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Physical and Sensory Characterization of Cocoa (*Theobroma Cacao*l) from Northin Peru

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Abstract
The purpose of this research was to characterize and establish the relationships between physical and sensory attributes of cocoa fruits *(Theobroma cacao*) identified within Arprocat Tumbes collection (CAT) – Centro Poblado Villa Uña de Gato, Tumbes district – Peru. Research was experimental with a design in divided plots with two factors at three levels, distributed in random blocks. Data analysis included descriptive statistics and Pearson correlation. Results showed cocoa liqueur was astringent and acidic, with intermediate values of nuts, bitterness, sweetness, cocoa, walnut, herbal and floral. Combinations of factor levels suggest being a factor influencing less frequent sensory notes (fresh fruits, wood, and species). However, treatments performed as determinants of sensory quality cannot yet be considered.
Keywords: Physical and sensory characteristics, cocoa liquor.

INTRODUCTION

Peruvian dry cocoa *(Theobromacacao*) is one of main agricultural export items and in the last decade its production level production as export volume 120 thousand tons (Morales & Jesús, 2019). Peruvian cocoa has been reported to have comparative and competitive advantages due to the difficulties faced by traditional producers in Africa, the increase in the international market coupled with the growing demand from China and India, as well as the support that the Peruvian State is providing to small producers (Barrientos, 2015). These aspects together are leveraged to configure the value chain based on the product. According to the International Cocoa Organization (ICCO), it is estimated that until 2023 the demand for cocoa will not be in balance with its production, which creates a gap that must be met by producers from the three continents.
Peru, based on recognition of its physical and ecological conditions for wide variety cultivation of cocoa types, has stimulated initiatives for production and positioning of fine cocoa aroma (CFdA), as well as encouragement to ventures stimulate the development of a cocoa culture and companies that guarantees social and environmental responsibility in its operations (Morales et al., 2015). Official sources point out that Peru is the second largest cocoa exporter worldwide, noting the main exporter of fine cocoa aroma, a product that is processed in Tumbes, Huánuco and Amazonas (Ministry of Agriculture and Irrigation, 2018).
Cocoa liqueur production includes several processes where some variables and their relationships are of particular interest. As for the variety of cocoa type, it has been determined to affect physical and chemical characteristics (Kongor et al., 2016). Other

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authors (Graziani et al., 2006; Kadow et al., 2013) describe that interactions between temporal variable and environmental conditions determine fermentation process, drying and organoleptic precursors that are activated with roasting (Kongor et al., 2016; Mayorga-Gross et al., 2016). Physicochemical and organoleptic composition of native Creole cocoa (*Theobroma cacao* L.) of the cocoa plots of Amazonas APROCAM was characterized, finding differences between the results of the districts of the Bagua and Utcubamba provinces in terms of physicochemical parameters and organoleptic attributes (Cedillo et al., 2019).

On the appearance of fermentation, it has been reported that increasing the fermentation days increases the probability increasing fermented grains percentage (Barrientos et al., 2019), while presence of cocoa beans with violet coloration decreases (Rivera et al., 2012). In Colombia, the microfermentation process of five cocoa clones, ICS 01, ICS 95, ICS 39, TSH 565 and CCN 51, was studied. These were characterized by their physicochemical properties followed by their fermentation process allowing these parameters to improve final cocoa quality and, therefore, increase its commercial value (Horta-Téllez et al., 2019). Studies on fermentation level and cocoa seeds sensory profile indicate that they are influenced by cocoa variety and climatic conditions (Barrientos et al., 2019; Rodriguez-Campos et al., 2012). Based on time factor interaction and its influence on fermentation level, it has been reported Trinitarian clones achieve optimal fermentation in an interval ranging from 3 to 6 days (Mayorga-Gross et al., 2016).

Influence of fermentation time and solar drying method on the sensory quality of cocoa liqueur (*Teobroma cacao* L.) Clone CCN51 Tingo María (Carrillo Arvildo, 2011). It was noted to ensure quality it is necessary to pay attention in harvest and benefit stages, emphasizing fermenting and drying of grains, and found that fermentation time significantly influenced taste of cocoa, acidity and bitterness of liquor, while solar drying method only significantly influences the product’s acidity. He recommended that cocoa beans from the CCN51 clone should be fermented for seven days and gradually dried in the sun to achieve adequate sensory differentiation. Sensory characteristics have been related to removals in fermentation process, which cause heterogeneous responses in sensory profile resulting from cocoa (Liendo, 2015; Graziani et al., 2006). Similarly, previous research establishes influence of time on level of fermentation and sensory profile (Graziani et al., 2006).

The association between cocoa sensory profile and almonds’ fermentation process has been reported (Mera & Ruíz, 2014), and that quality of the seed used, as well as the process management, condition the grain fermentation (Morales et al., 2015). When this is intermediate it affects sensory profile variables such as acidity, bitterness and astringent (Quintana-Fuentes et al., 2016). Changes in fermentation stage are associated with the flavor profile and variations in pale purple coloration (un fermented stage) to brown (full fermentation) (Kadow et al., 2013). Also the processing forms and their influence on sensory properties have been studied (Afoakwa et al., 2014; Apriyanto et al., 2016). The fermentation influence to increase fat yield and cocoa butter content extracted from seeds has also been highlighted (Servent et al., 2018).

Cocoa cultivation in Tumbes is characterized by the existence of low-technified systems with yields less than 500 kg ha/year, coinciding with the conditions prevailing in countries such as Colombia (Gil et al., 2017),so much remains to be developed on this crop and its processing. This research aims to provide input on the definition of the physical and quality characteristics of some of the cocoa genotypes currently used in crops in the north of the country, information necessary to shape and define the identity of the cocoa produced, with a view to obtaining the "Certificate of Origin" of the product.

MATERIALS AND METHODS

The research was carried outin a period of five months (August-December 2018) and was conducted in the far northwest of Peru in Tumbes region, Zarumilla Province, where the center of The Town of Uña de Gato, the host town of the Regional Cocoa Producers Association Benefit Center, is located. Geographically it corresponds to an intertropical zone, at a latitude of 03° 34° S, a longitude of 80° 27° O and an altitude of 6 meters above sea level. The region borders the Pacific Ocean to the west and north, Piura to the south, and Ecuador to the east. It has an average monthly temperature ranging from 23°C to 26°C, and annual rainfall ranges from 1210 to 1410.7 mm, depending on the ENOS influence. Its territory has an area of 4,669 km^2.

Experimental Design: a design was used insplit plots with two factors at three levels, distributed in completely randomized blocks, where three clones of cocoa (C1, C2, C3) were evaluated, the selection of which was based on the weight of their grains and the fermentation time (F1, F2, F3). Nine treatments and three repetitions were determined.

Factors levels and treatments under study: factors under study were two and were represented by the weight of cocoa beans *(T. cacao*) and fermentation time, with 3 levels each respectively and a total of 9 treatments (table 1).

Table1. Factors, levels and treatments.

Factors	**Niveles**	**Key**	**Combination**	**Treatments**
Weight of dried cocoa beans	CAT- 49 >2 g CAT-34 1.5 a 2 g CAT- CP < 1.5 g	C 1 C 2 C 3	C1F1 C1F2 C1F3 C2F1 C2F2 C2F3 C3F1 C3F2 C3F3	T1 T2 T3 T4 T5 T6 T7 T8 T9
Fermentation time of the grains.	6 days 7 days 8 days	F1 F2 F3		

Post-care procedure: main quality factors in the processing of chocolate from post-harvest to manufacturing were studied, covering topics such as cocoa cultivation and processing, with particular attention to grain composition and genotypic variations, fermentation and drying processes, and chemical and biochemical bases. to propose them for food and food use (Sira, 2015).

Physiologically mature cobs were used, harvested in the field. These fruits were cut with hand scissors in order not to damage the flower cushions of the plants. Only whole healthy grains were extracted and placed in separate containers intended for each sample while preserving traceability.

Selected Fruits: fruits of clones already identified within the ARPROCAT Tumbes (CAT) collection were selected, such as CAT- 49, for grains weighing more than 2 g; CAT-34, for grains weighing more than 1.5 and less than 2 g; and a productive Creole (CAT-CP) with the weight of its grains less than 1.5 g. for each dry grain.

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Heavy fresh grains: fresh grains were weighed on a digital precision balance, up to 1 kg. per sample (27 samples).
Preparation of the fresh sample: each sample was placed in mesh fabric bags in order toferment in microlots, which are filled with heavy fresh cocoa, where a code written on masqueting tape was added to maintain traceability.
Fermentation: fermentation process usually lasts 7 days in the Tumbes region, but for research purposes 6, 7 and 8 days have been considered according to the treatment that corresponded to it, with the samples in fermenter drawers where daily removals were performed.
Drying: once fermentation time indicated for each sample was reached, cement slings were removed in the sun, where periodicremovals were performed until optimal humidity was reached to perform the storage and/or roasting process.
Humidity Measurement: on the fifth day of sunny, moisture measurement was carried out with the help of a hygrometer, up to 7.5% humidity.
Heavysamples. 100 fermented and dried almonds were randomly collected and their weight recorded using a precision balance. They were used in the cutting test to observe the fermentation percentage.
Physical Analysis: physical analysis of the grains was carried out using the NTP format, taking into account the following criteria: dry weight, caliber, odor, color, % fermentation.
Sensory Analysis: As for the previous phase, each sample was tested at a temperature of 115°C, in an Arprocat laboratory toaster, for a time of 12 minutes. Then it proceeded to derail and grind, using a shell intended for this purpose, achieving at least a texture of 25°, for a time of at least 1 hour, and then packaging them in glass containers that were sent to the APPCACAO laboratory in Lima for the corresponding sensory analysis.
Main characteristics were evaluated with five taster judges and the following attributes were assessed: astringency – acidity – nuts – bitterness – sweetness – cocoa – walnut - herbal – floral – fresh fruits – wood – species. The evaluation ordinal scale was 1=Absent, 2=Low, 3=Medium, 4=High, 5=Very High, and/or Strong.
Statistical analysis: descriptive statistics (means, fashions, minimums, maximums, ranges) were applied to initially characterize study variables. Tables and figures were built to illustrate the data. The inferential analysis included nonparametric tests to explore normality (Kolmogorov – Smirnov), as well as correlation parametrics (Pearson). Hypothesis systems were designed and the trust level considered was 0,05.

RESULTS AND DISCUSSION

Physical characteristics of cocoa bean samples

Table 2 shows the analysis of samples by weight of dry grains, where an average of 370.22 g ± 31.08 g is observed, obtaining a range of 115 g ranging from 304 g to 419 g. Similarly, the Kolmogorov-Smirnov normality test suggests a normal distribution (P >0.05) of the dry grains weight.

Table2. Physical characteristics of cocoa bean samples.

	Media	**Standard deviation**	**Minimal**	**Maximum**	**K - S**	**Sig.**
Peso en seco(g)	370,22	31,08	304	419	0,456	0,985
Calibre (g)	1,793	0,64	1	3	1,282	0,75
% de fermentación	87,04	11,624	55	100	1,196	0,114

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Table 3 shows the samples analysis by grain gauge, where ± an average of 1,193 to 0,64 g is observed, obtaining a range of 2 g ranging from 1 g to 3 g. The above highlights the tendency to record average gauges above the lower limit (1.5 g) required by the Peruvian state (Indecopi, 2006). Similarly, the calculated variability value seems to show the grain homogeneity. On the other hand, the cumulative percentage in the fraction less than or equal to 1.7 g is shown to be 66.7%, while the percentage greater than or equal to 2.5 g reaches 33.3%. Thus, the absence of calibers between 1,7 – 2,5 grams stand out. Likewise, the analysis of the fermentation percentage variable in the samples indicates that an average of 87.04 %. ± 11.624 % was obtained, reaching a range of 45 gr. 55 % to 100 %.

Table3. Frequency distribution for grain caliber.

Fraction (g)	**Frequency**	**Percentage**	**Cumulative percentage**
1,0	1	3,7	3,7
1,1	5	18,5	22,2
1,2	2	7,4	29,6
1,3	1	3,7	33,3
1,6	8	29,6	63,0
1,7	1	3,7	66,7
2,5	4	14,8	81,5
2,6	1	3,7	85,2
2,7	3	11,1	96,3
3,0	1	3,7	100,0
Total	27	100,0	

In Table 4, the frequency distribution illustrates the grains absence in the range ranging from 60% to 75%. Similarly, the cumulative percentage in the fraction less than or equal to 60% is 11.1%, while the percentage greater than or equal to 75% is 88.9%. This highlights the absence of percentages located in the fraction 60-75%. This could result from variations in grain exposure processes to weather and environmental conditions on the fermentation process days. Authors have determined the interactions between the temporal variable and environmental conditions and their effects on the fermentation process, drying and organoleptic precursors that are activated with roasting (Graziani et al., 2006 ; Kadow et al., 2013) .

Table4. Frequency distribution for cocoa bean fermentation percentage.

Fraction (g)	**Frequency**	**Percentage**	**Cumulative percentage**
55	1	3,7	3,7
60	1	3,7	7,4
75	4	14,8	22,2
80	1	3,7	25,9
85	3	11,1	37,0
90	7	25,9	63,0
95	6	22,2	85,2
100	4	14,8	100,0
Total	27	100,0	

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External color of cocoa bean

In Table 5, the external coloration of the grain had three colors, with dark brown being the prevailing (55.6%). Light brown coloration achieved a frequency of 9 (33.3%) sample. Grey brown was the least common (11.1%). It has been reported that changes in the fermentation stage are associated with the flavor profile and variations in pale purple coloration in the un fermented stage, to brown when full fermentation has already been effected (Kadow et al., 2013). It has been observed in other works that increasing fermentation days increases the likelihood of increased % of fermented grains (Barrientos et al., 2019), and that the presence of violet-colored grains decreases (Rivera et al., 2012). Therefore, adequate fermentation levels are considered to have been achieved based on the colour indicator.

Table5. Frequencies and percentages of external cocoa bean color.

	Frequency	**Percentage**	**Porcentaje acumulado**
Marrón oscuro	15	55,6	55,6
Marrón gris	3	11,1	66,7
Marrón claro	9	33,3	100,0
Total	27	100,0	

Smell of cocoa bean

In Table 6, smell of grain had two manifestations, prevailing one corresponded to typical odor (77.8%) and acidic odor (22.2%).

Table6. Cocoa bean odour frequencies and percentages.

	Frequency	**Percentage**
Acid	6	22,2
Typical	21	77,8
Total	27	100,0

Relationship between dry cocoa bean weight, grain gauge and fermentation percentage

The correlation matrix (see Table 7) suggests that none of the variables are significantly correlated (P>0.05), which could be associated with the dispersion of the data.

Table7. Bivariate correlations between dry cocoa bean weight variables, grain gauge and fermentation percentage.

		Dry weight	**Grain gauge**	**% of grain fermentation**
Dry weight	Pearson r	1	0,331	-0,177
	Sig. (bilateral)		0,091	0,376
Grain gauge	Pearson r	0,331	1	0,360
	Sig. (bilateral)	0,091		0,065
% of grain fermentation	Pearson r	-0,177	0,360	1
	Sig. (bilateral)	0,376	0,065	

Based on these findings it can be noted that variables have behavior where there is no statistical relationship between them. It is therefore necessary to continue to work to establish possible relationships to improve the production processes of cocoa.

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Assessment of general sensory and organoleptic impressions of cocoa liqueur

Once sensory assessments were made for each type of treatment it was possible to obtain a general assessment that would result in the coarse characterization of cocoa liqueur. Standard averages and deviations were calculated to make an impression through a central trend measure, as well as an idea of their variability and summary of this data (see Figure 1).

In order to provide the summary of this data, the results were categorized based on the sensory assessment scale previously used by the evaluators (see table 8).

The cocoa liqueur of the sample is characterized as a highly astringent and acidic product, with medium values where sensations of nuts, bitterness, sweetness, cocoa, walnut, herbal and floral are highlighted in decreasing order. Notes with low presence are fresh fruits, woods and species. The different notes have a low dispersion close to the unit, which is uniformity indicator in terms of the judgments issued.

Results allow to obtain a first approximation to the cocoa quality based on the analysis of the physical, chemical and sensory attributes of cocoa fruits identified within the ARPROCAT Tumbes collection (CAT) –Villa de Gato, Tumbes – Peru.

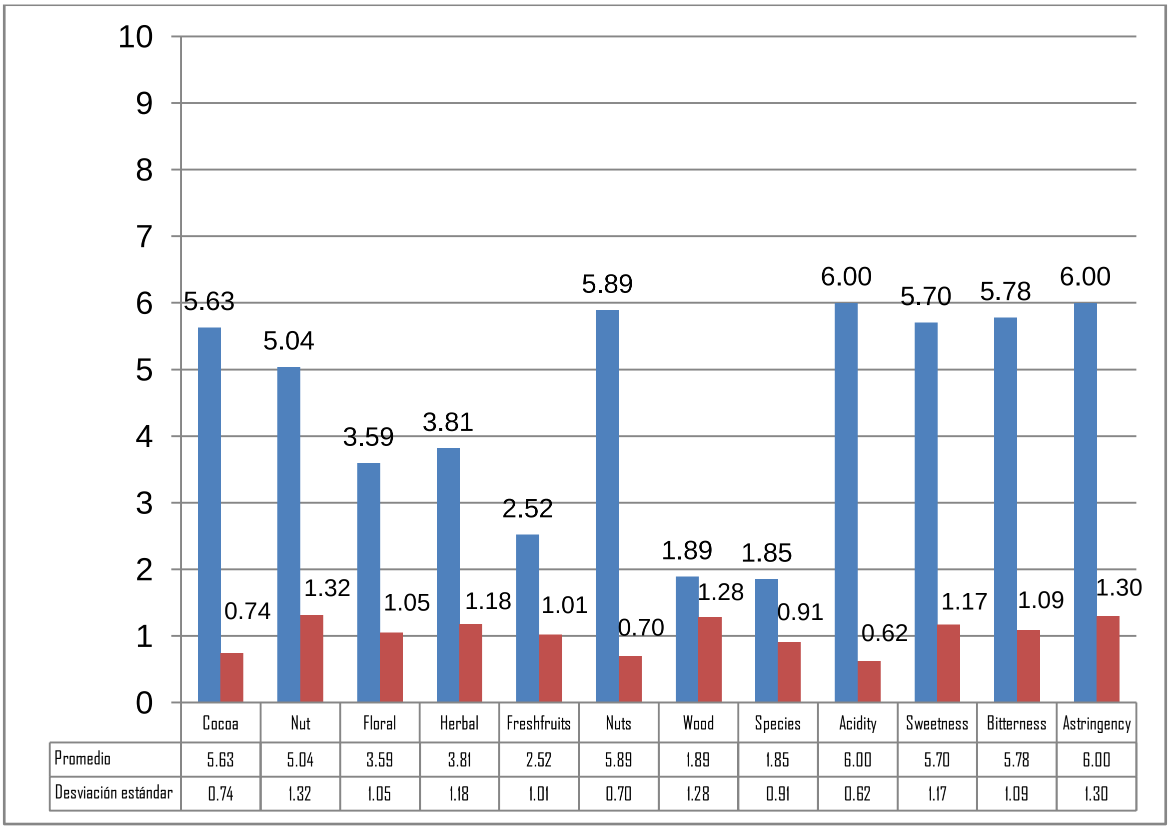

Figure1. Overall rating (averages) of sensory impressions of cocoa liqueur.

Table8. Categorization of sensory notes evaluated for cocoa liqueur samples.

Scale	**Sensory Variable**
9 – 10 Very High - Strong	--------
6 – 8 High	Astringency - Acidity
3 – 5 Medium	Nuts - Amargor - Sweetness Cocoa - Nut

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	Herbals - Florals
1 – 2 Low	Fresh fruits - Wood - Species
0 – Absent	--------

Although the prevalence by small producers of the use of drying methods in cement snouts has been highlighted which could influence physical and chemical properties as well as sensory properties (Benkovic et al., 2019). Fermentation is traditionally carried out from heaps, jute sacks, plastic containers and wooden drawers been worked from wooden drawers. The lack of knowledge and resources by producers limits them to the use of expired technology that can harm the quality in fine and aroma cocoa as noted by other authors (Cedillo et al., 2019), affecting the quality of chocolate (Ho et al., 2014; Horta-Téllez et al., 2019). Larger and more detailed fermentation processes have been reported in small producers in Ecuador (Quevedo et al., 2018), observing variations in organoleptic characteristics, after comparing the efficiency of the most commonly used fermenters: jute sack (T1), wooden rotor (T2), rumo or heap (T3), wooden box (T4) and plastic bucket (T5). With the use of the wooden rotor was obtained 96% physical quality of the grain and the best sensory profile with high ratings in cocoa, floral, fruity, walnut and caramel flavors and low ratings in astringent and bitter flavor. This method could raise the notes obtained as means with this test and thus relieve the astringency and acidity obtained.In this sense it is advisable to continue exploring with other methods to compare sensory attributes and then to seek the standardization of fermentation aimed at improving quality (Moreno-Martínez et al., 2019).

These results should continue to be explored in the light of new research where these methods used are replicated. Based on other methods, different results have been obtained. Studies on the level of fermentation and sensory profile of cocoa seeds indicate that they are influenced by the cocoa variety and climatic conditions (Barrientos et al., 2019; Kongor et al., 2016; Mayorga-Gross et al., 2016; Rodriguez-Campos et al., 2012). So far in the sector studied there are only clones, which have not been tested in terms of their characteristics with climate parameters. This physical aspect according to the results of Rodríguez-Campos et al. (2012) could help achieve a better definition of the organoleptic characteristics of the clones analyzed. Similarly, it is required to know the influence of the growing context on physical and chemical variables and their relationship to fermentation so that attributes such as pH and pigment index of fermented grains are known (Amorim et al., 2017).

Another aspect to consider is variations in fermentation time. This study considered an interval ranging from 6 to 8 days. Based on the the time factor interaction and its influence on the level of fermentation, it has been reported that Trinitarian clones achieve optimal fermentation in an interval ranging from 3 to 6 days (Mayorga-Gross et al., 2016). This indicates that there can be a wide variability in terms of the level of fermentation, which implies that this may be a factor that influences the organoleptic characteristics of the samples studied.

Based on these considerations, it was already identified in Venezuela the fermented time (7 days) and solar drying method on the sensory quality of cocoa liqueur (Clon CCN51 Tingo María) (Carrillo, 2011), and that these variables significantly influence the cocoa taste, acidity and liquor bitterness, while the method of solar drying only significantly influences the product's acidity. In the Peruvian Amazon these elements were also observed highlighting the fermentation time (5, 6 and 7 days) and removal model (Alvarez, 2018),while in Venezuela Liendo (2015), recorded optimal fermentation times of 48 and 72 hours with removal every 24, 48 and 72 hours. It follows that organoleptic characteristics are sensitive to multiple factors, including grain processing of specifying the product's quality is still in a budding phase as the results obtained in this work only from the experimental design carried out only allowed to differentiate the floral, herbal, fresh fruit dimensions, wood and species, which is a first approximation that will serve as a pattern of comparison for subsequent studies on the clones analyzed.

CONCLUSIONS

Weight of dry cocoa beans averaged 370.22 g ± 31.08 g; the caliber of cocoa bean averaged 1.193 g ± 0.64 g. The frequency test showed that the cumulative percentage in the fraction less than or equal to 1.7 g was prevalent (66.7%), while the percentage greater than or equal to 2.5 g was 33.3%. No available calibers were observed between 1.7 g and 2.5 g. This aspect invites you to review the cocoa variety and its influence on caliber and weight.

Fermentation rate of cocoa beans averaged 87.04 %. ± 11.624 %, reaching a range of 45 g 55% to 100%. Frequency review illustrates the grains absence in the range ranging from 60% to 75%. The cumulative percentage in the fraction less than or equal to 60 % is 11.1%, while the percentage greater than or equal to 75% reaches 88.9%. This could result from the type of fermentation method and variations in grain exposure processes to weather and environmental conditions, on the exposure days of the raw material to the fermentation process.

External color of the cocoa bean showed three colors: dark brown (55.6%), light brown (33.3%), grey brown (11.1%). From the color indicator it appears that adequate fermentation levels were reached. The grain's smell had two appreciations: typical odor (77.8%) acid odor (22.2%), this is favorable for the product.

The assessment of the general sensory and organoleptic impressions of cocoa liqueur indicated to be a highly astringent and acidic product, with intermediate values where appreciations of nuts, bitterness, sweetness, cocoa, walnut, herbal and floral are highlighted. Notes with low presence are fresh fruits, woods and species.

Finally, the combinations of the variables for each type of treatment seem to be a factor influencing the less frequent sensory notes according to the tasters. However, treatments performed as determinants of sensory quality cannot be considered. Organoleptic characteristics turn out to be sensitive to multiple factors so the process of characterization and standardization of product quality is still in an exploratory phase where the results obtained in this work constitute a reference approximation in the long study path on the clones analyzed.

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