid solution (97:3, v / v). The mixture was stored in refrigeration (8 °C) for 16-18 h. Then, it was filtered through a Whatman No. 1 filter paper. Finally, the filtrate was read at a wavelength of 460 nm and 530 nm in a spectrophotometer (Unico). All measurements were made in triplicate. The fermentation index was determined using the absorbance ratio of the filtrate between the readings (Equation 1).

$$IF = A460 / A530 \tag{1}$$

2.4 Obtaining dark chocolates (100% cocoa paste)

For the preparation of dark chocolates (100% cocoa paste), 1 kg was used for each of the four samples of dried fermented beans of CNFA. The cocoa beans were selected manually to make their size uniform and eliminate impurities. The medium roasting process was carried out in an oven (Merck, Peru) at a temperature of 120 °C for 20 minutes. Later, the beans were crushed to separate the *nibs* from the shells. To decrease the particle size (18 microns) a roll refiner (Premier, PG508, India) was used for 8 hours at 50 °C. The cocoa liquor was tempered manually and stirred constantly for 20-40 minutes, with alternating temperatures going from 50 to 28 °C and finally 30 °C. Subsequently, the cocoa liquor was molded, using 50 g polyethylene molds, which were labeled and refrigerated for approximately 15 minutes. The cocoa pastes were packaged in aluminum foil and stored at room temperature (18 °C) for further evaluation.

2.5 Sensory evaluation

Sensory analysis of cocoa samples was evaluated using the 9-point hedonic scale for sensation strength (1 extremely disliked; 9 extremely liked), where participants evaluated the attributes of aroma, color, flavor, and texture. Fifty-one participants (students and workers) from the Ceja de Selva Research Institute for Sustainable Development (INDES-CES) of the Toribio Rodríguez de Mendoza National University were selected for this test. The participants received the different samples of dark chocolate (1.5 cm × 1.5 cm × 1.0 cm) at 18 °C, which were randomly coded numerically with three digits. Participants were given a small bite of unsalted cookie and then drank water to rinse their palate between samples (Abdul Halim et al., 2019; Gültekin-Özgüven et al., 2020; Medina-Mendoza et al., 2021).

2.6 Statistical analyses

All the tests were carried out in triplicate and are shown as the mean of the repetitions. The significant difference between the different collection areas and the sensory analysis was determined through the ANOVA analysis of variance, using the Tukey test to determine the 5% significance ($P < 0.05$) between the means. Analyzes were performed in SPSS software, version 25 (IBM Corp., Chicago, USA).

3 Results and discussion

The results of the counting of the cocoa beans in 100 g show that less than 100 beans were necessary to reach 100 g (Table 1). Beans from the Cajaruro, La Palma and Llunchicate area used a greater number of beans (74, 70 and 73, respectively) to reach 100 g, values significantly different with the CNFA beans from

Naranjos Alto (54 cocoa beans for 100 g) (Table 1). Similar findings were obtained with the weight in 100 grains parameter (Table 1). The almond index (AI) determines if the almonds to be used are suitable for use, and for this the value must be greater than 1.0 g (Sánchez-Mora et al., 2014) since the lower AI, the more almonds to complete 500 g, a parameter that is related to performance. The AI of beans from the Naranjos Alto area (1.70) was significantly higher in relation to the CNFA from the other collection areas. In terms of the percentage of *nibs*, the CNFA from the Naranjos Alto, La Palma and Llunchicate areas were significantly higher with values greater than 85%, compared to CNFA almonds from the Cajaruro area which had 82.45% of *nibs*. Coincidentally, this area presented significant higher shell content (17.55%) and lower yield (76.21 ± 1.17%), while the CNFA beans from the other areas presented shell content values between 13 and 14.46% and yield values between 78 and 79%.

CNFA almonds from the northeastern region of Peru evaluated in this work have been evaluated in previous studies. CNFA almonds presented better quality parameters when compared with the national cocoa of Ecuador, CCN-51 (from Ecuador or Peru) and ICS-6 Peru (Álvarez et al., 2007; Andrade-Almeida et al., 2019; Vera-Chang et al., 2014). Therefore, CNFA cultivars from the northeastern region of Peru present larger beans, lower shell percentage and higher yields, characteristics of great interest in the chocolate industry.

No significant differences were found between the length of the cocoa beans, reporting values between 24.87 ± 2.47 and 25.12 ± 2.57 mm in length (Figure 1). However, it was observed that in terms of width and thickness, the CNFA grains presented an inverse relationship: those from the Naranjos Alto and Llunchicate areas were significantly greater in the width of the grains (with average values of 14.10 ± 1.46 and 13.95 ± 1.27 mm, respectively), but significantly lower in thickness compared to the grains from the Cajaruro and La Palma area (8.76 ± 2.67 and 8.31 ± 1.36, respectively) (Figure 1). These results are higher than those reported in the Ecuadorian national cocoa, whose values were 21.96 ± 0.13 mm long, 12.32 ± 0.17 mm wide and 8.19 ± 0.09 mm thick (Andrade-Almeida et al., 2019) and like those recorded by Álvarez et al. (2010) whose dimensions were 24.5 to 24.8 mm long, 13.3 to 13.4 mm wide and 9.5 to 10.7 mm thick.

The cutting test procedure to determine the degree of fermentation is fast and low-cost method, which by means of the coloring of the almonds and the formation of furrows (kidney-shaped form of the bean) indicates the fermentation effectiveness. We found that the CNFA collected in the different

Table 1. Quality parameters of dried CNFA beans from the Amazon Region of Peru.

Collected areas / Parameters	Cajaruro	Naranjos Alto	La Palma	Llunchicate
Index of almond (g / grain)	1.36 ± 26.88[a]	1.70 ± 39.62 [b]	1.44 ± 72.59 [a]	1.43 ± 42.13 [a]
% of *nibs*	82.45 ± 1.16[a]	86.40 ± 1.14[b]	85.54 ± 0.59 [b]	85.90 ± 0.26[b]
% of shell	17.55 ±1.16[b]	13.61± 1.14[a]	14.1 ± 0.59[a]	14.46 ± 0.26[a]
# of almonds/ 100 g	74 ± 1.52 [b]	59 ± 4.04[a]	70 ± 2.65 [b]	73 ± 1.53 [b]
Weight of 100 almonds	136.28 ± 26.8[a]	169.84 ± 39.6 [b]	144.5 ± 75.6 [a]	142.86 ± 42.1 [a]
Performance of grain (%)	76.21 ± 1.17[a]	79.82 ± 0.66[b]	79.33 ± 0.26 [b]	79.7 ± 0.59 [b]

Note. CNFA: Fine Aroma Native Cocoa. Results are expressed as the mean ± standard deviation of three replicates. Different letters in the same column indicate significant differences by the Tukey Test ($P < 0.05$) between the different collection areas.

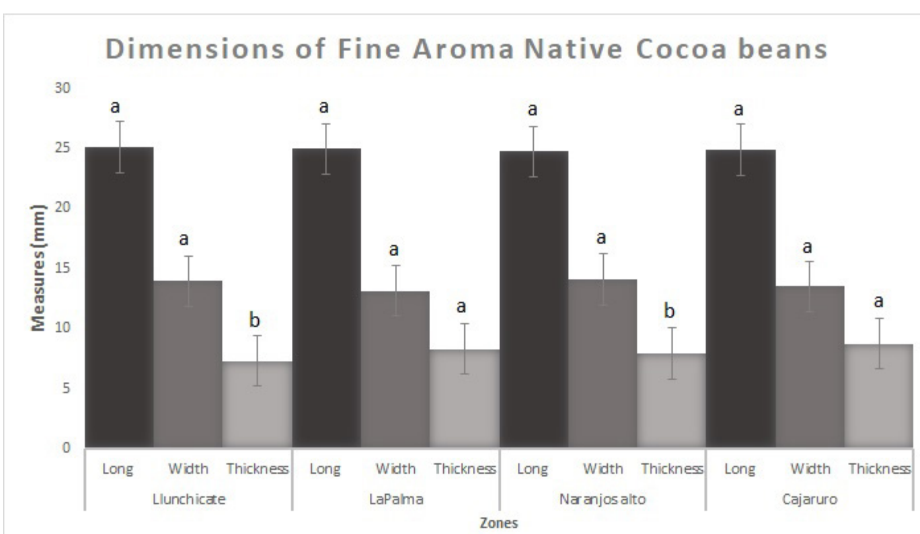

Figure 1. *Dimensions of fine aroma native cocoa beans in length, width, and thickness. Note.* Results are expressed as the mean ± standard deviation of three replicates. Different letters in the same column indicate significant differences by the Tukey Test ($P < 0.05$) between the different collection areas.

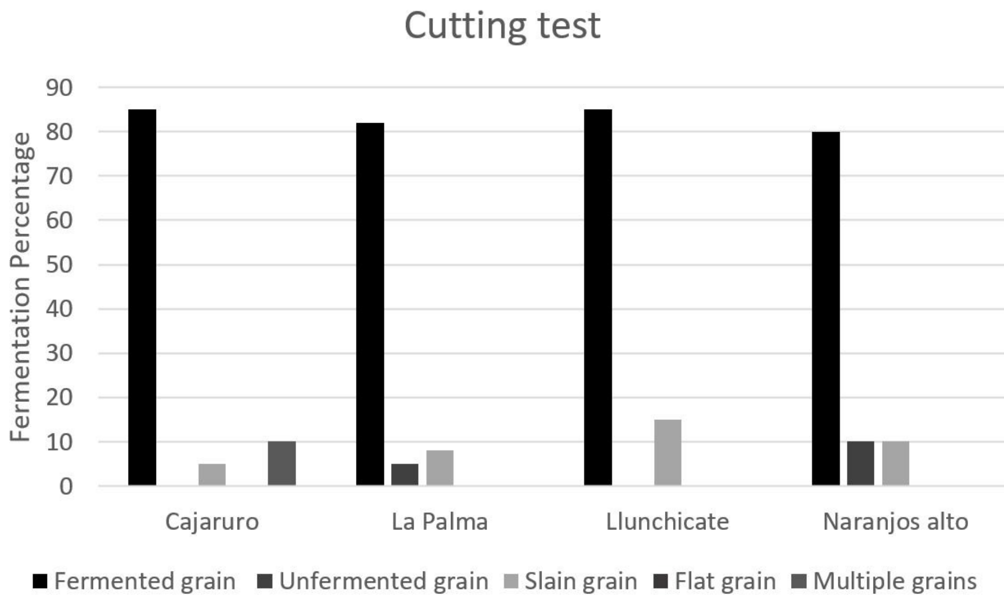

Figure 2. Degree of fermentation of fine aroma native cocoa beans.

zones presented values between 80-85% of fermentation (Figure 2), being classified as type I beans. To verify the results obtained by cutting test method, the fermentation index (IF) was determined (Gourieva & Tserevitinov, 1979). Cocoa beans must present an IF between 1.0 and 1.6, samples with greater values are considered over fermented (Bariah, 2014). In this study, our samples can be classified as fully fermented except for the CNFA from La Palma, which had an IF value of 0.96, significantly different to the CCN-51 (Figure 2), which presented an IF of 1.57 (Figure 3).

Acidity was measured by means of pH and titratable acidity analyzes of in the dried beans of CNFA (Table 2). We found pH values ≥ 5.50, i.e., high quality grains since authors such as Calvo et al. (2021) have pointed out that to generate better and pleasant aromatic and sensory profiles in cocoa, the pH value must be higher than 5.5. In this study, the CNFA beans from the Llunchicate and Cajaruro areas had pH values of 5.81 and 5.83, respectively, standing out over the other two areas. Conversely, the lower titratable acidity values, the higher quality for cocoa beans. The titratable acidity was significantly different for the CNFA beans from Naranjos Alto and La Palma, thus being considered of high acidity, which can affect the flavor and reduce the sensory quality. This is probably caused by the lack of acid elimination (mainly lactic and acetic acids) during the drying of the beans (Jinap & Dimick, 1990). This is related to the partial fermentation obtained from the cocoa beans from La Palma area. The values found in this research were different from those reported by Vera-Chang et al. (2014), who evaluated the pH of different cocoa clones from Ecuador, finding values between 6.33 and 6.88; those reported by Zambrano et al. (2010), with pH values between 4.6 and 5.1 in criollo cocoa from Venezuela; and those reported by Calderon Pena (2004).

Regarding ash content, a significant difference was found between the beans from Cajaruro (5.27) and beans from the other areas (Table 3). The fat percentage of CNFA beans were similar

Table 2. Acidity and pH analysis of fine aroma native cocoa beans.

	pH of the *nibs*	TTA
Naranjos Alto	5.58 ^{ab}	0.26^{b}
Llunchicate	5.81^{b}	0.22 ^{a}
La Palma	5.50 ^{a}	0.25 ^{b}
Cajaruro	5.83^{b}	0.23 ^{a}

Note. TTA. Total titratable acidity. Results are expressed as the mean ± standard deviation of three replicates. Different letters in the same column indicate significant differences by the Tukey Test ($P \leq 0.01$) between the different collection areas of CNFA.

in all samples, with values between 45.2 and 54.4%. These results are similar to those reported by various authors (Calvo et al., 2021; Grassia et al., 2019; Salazar et al., 2020). However, values lower than 52% of fat in cocoa are considered low, since a normal value is registered between 52 and 55% (Grassia et al., 2019; Salazar et al., 2020). The low-fat percentage values in the CNFA beans may be related to the fermentation time, since Afoakwa et al. (2013) and Aremu et al. (1995) reported that the fat content in cocoa beans is related to the greater number of days of fermentation. It may also be related to the increase in lipase activity in the release of free fatty acids responsible for the rancid taste produced during storage (Afoakwa et al., 2013).

The sensory analysis test (Table 4) showed samples had similar aroma scores ($P \geq 0.05$), which is probably related due to the mixture of varieties of CNFA that are cultivated in the province Utcubamba, and the fermentation process provided. At this stage the polyphenolic compounds decrease, which are related to the taste and palatability of the *nibs* (Anyimah-Ackah et al., 2019; Calvo et al., 2021). The intensity of the brown coloration of the chocolates is related to the cocoa concentration, that is, the higher the percentage of cocoa, the darker the chocolate will be. The 100% cocoa chocolates are characterized by having a dark and bright brown coloration (Afoakwa et al., 2008; Shin et al., 2022). In the samples evaluated, the participants determined that the Naranjos Alto samples (5.69 ± 1.449) was the least pleasant (Table 4).

The CNFA is characterized by being aromatic, with a mild flavor and low in bitterness generated during fermentation and drying since in these processes the level of amino acids and sugars increases (Ascrizzi et al., 2017; Qin et al., 2017). In this study, chocolate from the Llunchicate area was selected by the participants as the most pleasant taste sample (5.63 ± 1.886 sensory test values), presenting a perception of less bitterness and astringency, this related to the lower acidity presented in the dried bean (Table 2). Conversely, La Palma samples had the less acceptance, probably due to the bitter taste and astringency, characteristic of the presence of phenolic compounds, acidity (Table 2) and partial fermentation (Figure 3), which limits the acceptance by consumers (Oberrauter et al., 2018; Rottiers et al., 2019). Regarding the texture, there was no difference between the evaluated samples, because they also presented a similar percentage of fat, facilitating the melting speed and smoothness on the palate (Urbańska et al., 2021).

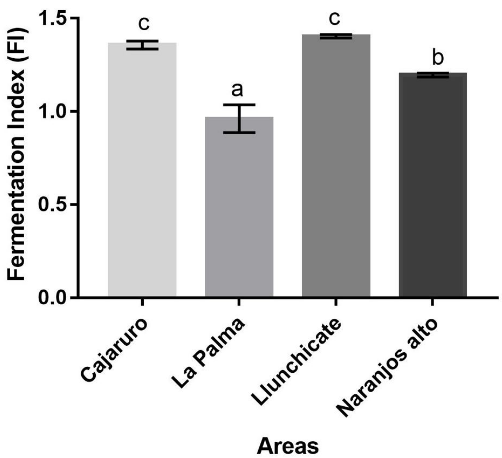

Figure 3. Fermentation index of fine aroma native cocoa beans. Note. Results are expressed as the mean ± standard deviation of three replicates. Different letters in the same column indicate significant differences by the Tukey Test ($P < 0.05$) between the different collection areas.

Table 2. Acidity and pH analysis of fine aroma native cocoa beans.

	pH of the *nibs*	TTA
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Llunchicate	5.81^{b}	0.22 ^{a}
La Palma	5.50 ^{a}	0.25 ^{b}
Cajaruro	5.83^{b}	0.23 ^{a}

Note. TTA. Total titratable acidity. Results are expressed as the mean ± standard deviation of three replicates. Different letters in the same column indicate significant differences by the Tukey Test ($P \leq 0.01$) between the different collection areas of CNFA.

Table 3. Analysis of ashes and fats of native fine aroma cocoa.

	Ash	% Fat
Naranjos Alto	2.95 ^{a}	45.51 ± 1.2^{a}
Llunchicate	3.11^{a}	45.21 ± 1.4^{a}
La Palma	2.70^{a}	51.16 ± 8.0^{a}
Cajaruro	5.27^{b}	54.44 ± 5.1^{a}

Note. Results are expressed as the mean ± standard deviation of three replicates. Different letters in the same column indicate significant differences by the Tukey Test ($P \leq 0.05$) between the different collection areas of CNFA.

Table 4. Sensorial test.

CHOCOLATE	FLAVOR	COLOR	TASTE	TEXTURE
La Palma	5.75 ± 1.25^{a}	6.35 ± 1.18^{abc}	3.96 ± 1.96 ^{bc}	6.00 ± 1.55 ^{ab}
Cajaruro	5.98 ± 1.17^{a}	6.20 ± 1.15^{abc}	5.10 ± 1.90 ^{ab}	5.82 ± 1.24 ^{abc}
Naranjos Altos	5.82 ± 1.23^{a}	5.69 ± 1.45^{c}	5.00 ± 1.83 ^{ab}	5.00 ± 1.37^{c}
Llunchicate	5.94 ± 1.36^{a}	5.98 ± 1.49^{bc}	5.63 ± 1.89 ^{a}	5.22 ± 1.54^{bc}

Note. Results are expressed as the mean ± standard deviation of three replicates. Different letters in the same column indicate significant differences by the Tukey Test ($P \leq 0.05$) between the different collection areas of CNFA.

4 Conclusions

The cocoa bean samples from the different collection areas of Utcubamba province presented adequate physical characteristics to be used in the industry. Despite the cut test has shown an adequate degree of fermentation, the Fermentation Index spectrophotometric test showed the same except for the samples from the La Palma area. However, it is highlighted that despite having carried out the same postharvest handling, the Cajaruro and Llunchicate samples presented lower acidity values and adequate pH, being the samples that presented greater acceptance in the evaluation for the flavor parameter and can be considered as an important raw material to be used in the industry and to be processed as a gourmet chocolate.

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