

Morphology, Hybridization Percent, and Sensorial Notes of Fruits of Cacao from Two Plantations of *Patanemo*, Carabobo State, Venezuela

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Abstract

Venezuelan cacaos are internationally recognized as 100% fine flavored, indeed, the most famous chocolatier have an excellent opinion of its sensorial properties, and usually, they want these cacaos for their formulation. All cacaos from Venezuela are fine flavored with an important and excellent variation in their sensorial notes, which are a function of the growing region. However, only a few regions where they grow are recognized by the chocolatier world. *Patanemo* region has cacaos with excellent sensorial properties inherent to this region. The goal of the study was to evaluate characteristic biometric, color, hybridization percent, and sensorial notes from fruits gathered from two plantations of *Patanemo*, Carabobo state, Venezuela. The *Patanemo* cacaos variability in their biometric, color and sensorial properties could be attributed to a natural hybridization, to the genetic origin of the materials that grow in the studied plantations, and to the natural selection due to the effects of the climatic conditions of the region without the occurrence of a significant change in its genetic. They are classified as *Criollos Modernos*. These cacaos have a percent of hybridization average that revealed them as descendent more towards the *Criollo* than the *Forastero*. The cacaos that grow in these two plantations located in *Patanemo* show an excellent sweet and acid good taste, with descriptors defined toward wood, citric, and peach notes.

Keywords: Cacao; *Patanemo*; Venezuela

Introduction

Silvestre or domesticated, the three-classified types of cacao plants; *forastero*, *criollo*, and *trinitario*, are growing in Venezuela. All of them have been characterized by the ICCO, in 2016 [1] as 100% cocoa fine flavored. According to ICCO, 2021 [2], the definition of fine or flavored cocoa remains controversial as no single universally-accepted criterion could be adopted as a basis for determining whether or not cocoa of a given origin is to be classified as fine or flavor cocoa. Usually, a combination of criteria is used to assess the quality of fine or flavor cocoa. These include the genetic origin of planting material, morphological characteristics of the plant, flavor characteristics of the cocoa beans produced, chemical characteristics of the cocoa beans, degree of fermentation, drying, acidity, off-flavors, and percentage of internal mould, insect infestation and percentage of impurities.

Perez and Silva, 2020 [3] had already defined Venezuelan cocoa as: "cacao fine aroma cocoa," which is a term that defines the unique and incomparable types of cocoa that develop in its fruits intense and different flavors, which grow in plantations in Venezuela. This privi-

leged characteristic in flavor shown by the Venezuelan cocoas is due that the climatic conditions where all-Venezuelan cocoa plants are growing are of a rain Forrest; this factor and the effect of the time have made them, in spite of their hybridizations, as cocoas with excellent and with different delicate and fine flavors. This developed fine flavor has led to the name Criollo *Modernos* [4,5]. Then, Venezuelan cacao can be defined as a fine-flavored *Criollo Moderno*.

Despite this advantageous characteristic associated with the region where cacaos are growing, only a few of them are recognized at the international level. An example is *Chua* region which is recognized internationally for its cacao.

Patanemo is also a fine-flavored cacao region located in the Venezuela Carabobo state. Indeed, all *Patanemo* plantations are settled in a rain forest, in a mountain in front of the sea of the Venezuelan north-central coast cordillera, with windy annual climatic conditions (*caldereta*) which also help the cocoas plants in its physiological and flavor develop. Furthermore, the characteristics of the fruits of the *Patanemo* region cocoas and the colors of its cotyledons are an index of its sensorial association as cocoa fine flavored. Moreover, such as all Venezuelan cacaos, its excellent flavorful flavors are different in descriptors or notes among the plantations as a function of the place where they are growing.

Aim of the Study

The goal of the research is to characterize morphologically external and internal the *Theobroma cacao* L. fruits and their seeds collected from plants from two plantations in *Patanemo*, Carabobo state, Venezuela, and their sensorial notes through a technical panel. The fruits for evaluation were chosen from the *La Ceiba*, and *Andomar* plantations located in the Sector Primavera, Patanemo, Carabobo state Venezuela.

Materials and Methods

Materials

Raw material

9 cacao specimens from *La Ceiba* plantation, and 7 from *Andomar* plantation.

Equipment and utensils

- Precision balance
- Cutter
- Knife
- Munsell color chart
- Digital caliper with a precision of 0.001 mm
- Rule
- Metric tape
- Camera
- Panelist.

Methods

The determination of the morphological descriptors of the fruits and seeds was based on the Phillips-Mora, *et al.* [6] researching.

Biometric determination

For to perform the biometric determinations, several fruits were selected randomly from two plantations of the Sector Primavera, *Patanemo*, Carabobo state, Venezuela, named *La Ceiba*, and *Andomar*. From *La Ceiba* plantation in addition to the previously selected, one was selected from a plant considered as 100% *Criollo* Cocoa.

Both batches were from the December harvest period of 2020. The biometric analysis was completed as an individual measurement of the length, width, and thickness of the fruits, using metric tape.

The length was measured from the base to the apex, excluding the stalk and the width and thickness measurements were performed in the midline of the fruits. After measurement, the fruits were individually weighed on an analytical balance accurate to 0.001g. On all of the quantitative characteristics data was made a descriptive analysis, calculated with Excel application such as: arithmetic mean, standard deviation, coefficient of variation, range of variation, and relative frequency of characteristics in the fruit. The descriptive aspects of the fruits were shape, color, pod texture, weight (pod and placenta weight), size and consistency of the pericarp, and seed number per fruit (for seeds line and total). On the seeds, the internal morphological characteristics color, hybridization percent, and the presence of black pigmentation on cotyledons were evaluated. To make the intern morphologic study of seeds easier, they were cut lengthwise.

Color

The color of fruits and seed 'cotyledons was analyzed by using the Munsell Color Chart. The Munsell color system is a color space that specifies colors based on three properties: hue (basic color), chroma (color intensity), and value (lightness) [7-9].

Hue

Red, yellow, green, blue, and purple, along with 5 intermediate hues (e.g. YR) halfway between adjacent principal hues. In practice, color charts conventionally specify 40 hues, in increments of 2.5, progressing as for example 10R to 2.5YR.

Value, or lightness

Varies vertically along the color solid, from black (value 0) at the bottom, to white (value 10) at the top Neutral grays lie along the vertical axis between black and white.

Chroma

Chroma, measured radially from the center of each slice, represents the "purity" of a color (related to saturation), with lower Chroma being less pure (more washed out, as in pastels).

To photograph, it was used a Samsung +9 camera 2 MP, AF Dual Pixel, OIS, aperture variable f/1.5-2.4 attached to a gripper tool in order to control a mechanical pickup. The distance between the camera and the fruit was estimated by measuring the dimensions of the fruit when locating the camera at different positions with a known distance between the two objects. The next step was to match the center of the fruit with the center of the image in order to align the gripper tool with the fruit. To shoot was chosen the time of day when the light was abundant and diffused for a softer looking.

Hybridization

The percent of hybridization was calculated by measurement of the number of seeds with cotyledons with a Medium Dark Purple Munsell color with a Munsell Value of 5RP 4/8, and subtracting this quantity of seeds with this medium purple from the total number of seeds and multiplying by 100.

Sensorial evaluation

The sensorial evaluation of the flavor and savor descriptors or notes was performed by the affective panel conformed of the technicians, who were considered semi-trained judges.

Results



Figure 1: Collection of cacaos from the plantation La Ceiba. Sector Primavera, Carabobo Slate, Venezuela. Cacao type: Hybrid or Criollo Moderno. Plantation La Ceiba with 52 ha, of which 25 are productive. The plantation is located on the Rain Forrest of the Cordillera Centro Norte Costera, near the National Park San Esteban.



Figure 2: Longitudinal fruit and seed sections of the cacao sample 1. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Green	Light Green	Oblong	Acute	Intermediate	Slightly apart	Intermediate	2.3

Table 1: Relevant morphological descriptors of the cacao fruit (sample 1) from the collection of the plantation La Ceiba.

Sample # 1	Fruit Color		Light green		Fruit Texture	Semi-wrinkled (Light)	Fruit weight		1.540		
	27 cm	Fruit wide	Munsell Value: 7.5G 8/2	11.5 cm			Indentations Number	10	Pod wide	1.18 cm	Pod weight
Seeds in line	9	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8		5	Hybridization: 56%	Seeds Total number	46	Seed + mucilage weight	0.300	
			Medium Dark Purple Munsell Value: 5RP 4/8		4					kg	

Table 2: Morphological characteristics of the cacao sample 1, and its seed, from the collection of the plantation La Ceiba.

Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 3: Longitudinal fruit and seed sections of the cacao sample 2. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Green	Yellow	Oblong	Absent	Acute	Slightly apart	Intermediate	1.9

Table 3: Relevant morphological descriptors of the cacao fruit (sample 2) from the collection of the plantation La Ceiba.

Sample # 2	Fruit Color		Yellow/green		Fruit Texture	Wrinkled (Intense)	Fruit weight		1.040		
	22.5 cm	Fruit wide	Munsell Value: 5Y 8/12	12 cm			Indentations Number	10	Pod wide	1.97 cm	Pod weight
Seeds in line	10	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8		10	Hybridization 100 %	Seeds Total number	49	Seed + mucilage weight	0.250	
			Medium Dark Purple Munsell Value: 5RP 4/8		0					Kg	

Table 4: Morphological characteristics of the cacao sample 2, and its seed, from the collection of the plantation La Ceiba.

Sensorial Evaluation. Citric notes taste.



Figure 4: Longitudinal fruit and seed sections of the cacao sample 3. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Light green	Pigmented Yellow	Elliptical	Absent	Attenuated	Intermediate	Intermediate	2.3

Table 5: Relevant morphological descriptors of the cacao fruit (sample 3) from the collection of the plantation La Ceiba.

Sample # 3	Fruit Color		Predominant Yellow		Fruit Texture	Semi-wrinkled		Fruit weight		0.780 Kg	
	23 cm	Fruit wide	10 cm	Indentations Number		10	Pod wide	1.22 cm	Pod weight	0.520 Kg	Placenta weight
Fruit large	23 cm	Fruit wide	10 cm	Indentations Number	10	Pod wide	1.22 cm	Pod weight	0.520 Kg	Placenta weight	40 Grams
Seeds in line	11	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8		4	Hybridization: 44%	Seeds Total number	51	Seed + mucilage weight	0.220 Kg	
			Medium Dark Purple Munsell Value: 5RP 4/8		7						

Table 6: Morphological characteristics of the cacao sample 3, and its seed, from the collection of the plantation La Ceiba.

*Intensity of anthocyanin present in the sides of the fruit.

Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 5: Longitudinal fruit and seed sections of the cacao sample 4. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Pigmented green	Intense Red	Oblong	Absent	Acute	Intermediate	Intermediate	2

Table 7: Relevant morphological descriptors of the cacao fruit (sample 4) from the collection of the plantation La Ceiba.

Sample # 4	Fruit Color	Red//Purple			Fruit Texture	Semi-wrinkled	Fruit weight				1.560 Kg	
		Munsell Value: 5RP 3/6					Pod wide cm	Pod weight	1.340 Kg	Placenta weight	40 Grams	
Fruit large	26 cm	Fruit wide	13 cm	Indentations Number	10	Pod wide						2.70 cm
Seeds in line	10	Cotyledons color	Light Purple		5	Hybridization: 50%	Seeds Total number	40	Seed + mucilage weight	0.200 Kg		
			Medium Dark Purple		5							
				Munsell Value: 5RP 6/8								
				Munsell Value: 5RP 4/8								

Table 8: Morphological characteristics of the cacao sample 4, and its seed, from the collection of the plantation La Ceiba.

Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 6: Longitudinal fruit and seed sections of the cacao sample 5. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/ Wide Ratio
Light green	Reddish Yellow	Oblong	Absent	Attenuated	Intermediate	Deep	2

Table 9: Relevant morphological descriptors of the cacao fruit (sample 5) from the collection of the plantation La Ceiba.

Sample # 5	Fruit Color		Predominant Yellow Munsell Value: 5Y 8/12		Fruit Texture	Wrinkled (Intense)		Fruit weight		0.700 Kg	
Fruit large	21.5 cm	Fruit wide	10,9 cm	Indentations Number	10	Pod wide	1.40 cm	Pod weight	0.560 Kg	Placenta weight	20 Grams
Seeds in line	7	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8		4	Hybridization 57%	Seeds Total number	23	Seed + mucilage weight	0.120	
			Medium Dark Purple Munsell Value: 5RP 4/8		3					kg	

Table 10: Morphological characteristics of the cacao sample 5, and its seed, from the collection of the plantation La Ceiba. Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 7: Longitudinal fruit and seed sections of the cacao sample 6. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/ Wide Ratio
Light green	Pigmented Yellow (Green)	Oblong	Absent	Attenuated	Light	Light	2.1

Table 11: Relevant morphological descriptors of the cacao fruit (sample 6) from the collection of the plantation La Ceiba.

Sample # 6	Fruit Color		Green Yellow *Munsell Value: 5GY 7/10		Fruit Texture	Wrinkled (Intense)		Fruit weight		0.960 Kg	
Fruit large	23 cm	Fruit wide	11 cm	Indentations Number	10	Pod wide	1.93 cm	Pod weight	0.840 Kg	Placenta weight	20 Grams
Seeds in line	7	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8		4	Hybridization 57%	Seeds Total number	23	Seed + mucilage weight	0.100	
			Medium Dark Purple Munsell Value: 5RP 4/8		3					Kg	

Table 12: Morphological characteristics of the cacao sample 6, and its seed, from the collection of the plantation La Ceiba.

* Intensity of anthocyanin present in the loins of the fruit.

Sensorial Evaluation: Sweet and acid good taste, but without defined note.



Figure 8: Longitudinal fruit and seed sections of the cacao sample 7. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Light green	Pigmented Yellow (Green)	Oblong	Absent	Attenuated	Light	Light	1.6

Table 13: Relevant morphological descriptors of the cacao fruit (sample 7) from the collection of the plantation La Ceiba.

Sample #	Fruit Color	Yellow/green		Fruit Texture	Semi-wrinkled	Fruit weight		1.080			
		Munsell Value: 5Y 8/10				Kg					
Fruit large	22.8 cm	Fruit wide	14 cm	Indentations Number	10	Pod wide	2,2 cm	Pod weight	0.960 Kg	Placenta weight	60 Grams
Seeds in line	8	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8		3	Hybridization 38%	Seeds Total number	43	Seed + mucilage weight	0.220 grams	
			Medium Dark Purple Munsell Value: 5RP 4/8		5						

Table 14: Morphological characteristics of the cacao (sample 7), and its seed, from the collection of the plantation La Ceiba.

*Intensity of anthocyanin present in the loins of the fruit.

Sensorial evaluation: Sweet and acid good taste, but without defined notes.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Red	Reddish Orange	Oblong	Absent	Attenuated	Intermediate	Intermediate	1.9

Table 15: Relevant morphological descriptors of the cacao fruit (sample 8) from the collection of the plantation La Ceiba.



Figure 9: Longitudinal fruit and seed sections of the cacao sample 8. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Sample # 8	Fruit Color		Red		Fruit Texture	Semi-wrinkled	Fruit weight		0.520		
	15.8 cm	Fruit wide	Munsell Value: 5R 3/6				10	Pod wide	0.380 Kg	Placenta weight	20 grams
Fruit large	15.8 cm	Fruit wide	8.5 cm	Indentations Number	10	Pod wide	0.3 cm	Pod weight	0.380 Kg	Placenta weight	20 grams
Seeds in line	8	Cotyledons color	Light Purple Munsell Value: 5RP 6/8		4	Hybridization 50 %	Seeds Total number	43	Seed + mucilage weight	0.120 Kg	
			Medium Dark Purple Munsell value: 5RP 4/8		4						

Table 16: Morphological characteristics of the CACAO sample 8, and its seed, from the collection of La Ceiba, plantation La Ceiba. Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 10: Longitudinal fruit and seed sections of the Criollo cacao sample 9. Collection of the plantation La Ceiba, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Light green	Yellow	Oblong	Light	Attenuated	Intermediate	Intermediate	2.1

Table 17: Relevant morphological descriptors of the Criollo cacao fruit (sample 9) from the collection of the plantation La Ceiba.

Sample # 9	Fruit Color		Light Yellow Munsell Value: 5Y 8/6		Fruit Texture	Semi-wrinkled (Intermediate)	Fruit weight		0.661 Kg		
Fruit large	20 cm	Fruit wide	9.5 cm	Indentations Number	10	Pod wide	1.8 cm	Pod weight	0.488 Kg	Placenta weight	9.2 Grams
Seeds in line	7	Cotyledons color	White	7	Hybridization 0%		Seeds Total number	33	Seed plus mucilage weight	0.119 Kg	

Table 18: Morphological characteristics of the Criollo cacao sample 9, and its seed, from the collection of the plantation La Ceiba. Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 11: Collection of cocoas fruits from the plantation Andomar, Sector Primavera, Carabobo State, Venezuela.



Figure 12: Longitudinal fruit and seed sections of the cacao sample 1a. Collection of the plantation Andomar, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Light green	Yellow red	Oblong	Attenuated	Absent	Intermediate	Intermediate	2.2

Table 19: Relevant morphological descriptors of the cocoa fruit (sample 1a) from the collection of the plantation Andomar.

Sample # 1a	Fruit Color	Yellow-reddish		Fruit Texture	Smooth	Fruit weight		0.460			
		*Munsell Value: 2.5Y 6/8				Kg					
Fruit large	17 cm	Fruit wide	7.9 cm	Indentations Number	10	Pod wide	1.44 cm	Pod weight	0.340 Kg	Placenta weight	10 grams
Seeds in line	7	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8		3	Hybridization 43%	Seeds Total number	36	Seed + mucilage weight	0.120	
			Medium Purple Munsell Value: 5RP 4/8		4					Kg	

Table 20: Morphological characteristics of the cacao (sample 1a), and its seed, from the collection of the plantation named Andomar.

* Intensity of anthocyanin present in the loins of the fruit.

Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 13: Longitudinal fruit and seed sections of the cacao sample 2a. Collection of the plantation Andomar, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Light green	Yellow	Oblong	Attenuated	Absent	Intermediate	Intermediate	2

Table 21: Relevant morphological descriptors of the cocoa fruit (sample 2a) from the collection of the plantation Andomar.

Sample # 2a	Fruit Color		Yellow		Fruit Texture	Semi-wrinkled	Fruit weight			0.740	
	Munsell Value: 2.5Y 8/10						Kg				
Fruit large	19	Fruit wide	9.5	Indentations Number	10	Pod wide	1.46	Pod weight	0.580	Placenta weight	20
	cm		cm				cm		grams		
Seeds in line	7	Cotyledons color	Light Purple Munsell Value: 5RP 6/8		5	Hybridization 71%	Seeds Total number	39	Seed + mucilage weight	0.140	
			Medium Purple Munsell Value: 5RP 4/8		2					Kg	
Note		Presence of acentric black dots in the cotyledons of one of the seeds (see circle)									

Table 22: Morphological characteristics of the cacao sample 2a, and its seed, from the collection of the plantation Andomar.

* Intensity of anthocyanin present in the loins of the fruit.

Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 14: Longitudinal fruit and seed sections of the cacao sample 3a. Collection of the plantation Andomar, Sector Primavera, Carabobo state, Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/ Wide Ratio
Light green	Green yellow	Oblong	Attenuated	Absent	Intermediate	Intermediate	1.9

Table 23: Relevant morphological descriptors of the cacao fruit (sample 3a) from the collection of the plantation Andomar.

Sample # 3a	Fruit Color		Green Yellow		Fruit Texture	Smooth	Fruit weight			0.700	
	Munsell Value: 2.5 Y8/8						Kg				
Fruit large	19	Fruit wide	10	Indentations Number	10	Pod wide	2.0	Pod weight	0.600	Placenta weight	10
	cm		cm				cm		grams		
Seeds in line	7	Cotyledons color	Light Purple Munsell Value: 5RP 6/8		5	Hybridization 71%	Seeds Total number	32	Seed + mucilage weight	0.100	
			Medium Purple Munsell Value: 5RP 4/8		2					kg	

Table 24: Morphological characteristics of the cacao sample 3a, and its seed, from the collection of the plantation Andomar.

* Intensity of anthocyanin present in the loins of the fruit.

Sensorial Evaluation: Sweet and acid good taste, but without defined notes.



Figure 15: Longitudinal section of the cacao sample 4a, and its seed, from the collection of Andomar plantation. Sector Primavera, Estado Carabobo Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/ Wide Ratio
Light green	Predominant yellow	Oblong	Acute	Absent	Light	Light	2.2

Table 25: Relevant morphological descriptors of the cacao fruit (sample 4a) from the collection of the plantation Andomar, Sector Primavera, estado Carabobo, Venezuela.

Sample # 4a	Fruit Color		Yellow		Fruit Texture	Semi.wrinkled		Fruit weight		0.940 Kg	
	19.5 Cm	Fruit wide	Munsell Value: 2.5Y 8/10	9 cm		Pod wide	1.5 cm	Pod weight	0.680 Kg	Placenta weight	20 grams
Fruit large	19.5 Cm	Fruit wide	9 cm	Indentations Number	10	Pod wide	1.5 cm	Pod weight	0.680 Kg	Placenta weight	20 grams
Seeds in line	8	Cotyledons color	Light Purple Munsell Value: 5RP6/8 Medium Purple	8	Hybridization 100%	Seeds Total number	38	Seed plus mucilage weight	0.140 kg		

Table 26: Morphological characteristics of the cacao sample 4a, and its seed, from the collection of the plantation Andomar. Sector Primavera, estado Carabobo, Venezuela.

*Intensity of anthocyanin present in the loins of the fruit.

Sensorial Evaluation: Sweet and acid good taste, but without defined notes.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of A Pair of Loins	Groove Depth	Length/ Wide Ratio
Light green	Yellow	Oblong	Attenuated	Absent	Intermediate	Intermediate	2

Table 27: Relevant morphological descriptors of the cacao fruit (sample 5a) from the collection of the plantation Andomar.



Figure 16: Longitudinal section of the cacao sample 5a, and its seed, from the collection of Andomar plantation. Sector Primavera, Estado Carabobo Venezuela.

Sample	Fruit Color		Yellow		Fruit	Semi-wrinkled	Fruit weight		0.940		
# 5a			Munsell Value: 2.5Y 7/10		Texture				Kg		
Fruit large	20.5 cm	Fruit wide	10.5 cm	Indentations Number	10	Pod wide	1.5 cm	Pod weight	0.640 Kg	Placenta weight	20 grams
Seeds in line	9	Cotyledons color	Light Purple Munsell value: 5RP 6/8 Medium Purple		9	Hybridization	Seeds Total number	44	Seed plus mucilage weight	0.220 kg	
Note	Presence of acentric and centric black dots in the cotyledons of some seeds (see circles)										

Table 28: Morphological characteristics of the cacao sample 5a, and its seed, from the collection of the plantation Andomar. Sensorial Evaluation. Excellent citric taste with a peach note.



Figure 17: Longitudinal section of the cacao sample 6a, and its seed, from the collection of Andomar plantation. Sector Primavera, Estado Carabobo Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of a Pair of Loins	Groove Depth	Length/Wide Ratio
Light green	Green Yellow	Oblong	Attenuated	Absent	Intermediate	Intermediate	2.6

Table 29: Relevant morphological descriptors of the cocoa fruit (sample 6a) from the collection of the plantation Andomar.

Sample	Fruit Color		Green Yellow		Fruit Texture	Semi-wrinkled	Fruit weight		1.100		
# 6a			Munsell Value: 2.5 GY 7/8						Kg		
Fruit large	25 cm	Fruit wide	9.5 cm	Indentations Number	10	Pod wide	2 cm	Pod weight	0.920 Kg	Placenta weight	20 grams
Seeds in line	8	Cotyledons color	Light Purple Munsell Value: 5RP6/8		4	Hybridization 50 %	Seeds Total number	33	Seed + mucilage weight	0.160	
			Medium Purple Munsell Value: 5RP 4/8		4					kg	
Note		Presence of two centric black dots in the cotyledons of some seeds (see circles)									

Table 30: Morphological characteristics of the cocoa fruit (sample 6a) from the collection of the plantation Andomar. Sensorial Evaluation: Sweet taste with wood notes.



Figure 18: Longitudinal section of the cacao sample 7a, and its seed, from the collection of Andomar plantation. Sector Primavera, Estado Carabobo Venezuela.

Immature Fruit Color	Ripe Fruit Color	Basic Shape	Apex Shape	Basal Constriction	Separation of s Pair of Loins	Groove Depth	Length/ Wide Ratio
Light green	Yellow	Oblong	Mammiform	Absent	Light	Superficial	1.5

Table 31: Relevant morphological descriptors of the cocoa fruit (sample 7a) from the collection of the plantation Andomar.

Sample	Fruit Color		Yellow		Fruit	Smooth	Fruit weight		0.520		
# 7a			Munsell Value: 2.5Y 7/8		Texture				Kg		
Fruit large	13.5 cm	Fruit wide	9 cm	Indentation Number	10	Pod wide	1.46 cm	Pod weight	0.380 kg	Placenta weight	10 grams
Seeds in line	10	Cotyledon's color	Light Purple Munsell Value: 5RP 6/8 Medium Purple		10 0	Hybridization 100%	Seeds Total number	39	Seed plus mucilage weight	0.140 kg	

Table 32: Morphological characteristics of the cacao sample 7a, and its seed, from the collection of the plantation Andomar. Sensorial evaluation: Sweet and acid good taste, but without defined notes.

Discussion

Biometric determination

From a botanical point of view, cocoa is considered an indehiscent drupe called the cob or maraca, which does not come off the tree even when it matures, keeping its interior hermetically closed. Inside these pods are the seeds, covered by slime, pulp, or mucilage, protected by a bark. It has been calculated 20 and 60 seeds per fruit and its size and shape vary according to the genetic type.

Figure 1 shows the eight cacao fruits gathered from the *La Ceiba* plantation. According to the Clone Characterization Catalog, CATIE, 2008, the *Angoleta* typical shape is the silhouette mostly prevalent, with a few fruits of *amelonada* shapes (cantaloupe-shaped). More in detail of the shape of the fruits is observed that they are oblong to rounded (but not spherical) were mostly observed, with the presence of an intense and semi-roughness, with light shapes at the apex and the presence of an intermediate, attenuated basal constriction, and acute. In figure 1 is missing sample 9, which is a special sample gathered from a *Criollo* cacao plant, which shall be discussed later.

Non-mammiform and attenuated curved apices at the fruits, and fruits with the absence of an evident basal constriction were observed. The depth of the grooves was intermediate with 2 specimens that appeared as deep grooves. Some samples with fused and intermediate spines (Fruits 2, 6, and 7) are observed in figure 3, 7, and 8.

Fruit weights ranged from 520 to 1,560 g with an average of 1,023 g. Their length, width, and thickness are 23 cm; 11 cm, and 2.0 cm, respectively; which is indicative of the morphotypes scarcity at the plantation. The length of the evaluated fruits is located between intermediate and large fruits (Table 1 to 18). The previous values were higher than those reported by Graziani de Fariñas., *et al.* [10] in hybrid materials from Cumboto, Aragua state (pods weight: 561g; L: 18.21 cm; A: 8.24 cm and E: 1.74 cm). The average length/width ratio of the fruit also presented a conservation in dimensions concerning to the pods evaluated. The weight of the placenta varied from 20g to 60g with an average of 38 grams, and the seed+pulp weight also varied among the fruits from 100 to 300 grams.

Figure 11 shows the seven cacao fruits gathered from the Andomar plantation. The biometric determination of each one of them is shown in table 19, 21, 23, 25, 27, 29, and 31. Such as, in the previous analysis the description of the shape of the different fruits evaluated was used the Catalog for the characterization of clones of CATIE, 2008.

The *Angoleta* type (oblong shapes) was the most predominant shape found, with a cantaloupe-shaped fruit (Figure 18, cacao sample 7a). All of the cacaos showed none or little basal constriction. The apex of most of the fruits is attenuated, except for sample code 7a, which has a blunt apex and a rounded shape. In this plantation, the weight of the fruits varied from 460g to 1,100g with an average of 771 grams of the total fruits collected. The length, width and thickness of the fruits on average were 19 cm, 9 cm, and 2 cm respectively. These values coincide with the values reported by Graziani de Fariñas., *et al.* [10] for Trinitario-type cocoa from the Cumboto region, Aragua state. The total number of seeds and the number of seeds per row were 37 and 8 on average, respectively.

Color

According to the values reflected from the *Munsell* Chart for plant tissues, the prevalent color for 5 fruits was situated on the yellow hue (5Y) with 8 value, meaning a medium yellow color and one of them is yellow chromed lightly (chroma 10) and the Criollo cacao most light yellow with a 6 of Chroma (Figure 2, 3, 5, 7, 9, and table 4-6, 9, 10, 13, 14, 17, 18).

Two fruits (Figure 5, 9 and table 7, 8, 15, 16) were red-purple and red (5RP and 5R hue) with a value of 3, and 6 of Chrome, meaning a dark red color in both. These predominant colors that have been considered present in the unripe fruits, varied from light green to red-purple colors. Once ripe, these fruits shall be light yellow, dark yellow, and red-orange. One fruit shows a green color 5G 8/2 or light green color (Figure 2, table 1, 2), and the pod from figure 7, table 11, 12 is lightly yellow-green (5GY 7/10).

Most of the fruits from Andomar plantation are light green, with intermediate roughness of the epicarp, except for sample 7a which has a smooth epicarp. The grooves of fruit 1a to fruit 6a are intermediate and visible, except for fruit 7a, which is fused. In relation to the quantified morphological characteristics, they are recorded in table 20, 22, 24, 26, 28, 30 and, 32.

Hybridization

All of the samples have a general average of 39 ± 10 seeds/fruit, a relevant characteristic of these hybrids in the area. The number of seeds per row on average was 9; being these physical characteristics superior to those found by Graziani de Fariñas, *et al.* [10] in materials from Cumboto, Aragua state.

The existing hybridization in the cacao samples 1 to 8 is ranging from 38% value (sample 7) up to 100% as the highest value (sample 2). The presence of the violet color in the fresh cotyledons shows that the type of existing material is of the hybrid type, referring to a type of cocoa called *Criollo Modern*. However, as was expected the *Criollo* cacao (sample 9 figure 10, table 17 and 18) have 0% of hybridization, without violet color in its cotyledons.

Within the selection in the colors of the seeds, a number of seeds with light purple colors and a proportion of seeds of dark intermediate violet in all the fruits analyzed with a total average of 56.5% of hybrid seeds were identified. It can be inferred that, in this Central region of Venezuela, there is an intermediate incidence of the violet color of the seeds of the predominant genotypes, with half of the genotypes of the ancestral *Criollo* type.

It can be inferred a wide diversity of materials in the *La Ceiba* plantation, with *Criollo* types tree, and marked influence from *Trinitarios* trees growing around. Cocoa is a cross-pollinated plant (allogamy), some being self-incompatible and propagated fundamentally through its seed, which has caused the crossing between the materials over time [10], resulting in the *Modern Criollo* cacaos. In the fruits of *Andomar* plantation, it is observed that the fruits contain a high number of light purple seeds (6) and a low value of dark purple seeds with medium shades (2), with an average hybridization percentage of 76%, a value high that represents the variability in the color of the seeds.

The materials coded with the numbers 2a, 5a, and 6a from *Andomar* plantation showed presence of black points, meaning the concentration of a high pigment at these points.

The sensorial notes or descriptors from the fruits of the two plantations were typified in most of the samples as sweet, and acid good taste. However, some of them have shown wood, citric, and peach notes.

Conclusion

The variability that characterizes cocoa from *Patanemo* is attributed to the level of natural hybridization, to the genetic origin of the materials that grow in the studied plantations, and to the natural selection, due to the effects of the climatic conditions of the region without the occurrence of a significant change in its genetic. They are classified as *Criollo Modernos*.

Despite the biometric heterogeneity observed in the fruits of these plantations, they have a percent of hybridization average that revealed them as descendent more towards the *Criollo* than the *Forastero*. Indeed, the cacaos that grow in these two plantations, located in *Patanemo*, show an excellent sweet and acid good taste, with descriptors defined toward wood, citric, and peach notes.

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