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Physical and sensory quality of the fine-flavored and aromatic cocoas growing in different Venezuelan regions

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Abstract

This work aimed to determine the cocoa's physical and sensory quality in different Venezuelan regions to use in specific flavored chocolate production. 49 samples of cocoa beans gathered in plantations from different regions of Venezuela were evaluated using methodologies described to analyze cocoa physicochemical standards. A trained panel selected twenty samples from this lot as standards of fine-flavored cacao. Eleven samples with the best sensory attributes of each region were selected from the lot of twenty. These eleven samples showed variability in the physical and physicochemical attributes. The Analysis of Variance (ANOVA) showed significant differences between aroma and taste attributes in the liquors evaluated. The Principal Component Analysis (PCA) expresses the variability of the eleven samples studied for the intensity of the sensory qualities of basic and complementary tastes (54.1%), and aroma (50.4%). Besides, the fermentation percent and the external and internal bean characteristics through typification and cut test analysis relevant for its commercialization, the study provides practical information on the sensory attributes that characterize Venezuelan fine-flavored cocoas from several regions that are used in the production of chocolate with regional-specific flavors.

Keywords: Attributes, Cocoa, Fermented, Flavor, Sensory profiles.

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Contents

Contribution of this paper to the literature
The research provides unpublished information on the physical, physicochemical, and sensory characteristics of fine-flavored cocoa beans growing in Venezuelan plantations, that are useful for its commercialization and regional flavored-specific chocolate production.

1. Introduction

Good postharvest practices are described as a set of activities that start from the classification and selection of the fruits harvested in their optimal maturation state in the corresponding time. Subsequently, the fruit is broken or shelled, the fresh seeds are extracted, followed by the fermentation process under the conditions of the production unit. Once the fermentation is finished, the drying, selection and cleaning, packaging, and transport of the dry cocoa bean continue [1].

Pérez and Silva [2] have defined the post-harvest benefit of cocoa, as any operation to which the agricultural product (cocoa seed) must be subjected to convert it, into a marketable article (beans and primary products). The products obtained must meet physical-chemical, sensory, nutritional, and safety quality criteria, which are determinants in their final acceptance by the consumer [3].

Determining the attributes and quality of cocoa and derivatives must be accorded with the export standards and regulations described. Usually, these standards and rules depend on the post-harvest and transformation technology used, with a marked influence on the region of origin and type of genetic material [4]. Venezuela is characterized by the diversity of cocoa plantations that produce beans classified as "Fine Flavor and Aroma Cocoa" with marked genotypic and phenotypic variations depending on the region [5]. Cocoa variety and the local harvesting practices (especially the selection of the pods) can greatly affect the quality of the fermented cocoa beans [6, 7].

Fermentation constitutes a transcendental stage in the processing or post-harvest benefit of cocoa beans. The characteristic aroma and flavor precursors of chocolate formed during fermentation are enhanced during roasting, causing variations in the chemical composition of the bean. During the process, physical and chemical changes occur in the cocoa beans due to biochemical reactions caused by microbial activity under aerobic and anaerobic conditions in an ecological or introversion succession [2].

This activity induces the development of those precursor chemical compounds that will continue to form during the drying and roasting of the beans and will be responsible for the final flavor of the chocolate. The natural drying stage in the sun completes the oxidative process started during fermentation; playing an important role in reducing the astringency, bitterness, and acidity of the beans.

The beans develop a brown coloration, which is the product of the condensation reactions between quinones and proteins after the enzymatic oxidation of the polyphenols (Hashim *et al.*, 1999 cited by Pérez and Silva [2]). Hence, the importance of generating the fermentation and drying protocols in the regions, due to the existing diversity between them. Subsequent operations after drying before roasting will guarantee a more homogeneous batch of beans according to size and reduce microbiological risks by following in accordance with the demands of the international market. Determining the physical characteristics of cocoa will allow it to be typified for a certain market, based on the uniformity in the bean's size, fermentation index, and the number of observable external defects and atypical flavors presented [5].

The classification of the commercial quality of cocoa is primarily due to the physical and aromatic composition of the bean, with the genotype and fermentation being the factors with the highest incidence in the flavor, smell, and color of the end product and the formation of flavor precursors in the chocolate [2, 5, 8]. The objective of the following research was to determine the physical and sensory characteristics of cocoa beans from production units in different Venezuelan regions with postharvest protocols that define the chocolate quality.

2. Materials and Methods

To recognize the work of cocoa farmers, it was necessary to organize the national Cocoa Excellence Competition, Venezuela 2023 edition, within the framework of the event "International Cocoa and Chocolate, 2023 (Cacao of Excellence Program) by Biodiversity International. A program of training and information activities was established (October-December 2022), directed by a National Organization Committee (NOC) managed by the presidency of the Venezuelan Socialist Cocoa Corporation (VSCC), National Institute of Agricultural Research-(INIA), and entities attached to the MPPAT (Ministry of Popular Power for Agricultural Production and Lands), private entities, and universities (Central University of Venezuela).

2.1. Technical Training and Call at the National Level

The period of sample selection was carried out from November to December 2022 by the territorial's ship, field technicians, and coordinators of the Venezuelan Socialist Cocoa Corporation (VSCC). These officials, after receiving instruction based on the national competition (online) would be responsible for selecting the best samples fermented and dried cocoa by region and farmer.

For the selection and conditioning of the samples, the "Technical Manual for the Selection and Sampling of Cocoa for Quality Purposes" directed by a National Organization Committee (NOC) was considered. National training workshops were done so that cocoa producers knew the important parameters for the National Bean Cocoa Quality.

2.2. Raw Material

Once the training process for the producers was completed, they were asked for a 10 kg sample of fermented and dried cocoa beans from the November-December 2022 harvest. The manual indicated the procedure for transporting and receiving the sample. Each sample received was randomly assigned a five-digit code, which would guarantee the anonymity of the sample throughout the process of evaluation and selection of the best samples for sensory quality. A total of 45 samples were received from the following states: Aragua, Amazonas, Apure, Barinas, Bolívar, Carabobo, Yaracuy, Portuguesa, La Guaira, Miranda, Monagas, Mérida, and Sucre.

The samples were stored in adequate conditions to avoid contamination for posterior analysis. From the total population of bean samples, a representative number that met the physical and sensory quality requirements demanded by the norms or standards was preselected as follows:

2.3. Physical Quality Characteristics

The protocol of the external analysis beans, dimensions and weight average, the number of beans/100 g sample, and the cut test quality were carried out according to the Manual of International Standards for the Assessment of Cocoa Quality and Flavour [9]; Comisión Venezolana De Normas Industriales [10]; Comisión Venezolana De Normas Industriales [11] and Comisión Venezolana De Normas Industriales [11] in its second revision.

2.4. Sensory Evaluation of Cocoa Pastes or Liquors

The sensory characterization (taste and aroma) was carried out to know the sensory profiles of the materials evaluated. The characterization sessions for sensory profiles were carried out at the Sensory Quality Control Laboratory of the Venezuelan Company Intercacao, located in Caracas. The protocol used for roasting the beans cocoa, and refining nibs into cocoa liquor was carried out according to International Standards for the Assessment of Cocoa Quality and Flavour (ISCQF) [12] available on website Cocoa Guide Cocoa of Excellence. The group of panelists participating as sensory assessors of the cocoa´s pasta was made up of eight (8) trained chocolatiers, who were calibrated for the sensory profile's characterization of the pasta according to criteria defined in the International Standard Organization [13] and International Standards for the Assessment of Cocoa Quality and Flavour (ISCQF) [12].

2.5. Recruitment of the Sensory Assessors

The judges (8) were selected from several applications based on an exhaustive review of their curricular synthesis and subsequently submitted to selection according to the criteria defined in international standards for the evaluation of cocoa quality and flavor [12]. The selection of the sensory assessors was carried out in December (2022). A survey was carried out requesting information regarding the age, interest, health, feeding schedules, and availability of the candidates recruited.

According to their answers in the survey in the basic taste detection test and odor recognition based on standards International Standard Organization [13] the members of the group were selected to participate in the evaluation of sensory profiles of cocoa´s pastes. The selected candidate's group had previous experience in the sensory evaluation of food and had been trained in cocoa and chocolate-tasting tests, and they were previously informed about the objectives of the study and the initial considerations for carrying out the training.

2.6. Application of the Umbral Tests of Basic Tastes and Odor Detection

During the training, the selected judges were instructed on the aspects of sensory physiology and sensory evaluation as a quality control tool for cocoa and chocolate. They were instructed on the aspects and considerations of the lexicon and notes (attributes and sub-attributes) used in cocoa and chocolate. The tests for the detection of basic tastes and odors were carried out on the evaluators to verify their training using the International Standard Organization [13] standard. The evaluating jury used the forms or formats designed for the training and calibration phases.

2.7. Training and Calibration

The selected judges were trained for six days, and they were to a calibration following the international regulations for the evaluation of the quality and flavor of cocoa [12]. The training was carried out by qualified personnel in the Food Technology Area. The training and calibration activity was gone in December 2023 and January 2024. The calibrations were carried out using different pastes or liquors of different origins obtained from the production units participating in the national contest through the use of the triangle test.

2.8. Triangle Test

Triangle taste test is a discriminative method commonly used in sensory research and recommended by International Standard Organization [13]. The test requires a minimum of at least five participants to state if there is a significant difference. The panel's sensory assessors were presented with three samples, of which one was different and two similar. The two similar samples are made of the same raw material, the same protocol of elaboration, and the same origin. This discriminative test allowed the jury to differentiate between 3 samples, that is, it consisted of simultaneously presenting them with three coded samples, of which two were the same and one was different. The jury had to identify the sample with a different flavor.

2.9. Sensory Evaluation Sections

The trained and calibrated judges were summoned to appear at the sensory evaluation laboratory of the Inter Cacao Company, in several sessions to preselect the best samples (11) of cocoa paste or liquor that would go on to the final evaluation by using the aroma and taste profile test.

2.10. Final Evaluation of Taste and Aroma Profiles: The Grand Jury (Sensory Assessors)

The judges (8) that made up the final great jury were called to meetings for the sensory evaluation of the best attributes of the preselected cocoa pastes. Liquor samples were evaluated, performing three repetitions for each one. The judges panel assigned scores according to the intensity of each attribute on a scale of 0 to 10, with 0 being the absence of the attribute and 10 being the maximum intensity. The judges received a format for the taste and aroma evaluation of cocoa paste based on the attributes and sub-attributes established by the International Standards for the Assessment of Cocoa Quality and Flavour (ISCQF) [12]. Thirteen (13) taste attributes for cocoa paste were evaluated: cocoa, chocolate, acid, sweet, astringent, bitter, fruity, nutty, floral, wood, spicy, smoky, and

metallic. Twelve (12) aroma descriptors as such as cocoa, chocolate, acid, fruity, nutty, floral, woody, spicy, smoky, metallic, putrid, and moldy were also evaluated. The average values of the ratings assigned by the panelists were presented in radial graphs called "spider webs".

2.11. Statistical Analysis

Pearson's linear correlation coefficient was applied for the characteristics of the length, width, and thickness of the cocoa bean samples. A descriptive analysis of the physical characteristics of the quality bean was applied through the cut-test using bar graphs to compare the means between samples according to their attributes. The taste and aroma descriptors were evaluated by a Principal Component Analysis (PCA) carried out using the Di Rienzo [14] student statistical software version. Mean flavor profiles were calculated. The comparison of means of the cocoa pastes (ANOVA) was obtained using the Tukey test ($p \geq 0.05$) according to panelists-attributes interaction. The ANOVA test was carried out with InfoStat, statistical software updated to version 2020. The graphical representation (radials charts) was carried out in Microsoft Excel 2010.

3. Results and Discussion

Table 1 shows the origin of the eleven (11) cocoa bean samples that presented the best physical and sensory characteristics.

Table 1. Origin of cocoa samples from different regions (states) of Venezuela.

N° sample	1	2	3	4	5	6	7	8	9	10	11
Origin (Regions)	Apure	Barinas	Bolívar	Bolívar	Yaracuy	Yaracuy	Miranda	Miranda	Monagas	Carabobo	*Clone
Assigned code	65127	48747	78882	19257	97825	91197	17232	76192	50694	66010	54184

Note: *Clone reference.

3.1. Physical Quality Characteristics: Average Dimension Beans

Table 2 summarizes the physical quality requirements demanded for the national and international regulations of the eleven (11) samples from the total selected population. The table indicates the origin place, the random code assigned, and the correlations between the average dimensions (length, width, and thickness) of the cocoa samples selected.

Strongly positive correlations (0.50-1.00) between length and width beans were observed for pastes from Apure (65127), Bolívar (78882), Carabobo (66010), Yaracuy (91197) states, and reference clone (54184). Weak or negative correlations for the rest of the cocoa samples were observed. The reflected positive correlation between the length and width of the dry bean is related to the swelling index during the fermentation process. The variable nature of the cocoa lots allows us to infer that there is a high presence of beans with different shapes (oblong, elliptical, or ovoid), which are the product of the existence of different cocoa materials in the plantations, in this case, with the presence of hybrids called Trinitarians.

No correlation was found between the length and thickness and vice versa, of the cocoa beans, which indicates that there is no effect of the fermentation and drying process on these variables. The results show that the mixtures of beans with variable and intermediate shapes in width and thickness do not reach the swelling process of the seeds during fermentation. When dealing with batches from materials with a homogeneous shape, there is a greater possibility of a positive and significant correlation, such is the case of Criollo-type cocoas.

3.2. Cut-Test, Humidity Content (%), Individual Weight and Weigh by 100 Dry Beans (Averages), and Dry Beans Counting

Cut test are an effective way to check for internal defects, and evaluate the level of fermentation, and the health standards in a batch of cacao beans. The cut test is carried out to identify, quantify, and separate broken beans, slaty, moldy, infested by insects, violet or purple beans, partially fermented (partially purple), unfermented (purple and smooth), germinated beans, and well-fermented brown beans [1, 4, 5, 15].

Figure 1 shows of important physical attributes of the eleven (11) samples tested. The critical defects referred to the presence of molds, insect infestations, impurities, and black, flat, and double grains, complied with the standards established by Comisión Venezolana De Normas Industriales [10] and Comisión Venezolana De Normas Industriales [11] and International Standards for the Assessment of Cocoa Quality and Flavour [9].

Table 2. Pearson´s lineal correlation between the length, width and thickness of the cocoa beans.

	Average dimensions		
Origin	**Length (cm)**	**Width (cm)**	**Thickness (cm)**
Apure state (65127)			
Length (cm)	1.00	0.51	0.25
Width (cm)	0.51	1.00	-0.15
Thickness (cm)	0.25	-0.15	1.00
Barinas state (48747)			
Length (cm)	1.00	0.48	0.02
Width (cm)	0.60	1.00	0.12
Thickness (cm)	0.02	0.35	1.00
Bolívar state (78882)			
Length (cm)	1.00	0.60	0.05
Width (cm)	0.60	1.00	0.12
Thickness (cm)	0.05	0.12	1.00
Bolívar state (19257)			
Length (cm)	1.00	0.38	-0.03

Average dimensions			
Origin	**Length (cm)**	**Width (cm)**	**Thickness (cm)**
Width (cm)	0.38	1.00	-0.10
Thickness (cm)	-0.03	-0.10	1.00
Carabobo state (66010)			
Length (cm)	1.00	0.64	0.16
Width (cm)	0.64	1.00	-0.13
Thickness (cm)	0.16	-0.13	1.00
Average dimensions			
Origin	Length (cm)	Width (cm)	Thickness (cm)
Miranda state (17232)			
Length (cm)	1.00	0.28	0.06
Width (cm)	0.28	1.00	0.35
Thickness (cm)	0.06	0.35	1.00
Miranda state (76192)			
Length (cm)	1.00	-0.17	-0.16
Width (cm)	-0.17	1.00	-0.32
Thickness (cm)	-0.16	-0.32	1.00
Monagas state (50694)			
Length (cm)	1.00	0.45	-0.23
Width (cm)	0.45	1.00	0.16
Thickness (cm)	-0.23	0.16	1.00
Yaracuy state (97825)			
Length (cm)	1.00	-0.23	-0.06
Width (cm)	-0.06	1.00	-0.18
Thickness (cm)	-0.06	-0.18	1.00
Yaracuy state (91197)			
Length (cm)	1.00	0.70	0.03
Width (cm)	0.70	1.00	0.06
Thickness (cm)	0.03	0.06	1.00
Reference clon (54184)			
Length (cm)	1.00	0.60	-0.15
Width (cm)	0.60	1.00	0.17
Thickness (cm)	-0.15	0.17	1.00

The moisture content varied in a range of 6.0±0.0 [97825-Yaracuy] to 7.5±0.1% (50694-Monagas), values that conform to those allowed by the national and international standards by fermented and dry cocoa.

The moisture values show the good drying practices used by the producers to obtain dry and microbiologically stable beans (low microbial growth). None of the samples showed moisture values above 8.0 %, which represents a critical value to increase the growth of molds that would cause the deterioration of the coca commercial quality bean [9]. During the inspection phase of the selected samples, an adequate selection and cleaning was observed, registering a low percentage of broken, flat, and multiple beans, which is indicative of good postharvest practices (Figure 1).

The internal surface of the cotyledons exposed by the longitudinal cut (cut test), allowed them to be classified according to the degree of fermentation into well-fermented beans, partially fermented beans, purple, and slaty beans categorized as non-fermented cocoa [5, 10, 11].

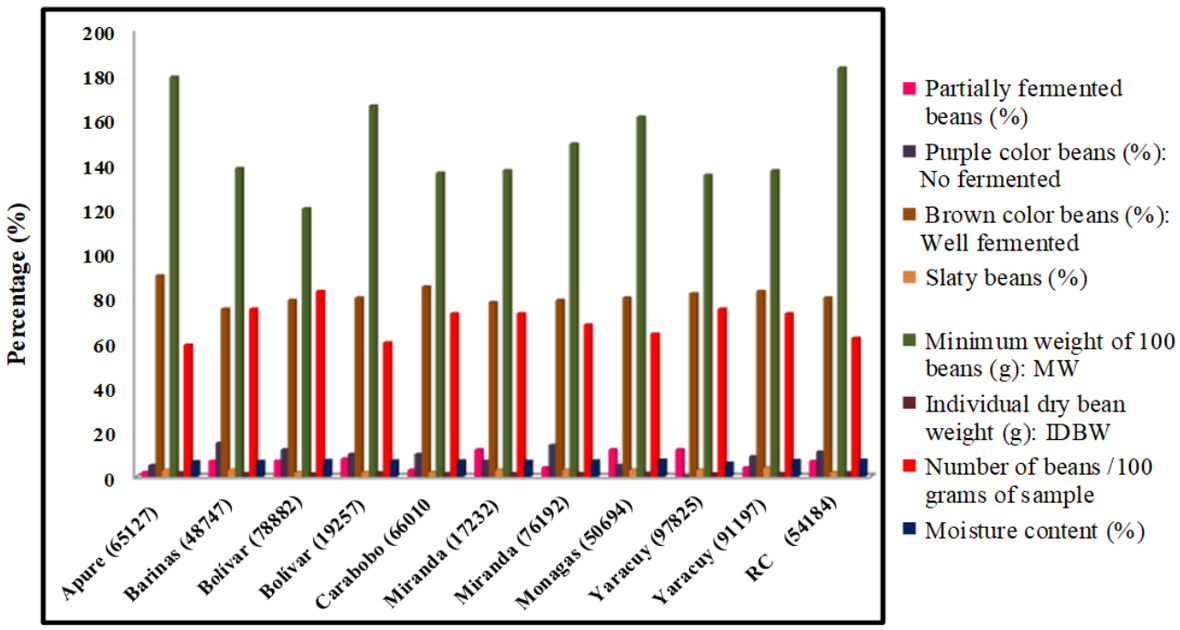


Figure 1. Physical quality characteristics were obtained through the cut test.

3.3. Insufficiently Fermented Beans and Violet or Purple Color

Dried cotyledons insufficiently fermented showed compact surfaces of purple color (light and dark) depending on the type of cocoa. These violet-colored beans result from a minimal fermentation process depending on the fruit's maturity, making the release and oxidation of polyphenolic (taste-responsible) compounds impossible due to poor fermentation.

65127-Apure and 66010-Carabobo samples presented low percentages of insufficiently fermented beans, with 2.0±1.0% and 3.00±0.6% respectively. Apure sample presented a lighter brown tone, representing a characteristic of Criollo beans, while the rest consisted of a hybrid or Trinitarian-type cocoa population. Those with dark breaking usually are Trinitarian (Criollo Moderno). The 97825-Yaracuy sample did not show intense purple beans; however, 65127-Apure and 50694-Monagas samples presented lower and similar values to each other (Figure 1). The fermentation method (fermenter type), process time, intervals in the removal of the cocoa mass, and environmental conditions, soil type, are determining factors so that fresh seeds do not reach complete fermentation [5, 8].

These characteristics were grouped by the International Standards for the Assessment of Cocoa Quality and Flavour [9] into 4 categories according to the internal color of the cotyledons: well fermented (dark to light brown), partially purple or violet, totally purple or violet, and slaty beans. All the analyzed samples showed levels of slaty grains within the limits established by Comisión Venezolana De Normas Industriales [10] and Comisión Venezolana De Normas Industriales [11]. The results explain the good selection of the fruits in their physiological maturity state carried out by Venezuelan cocoa producers.

3.4. Brown Colored Beans (Fermented): Fermentation Index (%)

Figure 1 shows that the fermentation index varied between 75% and 90% in the samples, which corresponds to the limit's standard by Comisión Venezolana De Normas Industriales [11] for fermented and dry beans. First-class Fine cocoa (F1≥74%) was based on samples that exhibited a percentage of 75.0±1.0% (48747-Barinas), 78.0±2.0% (17232-Miranda), 79.0±2.1% (76192)-Miranda, 80.0±1.0% (50694-Monagas), and 80.0±2.1% (19257-Bolívar)

The Class Extra fine cocoa corresponded from two (2) Yaracuy samples: 97825-(82.0±2.5%), and 91197 with 83.0±1.0%. Fermented and dry cocoa beans from 65127-Apure, 66010-Carabobo, and the reference clone (54184) showed fermentation high indices of 90.0±2.0%, 85.0±1.2%, and 80.0% respectively.

Deep and well-defined grooves and striations inside were present in the brown cotyledons, and their fragile shell was easily detachable, all signs of a well-fermented bean. At the start of the fermentation process, the fresh seed has a coloration that is between light to dark purple and/or white. The cocoa's color will change from light dark brown or reddish at the end of the process [4].

According to the International Standards for the Assessment of Cocoa Quality and Flavour [9] external and internal evaluations take into account the level of fermentation, the color of cotyledons, and beans with internal infections (molds), and infestation (insects). Figure 1 shows that fermentation values correspond to the limit's standard of Comisión Venezolana De Normas Industriales [11] for fully-fermented and dry beans. The color changes that occur inside the grain are due to the oxidation reactions of the anthocyanin compounds, which form brown pigments color. This pigment has a significant on reducing the astringent of the fermented bean (Guzman, 2007; González *et al.*, 2012 cited Pérez and Silva [2]).

3.5. Weight of 100 G Dry Beans, and the Count Per 100 Grams of Sample

The weight of 100 dry cocoa beans varied in a range from 120.3±1.5 g to 183.0±1.0 g. The highest value was for the 54184-reference clone (183.0±1.0g) followed by the 65127-Apure sample (179.1±2.7 g). These values are not in accordance with the commercial cocoas established by Comisión Venezolana De Normas Industriales [11] for the F1 class. The weights are equivalent to cocoa that is commercially classified as Extra-fine, but the final classification is determined by quality defects and the fermentation index. The amount of edible and usable fat in the bean would be determined by the weight parameter, taking into account the butter, husk, and cotyledon content.

The variability of the number of beans/100 g sample varied from 59.00±1.15 to 83.00±1.53 beans/100g. The lowest value in the bean count/100 grams of sample was represented by 65127-Apure (59.0±1.15), 19257-Bolívar (60.0±2.08), and the 54184-reference clone (62.0±1.0). These characteristics classify them as large beans, categorizing them as a standard bean, with desirable and acceptable sizes for international trade [3]. The individual weight of the dry bean varied from 1.21±0.12 g to 1.80±0,37g, with 65127-Apure dry bean being the heaviest (1.80±0.37g), followed by 19257-Bolívar (1.76±0.70g) and 50694-Monagas (1.60±0.41g).

In this context, cocoa beans from Venezuela that are produced for commercial purposes have a weight above 1.2 g [16] . This value is considered as a reference for the international market. According to the previous authors, a bean index above 1.2 g is believed to guarantee a higher yield per hectare and is favored by marketers and industrialists. The physical parameters reveal differences that indicate the presence of microbiota or bacterial microflora in the fermentation. The fermentation process could also vary depending on the composition of the pulp (sugar content), moisture content, and the genetics of the cocoa.

During the benefit process, the environmental conditions and soil characteristics influence the changes that occur in the cotyledons [8]. Therefore, it is important to carry out fermentation protocols that classify cocoa types and establish maximum yields according to their quality.

3.6. Results of Training the Evaluating Jury in Basic Taste Tests

A group of four (4) women and four men aged 30 and 40 made up the panel of evaluators from the beginning of the study. They received training following international standards described in the methodology. Table 3 shows the results obtained (%) by the evaluators during the odor identification and basic taste detection tests.

Table 3. Results of odor identification and basic taste detection tests, expressed in percentages of right guess.

Tests (%)	*Trained panel (Jury)								
	*E1	*E2	*E3	*E4	*E5	*E6	*E7	*E8	% Total correct answers/Group
Smells	90	92	89	90	88	98	90	90	91.0
Basic tastes	100	100	100	80	100	100	100	100	98.0
Percentage of correct answers/ Jury	95	96	95	85	94	99	95	95	94.0

Note: *Jury code.

The trained panel's evaluation jury reported a mean score of 94% for the two tests conducted (smell and flavor). The lowest value was 85% and the highest was 99% (Table 3). The group of evaluators is capable of identifying and distinguishing between various odor and taste substances at concentrations that are set by International Standard Organization [13] standards. During the training process, 100% of the panelists were able to identify the various cocoa paste samples through the discriminative test (triangle test differentiation).

3.7. Variance Analysis (ANOVA). Panelists · Attributes (Aroma/Taste) Interaction

Table 4 shows the global averages of the intensities reported by the evaluation jury of seven (7) sensory attributes for aroma and ten (10) for taste attributes. The intensity values showed statistically significant differences between the aroma and taste attributes data from cocoa pastes. The results also indicated that there were no significance moldy, putrid, smoky, and metallic defects ($p > 0.05$). According to the Tukey test, there is no significant difference in the cocoa and chocolate attributes between these pastes ($p > 0.05$). The magnitude of the significance values for the remaining flavor (aroma/taste) attributes are presented in Figure 2. The average value for the bitterness and astringent taste remained at intermediate intensities, contributing to the flavor characteristics of the cocoa paste. The Figure 2 shows a moderate bitterness and astringency intensity notes, and low floral, nutty, and wood notes. The intensity of the sweet taste was low; however, the acidity of the pastes is influenced by the fruity attribute as a characteristic descriptor of Trinitarian cocoas. The commercial cataloging of fine or flavored cocoa in Trinitarian hybrid clones reveals similar results from Sukha, et al. [17]. The flavor profiles for these local clones revealed that they consistently had higher fruity and acid notes. Astringency and bitterness did not vary significantly between the local clones.

Table 4. Differences in the global means of aroma and taste attributes were observed using Tukey test.

Aroma attributes	*Global means	Tukey test ($p > 0.05$)	Taste attributes	*Global means	Tukey test ($p > 0.05$)
Cocoa	7.25	A	Cocoa	7.58	A
Chocolate	5.41	B	Fruity	5.07	B
Fruity	4.44	C	Chocolate	4.91	C
Acidity	3.46	D	Acidity	4.52	D
Wood	3.17	E	Bitter	3.92	E
Nutty	2.62	F	Astringent	3.46	F
Floral	2.53	F	Nutty	3.3	G
Smoked	0.33	G	Wood	3.05	H
Spicy	0.32	G	Floral	2.47	I
Moldy	0.26	GH	Sweet	2.08	J
Putrid	0.14	HI	Smoked	0.46	K
Metallic	0.07	I	Spicy	0.34	K
-	-	-	Metallic	0.02	L

Note: *Means with a common letter are not significantly different ($p > 0.05$).

This study found that pastas from different Venezuelan regions had significant differences, with genetics and post-harvest handling being the main causes of the variability. The bitter taste of the liqueurs showed acceptable average values, which is an indicator of a higher quality of the liqueur. This attribute has an inverse relationship with the quality of the final product. The greater the bitterness, the lower the organoleptic quality of the paste. Besides, one of the reasons why the cocoa processing process is carried out is precisely to minimize the levels of bitterness in the beans, which is related to the content of purines (caffeine and theobromine) [18].

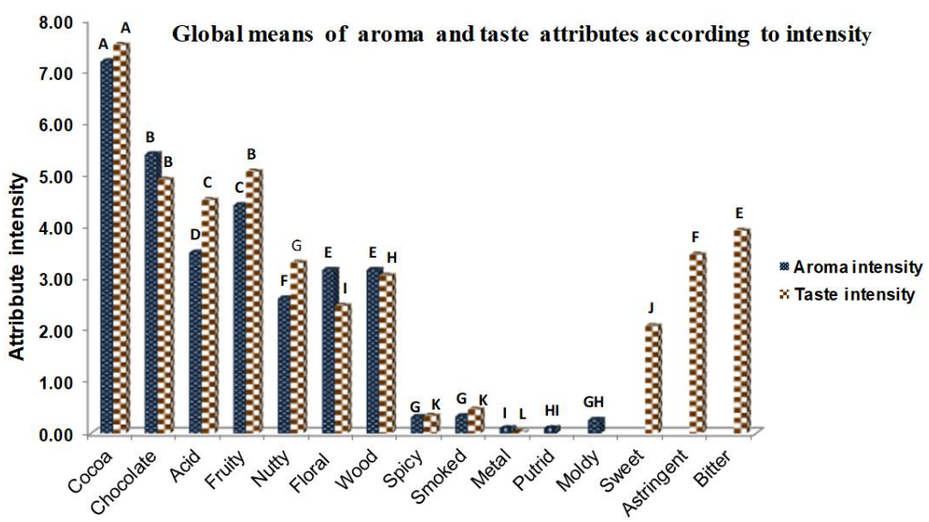


Figure 2. Global means for the different aromas and tastes.

Note: Means with the same letter are not significantly different ($p > 0.05$).

Figure 3-A revealed the statistically significant differences between the aroma intensities of eight (8) liquors evaluated. These liquors or cocoa pastes presented the best attributes or strong notes of chocolate, fruity and cocoa with an intermediate acidity. The intermediate notes for the nutty attribute only corresponded to the liquors from (7)-Miranda (17232), (3)-Bolívar (78882), and (2)-Barinas (48747) states. The Barinas liqueur was characterized by intense chocolate and fruity notes (aromas) and a strong cocoa flavor balanced with a soft nutty aroma.

The liquor from (1)-Apure state (65127) obtained the best notes of chocolate, fruit, and cocoa in aroma and taste, balanced with low bitterness and sweetness Figure 3-B. The evaluation jury designated the intensities of acidity and astringency for this liquor, in intermediate values of 5.00 points with low astringency of 3.30 points on average. In summary, the taste and aroma attributes are statistically significant between the liquors from different areas evaluated ($p > 0.05$).

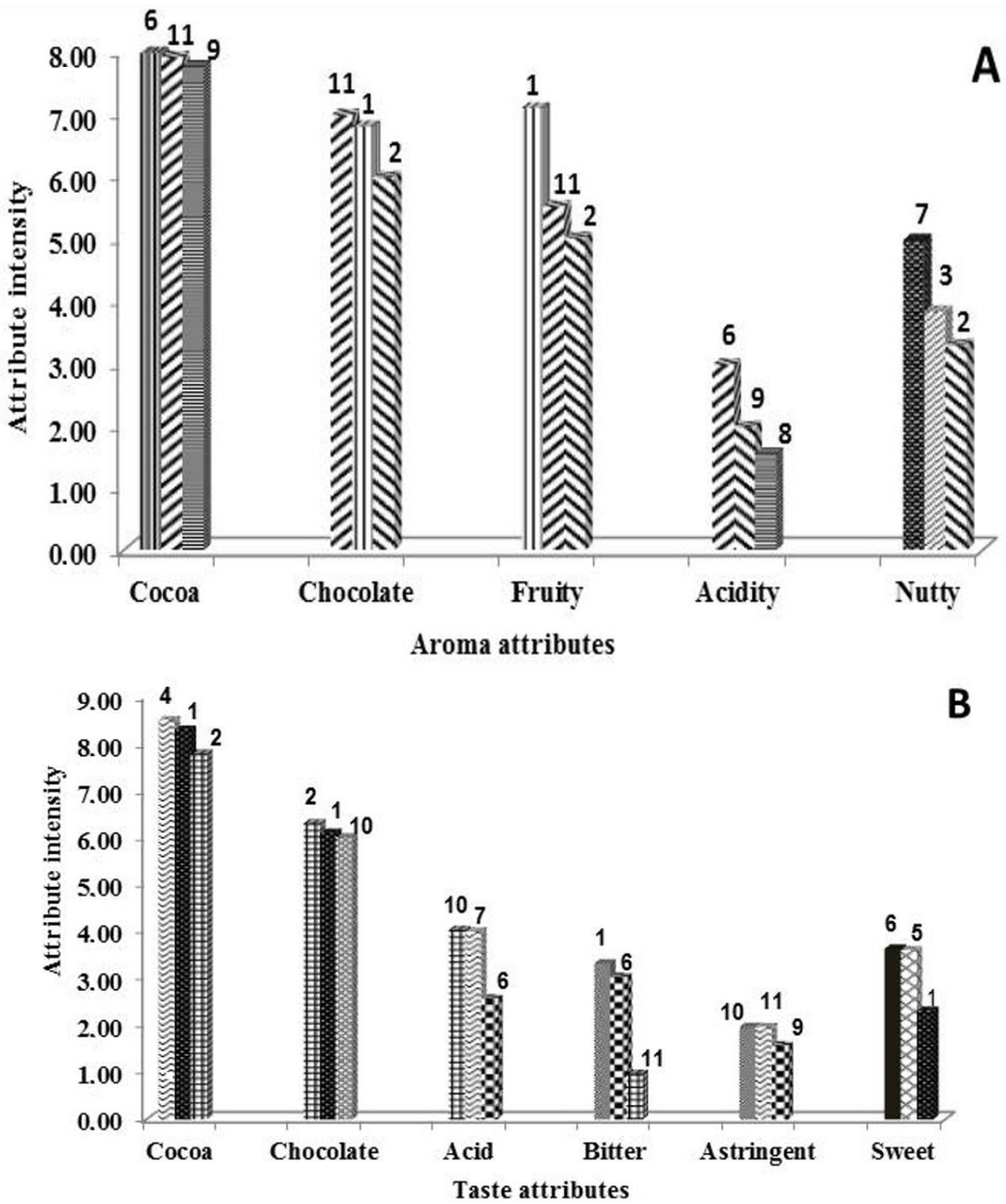


Figure 3. Cocoa liqueurs or pastes with the best aroma **(A)** and taste **(B)** Attributes: 1-(65127-Apure), 2-(48747-Barinas), 3-(78882-Bolívar), 4-(19257-Bolívar), 5-(97825-Yaracuy), 6-(91917-Yaracuy), 7-(17232-Miranda), 9-(50694-Monagas), 10-(66010-Carabobo), and 11-(54184-Reference clone).

3.8. Principal Component Analysis for Taste and Aroma Attributes of Cocoa Paste (Liquors) Samples

Principal Component Analysis (PCA) is a statistical tool that determines the most important taste and aroma attributes that define the profiles of cocoa paste samples, and how they correlate with each other. PCA compresses the data based on similarities and differences by reducing dimensions without much loss of information and defining the number of principal components (PCs) [19, 20] . The PCA showed the variability of the eleven (11) cocoa materials under study concerning the intensity of the taste attributes, with a 54.1% variation value of the two components (CP1, CP2), as seen in Figure 4.

Figure 4 shows three (3) large groups differentiated mainly by the basic and complementary intensities tastes. The first Group (I) conformed by 76192, 50694, and 54184 liqueur, they revealed a greater intensity in the basic tastes of astringency, bitterness, and low intensity in acidity, combined with soft woody notes. The 48747, 19257, 65127, and 66010 codified liquors samples from the second group (II) showed an intermediate balance in the complementary attributes of fruit, cocoa, and chocolate taste. The liqueur 97825 of Group III presented attributes in the sweet, floral, and nutty flavors combined with very low spicy notes, while 91197 liqueur showed the lowest notes in the previous attributes. The metallic taste was not detected in the liquor 78882; the value of this atypical flavor is not exceeding 2 points.

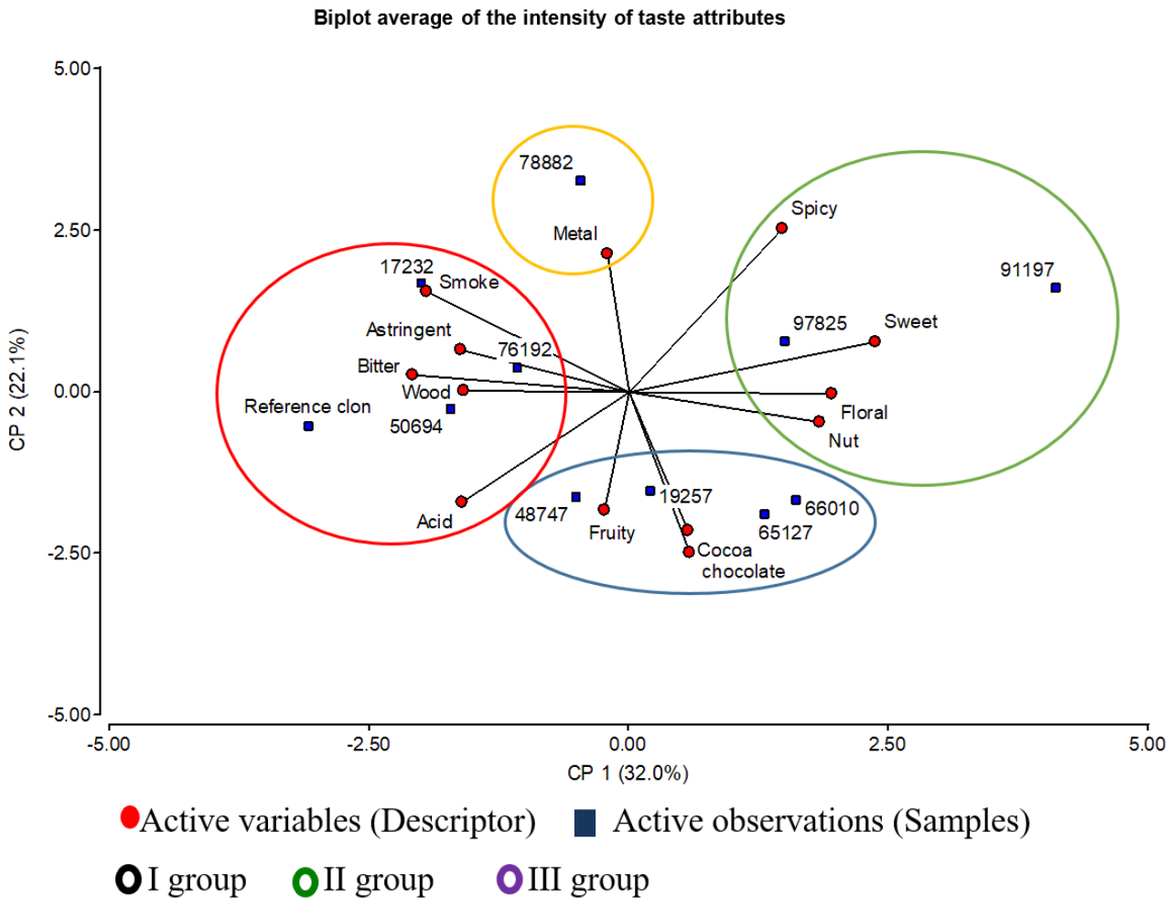


Figure 4. Principal component analysis for taste attributes on eleven (11) selected liquors of cocoa.

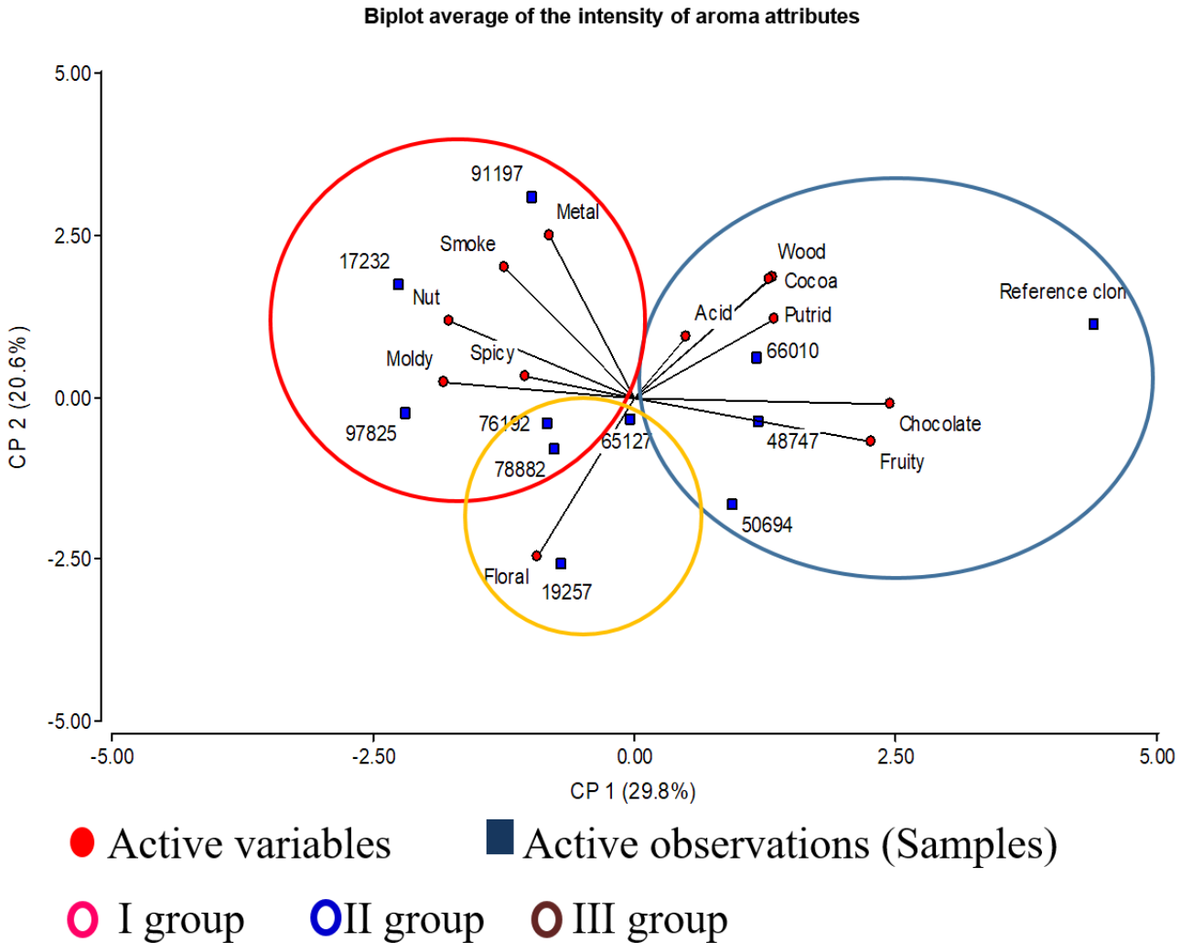


Figure 5. Principal component analysis for aroma attributes on eleven (11) selected liquors of cocoa.

The value of the variability observed in the aroma was 50.4% in the two components of the PCA (Figure 5). Liqueur 1732 from the first group (I) was characterized by an intermediate balance of some more intense aroma attributes (spicy and fruity). Liquors 76192, 78882, 97825, and 91197 showed very low values in the intensity of moldy and smoky odors. Liqueur 19257 from the second group (II) showed a notable intensity in the floral aroma

but very low in this attribute in liquors 65127, 78882, and 76192 respectively. Liqueur 54184 corresponding to the reference clone showed significant separation within the second group as special attributes liqueur (Figure 5).

The liquors 66010 and 48747 of the third group (III) were characterized by presenting strong intensities of cocoa and chocolate aromas combined with high acidity and low fruity and woody notes. While liquors 50694 and 54184 showed very soft notes of chocolate and fruit.

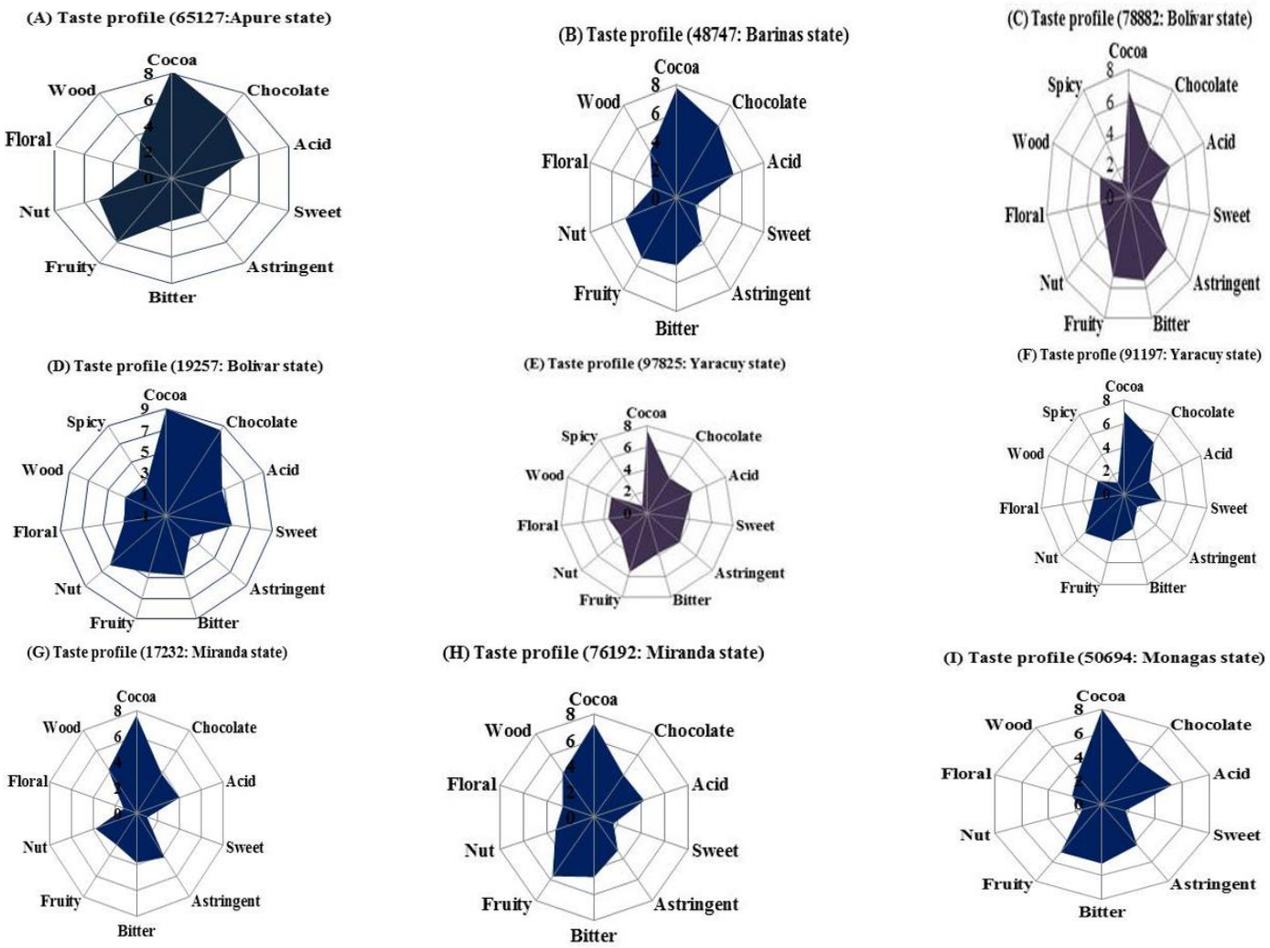
3.9. Taste Profiles of the Eleven Cocoa Pastes Selected (Liquors)

The intensity values of basic and complementary taste attributes were averaged. The intensity scores (0-10) of the flavor attributes were obtained by the average of each evaluating jury in the sessions. In the basic tastes (cocoa, bitterness, astringency, sweetness, and acidity) a score from 5 to 6 was obtained, in the scale range of 0 to 10 points with an intermediate intensity rating in most of the samples (Figure 6). Similar results were obtained by Rodríguez-Silva, et al. [21] on Colombian genotypes classified as fine cocoa with flavor and aroma. The dried and fermented cocoa beans, after the roasting showed strong cocoa and chocolate notes.

The strong notes of cocoa and chocolate were: 65127-Apure, 48747-Barinas, 91197-Yaracuy, 66010-Carabobo, and 54184-clon reference as shown in Figure 6 (A, B, F, J, K). The maximum strong cocoa and chocolate intensity (9 points) corresponded to the 19257-Bolívar liqueur. Figure 6, it was also observed that there is a balanced combination of bitterness, fruity, acidity, and astringency notes in all samples, which can be inferred that the producers applied good postharvest practices (harvest, fermentation, and drying). Defect intensity or atypical tastes were very low and did not represent a critical value or risk for the final product.

The intensity value in the smoked taste (atypical flavor) ranged from 1 to 2 points, corresponding to 2 samples from the Miranda state (17232 and 76192), Monagas (50694), and the reference clone (54184). According to the International Standards for the Assessment of Cocoa Quality and Flavour (ISCQF) [12], the previous scores (1-2) are considered low intensity to be categorized as a critical risk. The moldy and metallic notes were absent in the cocoa paste which are considered atypical flavor defects. Figure 4 (C-D, E-F, G, H) observed that samples processed in the same state (Bolívar, Yaracuy, and Miranda states) had profiles with different flavor intensities, demonstrating that cocoa type, traditional post-harvest technology, and the agronomic-ecological conditions local have a direct effect on these profiles.

The nutty and fruity notes considered complementary attributes were quantified with a maximum value of 6 points. The highest fruity notes (6 points) corresponded to liquors from 65127-Apure, 19257-Bolívar, 97825-Yaracuy, 76192-Miranda, and 66010-Carabobo. The floral notes were very low (2 to 4 points), being the highest for the 97825-Yaracuy liqueur. Spice notes were perceived with low intensity in all samples. The wood attribute ranged from 3 to 4 points in intensity with intermediate tenors (4 points maximum) for 65127-Apure, 48747-Barinas, 97825- Yaracuy, and two (2) liquors from Miranda state (17232 and 76192).



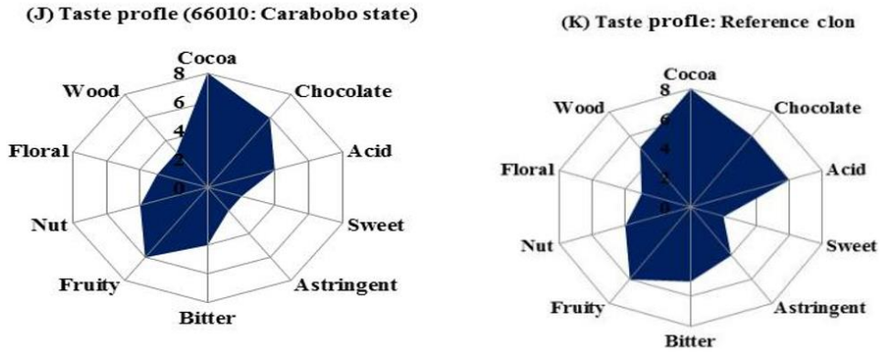


Figure 6. Taste profiles of eleven (11) Samples of cocoa pastes were selected that describe the basic and complementary attributes according to sensory analysis and origin (Venezuelan states): (A) 65127-Apure; (B) 48747-Barinas; (C) 78882-Bolívar; (D) 19257-Bolívar; (E) 97825-Yaracuy; (F) 91197-Yaracuy; (G) 17232-Miranda; (H) 76192-Miranda; (I); 50694-Monagas; (J) 66010-Carabobo; and (K) 54184-Reference clone.

4. General Conclusions

The analyzed cocoa samples presented a characteristic sensory profile with different intensities, confirming the effect of harvest and postharvest handling in the formation of the chocolate precursors. It is concluded the values obtained in the physical quality and cut-test do not constitute the fingerprint to generate quality profiles in cocoa beans. The majority of producers had complied with good post-harvest practices in the cocoa bean samples, as a requirement for the presentation of excellent quality beans. Finally, only eleven (11) samples were for the sensory analysis; since they met the physical quality requirements. Selected samples were classified, according to national standards, mostly like "Fine or Extra-fine cocoa" with the lowest number of defects and atypical flavors.

A trained taster's sensorial panel properly evaluated the sensory notes of the samples. The results of the statistical calculation produced by the responses of the panelists indicated that each type of cocoa presented a different sensory profile in its intensity classifying Venezuelan cocoa as fine and extra-fine.

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