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Quality variables for technological application of cocoa clones from the Brazilian semiarid region[1]

Variáveis de qualidade para aplicação tecnológica de clones de cacau do semiárido brasileiro

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HIGHLIGHTS:
The CCN 51 clone has larger and heavier fruits.
Investigated clones presented no difference in the number of seeds in the fruit.
Clone PS 1319 presented fruits with higher pulp yield.

ABSTRACT: Characterization of cocoa clones produced in the semiarid region is necessary to enlarge the database about these implanted clones and thus enhance the quality of their by-products. Therefore, this study aims to evaluate physical, chemical, and physicochemical characteristics of the CCN 51, CEPEC 2004, CEPEC 2005, and PS 1319 clones, produced in the region of Vale do Jaguaribe in the state of Ceará (Brazil), and to suggest food processes or products for them. The clones were evaluated according to their physical traits (total fruit mass, rind, pulp, seeds, and placenta and pulp with seeds), fruit transverse diameter (FTD), fruit longitudinal diameter (FLD), the ratio FTD/FLD; rind external thickness (ERT), rind internal thickness (IRT), the ratio ERT/IRT, number of seeds, seed thickness, seed transverse diameter (STD), seed longitudinal diameter (SLD), and the ratio STD/SLD, yield, pulp color, chemical traits (humidity, lipids, proteins, ashes, crude fiber, and carbohydrates), and physicochemical traits (titratable acidity, pH, soluble solids, and reducing sugars) were evaluated. The CCN 51 and CEPEC 2005 clones are the most suitable for the process of cocoa fermentation. For desserts, jams, pulp, and nibs for fat-restricted diets, the most suitable clones are CCN 51, CEPEC 2005, PS 1319 and CEPEC 2004, respectively.

Key words: *Theobroma cacao* L., cocoa tree, chemical composition

RESUMO: A caracterização dos clones de cacau produzidos no semiárido faz-se necessária para aumentar a base de dados sobre esses clones implantados e assim melhorar a qualidade dos seus subprodutos. Dessa forma, objetivou-se avaliar as características físicas, químicas e físico-químicas dos clones CCN 51, CEPEC 2004, CEPEC 2005 e PS 1319, produzidos no Vale do Jaguaribe no Estado do Ceará e indicá-los para um processo ou produto alimentício. Os clones foram avaliados quanto às características físicas (massa total do fruto, casca, polpa, sementes, cibirra e polpa com sementes; diâmetro transversal (DTF) e longitudinal (DLF) do fruto e a relação DTF/DLF; espessura da casca externa (ECE) e interna (ECI) e a relação ECE/ECI; número, espessura, diâmetro transversal (DTS) e longitudinal (DLS) das sementes e a relação (DTS/DTS); rendimento e cor da polpa), químicas (umidade, lipídios, proteína, cinzas, fibra bruta e carboidratos) e físico-químicas (acidez titulável, pH, sólidos solúveis e açúcares redutores). Os clones CCN 51 e o CEPEC 2005 são os mais indicados para o processo de fermentação de cacau. Para doces, geleias, polpa e nibs para dieta com restrição de gordura indicam-se os clones CCN 51, CEPEC 2005, PS 1319 e CEPEC 2004, respectivamente.

Palavras-chave: *Theobroma cacao* L., cacaueiro, composição química

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Introduction

The cocoa tree (*Theobroma cacao* L.) is native to the Amazon region. Belonging to the Malvaceae (APG II, 2003) family, humid weather and rainfall ranging from 1400 mm to 2000 mm per year are ideal for its production, as well as temperatures between 20 and 30 °C (Jesus et al., 2013). The different kinds of knowledge about the production system are analyzed as strategies to increase cocoa productivity (Medauar et al., 2018; Santos et al., 2017).

Its fruit, called cocoa, grows directly from the tree trunk and weighs between 300 and 700 g, containing seeds covered by a bittersweet mucilage, white or reddish. One parent tree can yield up to 2 kg of seeds per year (Ascrizzi et al., 2017; Beg et al., 2017).

Cocoa almond is the raw product used for chocolate production, which involves a complex process, including fermentation (Brito et al., 2017). Commercial pulp, desserts, jams, juices, liquors, among other products, are produced from the cocoa pulp (Santos et al., 2014).

In the semiarid region of Brazil, cocoa production has been implemented in the Irrigated Perimeter of Tabuleiro de Russas, state of Ceará, in 2009, through a project of alternative farming with clones recommended by CEPLAC (CP 49, PS 13.19, PH 16, CEPEC 2002, CEPEC 2004, CEPEC 2005, CEPEC 2006, CCN 10 e CCN 51). These clones are disease resistant and have favorable agronomic traits (Brasil, 2017).

The insertion and improvement of clones in crops to solve problems such as low yield and pests (as witch's broom) (Menezes et al., 2016) generate fruits with differentiated traits, which can also influence the quality of their by-products.

Thus, this study aims to evaluate the physical, chemical, and physicochemical traits of the CCN 51, CEPEC 2004, CEPEC 2005, and PS 1319 clones produced in the region of Vale do Jaguaribe in the state of Ceará, Brazil, and to suggest food processes and products for their proper use.

Material and Methods

The project of implementing cocoa cultivation in the state of Ceará, which started in 2009, was developed by a partnership between the following institutions: Development Agency of the State of Ceará (Agência de Desenvolvimento do Estado do Ceará - ADECE); Executive Commission of the Cocoa Cultivation Plan (Comissão Executiva do Plano da Lavoura Cacaueira - CEPLAC, BA); Vale do Jaguaribe Agribusiness Union (União dos Agronegócios no Vale do Jaguaribe - UNIVALE); and Frutacor Farm. This partnership is intended to verify the adaptation of this cultivation in the semiarid environment of the Irrigated Perimeter of Tabuleiro de Russas in the state of Ceará.

The fruits from the CCN 51, CEPEC 2004, CEPEC 2005, and PS 1319 clones were harvested in an orchard located in the municipality of Russas, Ceará, between August and November 2018 (latitude 5° 37' 20" S; longitude 38° 07' 08" W; and 81.50 m height above sea level). The crop was installed in 2010, intercropped with banana during the first three months, employing *Spondias cythera* and *Casuarina* sp as windbreaks. The crop area has a drip irrigation system, with 4.0 x 2.0 m spacing in double rows and a density of 1.250 plants per ha^{-1}, totalizing 4.0 ha.

Initially, the fruits underwent a selection inside the field to discard fruits with the following conditions: immature, deficient, affected by a pest, and/or in an advanced maturation stage. Ten fruits of each clone were collected, totalizing 40 fruits.

The total mass of fruit (TMF), fruit longitudinal diameter (FLD), fruit transverse diameter (FTD), and the FLD/FTD ratio were evaluated. Also, rind thickness was analyzed, being made two measurements: one on the thickness in the central region of the internal rind (IRT), and another on the central region of the external rind (ERT); and ERT/IRT. Rind total mass (RMS) and total mass of pulp (PMS) were also analyzed. About the seeds, the total number of seeds (NTS); total mass of seeds (TMS); seed thickness (ST); seed transverse diameter (STD), seed longitudinal diameter (DLS); and the STD/DLS ratio were evaluated. The total mass of the placenta (PTM), pulp+seed mass (PSM), and pulp yield (PY) were also assessed.

The color of the pulp and of the ground seeds was determined using the digital colorimeter miniScan EZ HunterLab®. The measurement of the coordinates L*, a*, and b* were conducted by using the CIELAB system, where L* represents luminosity, which varies from black to white, a* represents the red/green spectrum (positive - red color; negative - green color), and b* indicates the yellow/blue spectrum (positive - yellow color; negative - blue color). Chroma value (C*), which represents color purity, and hue angle (h*), which represents color tonality, were obtained through mathematical calculations (McGuire, 1992).

The pulp and the ground seeds' centesimal composition was determined following the methodology described by AOAC (2000). This methodology consists of the following analyses: moisture (%) by gravimetry in an oven at 105 °C; total lipids (%), using the Bligh-Dyer method; crude protein (%), using Kjeldahl method with a conversion factor of 6.25; ashes (%) by calcination at 550 °C during 6 hours in a muffle furnace. Crude fiber (%) was determined by acid and basic hydrolysis using a fiber analyzer. The percentage of carbohydrates was obtained by calculating the macronutrients - humidity (%), total lipids (%), crude protein (%), ashes (%), and crude fiber (%), subtracting them from 100.

For the physicochemical evaluation, the following variables were determined: titratable acidity (% of citric acid) by volumetric titration with NaOH 0,1M, using the indicator phenolphthalein 1% to verify the turning point (AOAC, 2000); pH by potentiometry using a Hanna Instruments® digital pH meter, previously calibrated with buffer solutions of pH 4.0 and 7.0; soluble solids (°Brix) through the measurement in an Abbe Refractometer Optronics® digital refractometer; and reducing sugars through a measure at 540 nm in a Femto 600 plμs® spectrophotometer using the 3.5-dinitrosalicylic (DNS) acid method with a 1% standard glycose curve (Miller, 1959).

The results were submitted to variance analysis, and the means were compared among them through the Tukey test at $p \leq 0.05$, with the aid of the software Statistica® version 7.

Results and Discussion

Based on the results of total mass, fruit longitudinal and transverse diameter (Table 1), the clone CCN 51 presented the greatest fruits with more mass, standing out from the other clones tested.

Moreira (2017), while evaluating the total mass of fruit of the CCN 51, CEPEC 2004, CEPEC 2005, and PS 1319 clones collected at Frutacor Farm, municipality of Russas, Ceará - observed higher mean values for the clone PS 1319 (477,92 g). In contrast, this research found that the fruits of this same clone presented lower mass (385 g). In the present study, the clone was collected in the harvest season, while Moreira (2017) collected earlier, the higher number of fruits in the plant may have affected the size of the fruit.

Moreira et al. (2018) also found results differing from the present study for the CEPEC 2004 clone, collected in the main harvest of 2013 in the state of Bahia, Brazil, in the variables fruit longitudinal diameter (22.0 ± 2.0 cm) and fruit transverse diameter (11.0 ± 0.3 cm).

The values of the ratio between longitudinal and transverse diameters show that the CCN 51 and CEPEC 2004 clones have fruits with a more oblong trait, while the fruits of the CEPEC 2005 and PS 1319 clones are more oval. Similar results were obtained by Alexandre et al. (2015), which, while studying the CCN 51 and PS 1319 clones, found mean values of 2.40 and 1.80, respectively.

Rind total mass was higher in the fruits of the CCN 51 and CEPEC 2004 clones, as well as the ratio between external and internal rind thickness (Table 2).

Rind thickness is an attribute associated with resistance to pathogens. According to Nyadanu et al. (2011), cocoa genotypes with thicker rind tend to be more resistant to infections caused by *Phytophthora palmivora* than those with thinner rind. This pathogen affects the waxy cuticle and attacks the fruit epidermis (Vanegtern et al., 2015), being the agent of brown rot in cocoa trees. For many years, this disease caused losses in the production of the south region of the state of Bahia (Oliveira & Luz, 2005).

The rind is the most generated residue in the processing of cocoa. Approximately six tons of fresh rind resultant from the smashing of fruits are generated annually in each hectare of cocoa cultivation. It is possible to recycle these rinds as a source of potassium in the production of cocoa seedlings (Sodré et al., 2012), as well as an ingredient in animal nutrition and a source of alkali to produce soap and fertilizers (Oddoye et al., 2013).

The fruits of all clones studied did not differ statistically concerning the number of seeds, although the mass of seeds of the CCN 51 clone was higher (Table 3). The seeds from the PS 1319 clone were flatter and more oblong in shape compared to the others.

The number and mass of seeds are criteria that must be considered when considering a clone for fermentation. A fruit with a higher amount of seeds will result in more fermented almonds with fewer fruits. Thus, the harvest and the smash of the fruits will be easier since the time needed for this stage will be reduced, as there are fewer fruits to manage.

According to CEPLAC (2019) data, the CEPEC 2004 and CEPEC 2005 clones have a mean of 49 and 32 seeds per fruit, respectively. This study verified that CEPEC 2004 produces a higher number of seeds than CEPEC 2005, supporting the author's results. Ramos et al. (2014) found similar values for the PS 1319 clone in the variable seed number (48 ± 4) during the 2012 season in the state of Bahia, Brazil.

Table 1. Mean and standard deviation of mass (TMF), longitudinal diameter (FLD), transverse diameter (FTD), and the diametral ratio (FLD/FTD) of cocoa fruits of four clones produced in the region of Vale do Jaguaribe, Ceará, Brazil

Clones	TMF (g)	FLD (cm)	FTD (cm)	FLD/FTD
CCN 51	675.50 a ± 111.71	20.25 a ± 1.83	8.79 a ± 0.57	2.31 a ± 0.17
CEPEC 2004	485.00 b ± 145.16	17.49 b ± 2.47	7.90 b ± 0.39	2.21 ab ± 0.24
CEPEC 2005	443.50 b ± 65.19	15.57 b ± 1.37	7.70 b ± 0.46	2.03 b ± 0.22
PS 1319	385.66 b ± 70.57	15.53 b ± 1.58	7.76 b ± 0.49	2.00 b ± 0.13

Means followed by same letters in the column do not differ among them according to the Tukey test (p ≤ 0,05)

Table 2. Mean and standard deviation of rind mass (RMS), external rind thickness (ERT), internal rind thickness (IRT), and the ERT/IRT ratio of cocoa fruits of four clones produced in the region of Vale do Jaguaribe, Ceará, Brazil

Clones	RMS (g)	ERT (cm)	IRT (cm)	ERT/IRT
CCN 51	475.50 a ± 78.05	1.18 a ± 0.15	0.39 b ± 0.09	3.19 a ± 0.98
CEPEC 2004	375.00 ab ± 129.94	1.11 a ± 0.15	0.40 b ± 0.07	2.87 a ± 0.62
CEPEC 2005	327.51 bc ± 51.58	0.81 b ± 0.07	0.49 a ± 0.08	1.68 b ± 0.24
PS 1319	258.44 c ± 53.69	0.71 b ± 0.09	0.40 ab ± 0.07	1.77 b ± 0.16

Means followed by same letters in the column do not differ among them according to the Tukey test (p ≤ 0,05)

Table 3. Mean and standard deviation of the number of seeds (NTS), the mass of seeds (TMS), seed thickness (ST), seed longitudinal diameter (SLD), seed transverse diameter (STD), and the SLD/STD ratio of cocoa fruits of four clones produced in the region of Vale do Jaguaribe, Ceará, Brazil

Clones	NTS	TMS (g)	ST (cm)	SLD (cm)	STD (cm)	SLD/STD
CCN 51	45.60 a ± 6.69	107.00 a ± 22.87	0.96 a ± 0.12	2.67 a ± 0.18	1.28 a ± 0.10	2.09 ab ± 0.20
CEPEC 2004	41.10 a ± 9.89	71.30 b ± 17.86	1.00 a ± 0.12	2.66 a ± 0.43	1.38 a ± 0.07	1.93 bc ± 0.25
CEPEC 2005	39.40 a ± 5.56	54.89 b ± 9.72	0.96 a ± 0.08	2.34 ab ± 0.19	1.30 a ± 0.08	1.81 c ± 0.22
PS 1319	45.10 a ± 2.28	60.27 b ± 13.88	0.82 a ± 0.07	2.37 b ±0.11	1.09 b ± 0.08	2.18 a ± 0.12

Means followed by same letters in the column do not differ among them according to the Tukey test (p ≤ 0,05)

Table 4. Mean and standard deviation of pulp+seed mass (PSM), pulp mass (PMS), the mass of placenta (PTM), and pulp yield (PY) of cocoa fruits of four clones produced in the region of Vale do Jaguaribe, Ceará, Brazil

Clones	PSM	PMS	PTM	PY
		(g)		(%)
CCN 51	167.00 a ± 39.03	21.50 a ± 11.32	21.50 a ± 4.74	3.13 b ± 1.24
CEPEC 2004	105.95 b ± 29.09	15.39 a ± 8.37	10.53 c ± 3.43	3.13 b ± 1.56
CEPEC 2005	85.19 b ± 16.65	11.65 a ± 4.36	13.42 bc ± 2.90	2.64 b ± 0.92
PS 1319	104.36 b ± 17.75	19.04 a ± 7.40	15.22 b ± 3.76	4.89 a ± 1.55

Means followed by same letters in the column do not differ among them according to the Tukey test (p ≤ 0,05)

It was observed that the CCN 51 clone has a higher seed+pulp, pulp, and placenta masses (Table 4). The placenta is the part that sticks the seeds together inside the cocoa fruit and is separated during the fermentation process (D'Souza et al., 2018). However, the placenta can be used for the elaboration of other food products.

The higher pulp yield (4.89%) was observed in the PS 1319 clone, differing statistically from the others. Pulp yield is an important trait for farmers whose goal is pulp production, and, as verified in this study, the PS 1319 is the more indicated clone for this industry. The cocoa pulp can be used to produce juices, sodas, citric acid, vinegar, cocoa jam, and in the alcohol industry (Oddoye et al., 2013).

Pulp yield also is important for the cocoa fermentation process, as it contains compounds such as glucose, fructose, and citric acid. These compounds are extracted in the initial stages of fermentation, especially the sugars for ethanol production (Batista et al., 2015). Thus, it is worth mentioning that the PS 1319 clone also is indicated for the cocoa fermentation process.

There was no significant difference between the cocoa pulps of the clones studied (p > 0.05) in all variables determined by instrumental colorimetry (Table 5).

Coordinate L* comprehends the range between 0 and 100, being the values closer to 0 darker and closer to 100, lighter. For this coordinate, the pulps presented results varying between 59.82 and 75.32, that is, with a tendency to lighter colorations.

The value C* found infers that the pulp does not have a strong and bright color since the result is closer to the coordinates' origin (17.59 - 19.73°). The Hue* angle is situated between 69.33 and 81.26°, demonstrating that the pulp is yellower, as it is close to the 90° angle.

The luminosity of cocoa seeds is closer to zero, indicating that they have a darker coloration. The CEPEC 2005 clone presented the higher mean of luminosity, differing statistically (p ≤ 0.05) from the other samples, being thus darker (Table 6).

The values of C* and Hue* angle found in cocoa seeds of the CEPEC 2005 clone were the highest, differing statistically from the others, presenting a stronger and brighter tonality with an orangish coloration.

There was no significant difference among the clones in the variables total lipids and crude protein (Table 7). Similar results were presented by Brasil (2015), which observed values of 1.0; 0.1; 19.4% for crude protein, total lipids, and carbohydrates, respectively.

Moreira (2017), while evaluating the centesimal composition of cocoa pulps of the CEPEC 2004, CEPEC 2005, CCN 51, and PS 1319 clones, found more elevated lipid values for all the clones (0.86 a 1.28%) and similar values of protein (1.22 a 1.41%); except in the CEPEC 2005 clone, which was lower (0.95%). For humidity and ashes, the author found higher values for all clones than this study.

About the centesimal composition of cocoa seeds (Table 7), it was observed that the PS1319 clone presented a higher value of humidity. It was also noticed that the CEPEC 2005 clone showed a higher concentration of lipids, protein, fiber, and energy value.

Table 5. Instrumental color (CIE Lab) of cocoa pulps of four clones produced in the region of Vale do Jaguaribe, Ceará, Brazil

Clones	L*	C*	H*
CCN 51	66.18 a ± 4.55	19.73 a ± 0.97	76.54 a ± 6.88
CEPEC 2004	75.32 a ± 1.40	17.59 a ± 0.87	81.26 a ± 0.58
CEPEC 2005	59.82 a ± 18.20	19.37 a ± 2.44	79.11 a ± 2.64
PS 1319	63.25 a ± 0.67	18.68 a ± 1.71	69.33 a ± 6.60

Means followed by same letters in the column do not differ among them according to the Tukey test (p ≤ 0,05)

Table 6. Instrumental color (CIE Lab) of cocoa ground seeds of fours clones produced in the region of Vale do Jaguaribe, Ceará, Brazil

Clones	L*	C*	H*
CCN 51	26.46 b ± 0.85	22.27 c ± 0.66	52.24 c ± 0.19
CEPEC 2004	26.33 b ± 0.95	26.29 b ± 0.29	54.38 b ± 0.41
CEPEC 2005	34.93 a ± 1.14	34.25 a ± 2.23	58.17 a ± 0.41
PS 1319	24.04 b ± 1.17	26.96 b ± 1.03	54.88 b ± 1.02

Means followed by same letters in the column do not differ among them according to the Tukey test (p ≤ 0,05)

Table 7. Centesimal composition and energy value of cocoa pulps of four clones produced in the region of Vale do Jaguaribe, Ceará, Brazil

	Clones	Moisture	Total lipids	Crude protein	Ashes	Crude fiber	Carbohydrates	Energetic value
				(%)				(kcal 100g^{-1})
Pulp	CCN 51	77.33 b ± 1.35	0.18 a ± 0.02	1.38 a ± 0.69	0.36 b ± 0.08	0.00 b ± 0.00	20.74 a ± 0.78	90.14 a ± 5.62
	CEPEC 2004	79.73 b ± 0.72	0.19 a ± 0.02	1.56 a ± 0.45	0.20 c ± 0.02	0.00 b ± 0.00	18.31 b ± 0.30	81.22 a ± 2.93
	CEPEC 2005	79.65 b ± 0.64	0.16 a ± 0.01	1.34 a ± 0.17	0.29 bc ± 0.06	0.00 b ± 0.00	18.56 b ± 0.73	81.25 a ± 1.72
	PS 1319	83.90 a ± 0.28	0.15 a ± 0.03	1.10 a ± 0.10	0.57 a ± 0.05	0.62 a ± 0.01	13.74 c ± 0.01	60.32 b ± 1.13
Seed	CCN 51	43.33 b ± 1.95	5.46 a ± 0.71	9.56 a ± 0.70	2.15 a± 0.04	25.01 a ± 2.32	14.49 a ± 3.37	145.31 ab ± 13.38
	CEPEC 2004	42.90 b ± 1.73	3.81 ab ± 0.85	9.59 a ± 0.75	2.21 a ± 0.07	26.04 a ± 0.65	15.45 a ± 2.52	134.48 ab ± 5.59
	CEPEC 2005	38.80 b ± 2.26	5.83 a ± 0.34	10.21a ± 0.00	1.95 b ± 0.03	27.71 a ± 0.45	15.49 a ± 2.40	150.47 a ± 12.24
	PS 1319	57.45 a ± 0.78	2.16 b ± 0.00	5.46 b ± 0.14	1.91 b ± 0.08	12.52 b ± 0.25	20.49 a ± 1.25	118.03 b ± 3.01

Means followed by same letters in the column do not differ among them according to the Tukey test (p ≤ 0,05)

Table 8. Physicochemical characterization of cocoa pulps of four clones produced in the region of Vale do Jaguaribe, CE, Brazil

Clones	Titratable acidity (%citric acid)	pH	Soluble solids (ºBrix)	Reducing sugars (% glucose)
CCN 51	0.98 a ± 0.38	3.91 b ± 0.01	14.60 a ± 0.87	19.91 b ± 0.29
CEPEC 2004	0.56 b ± 1.56	3.89 b ± 0.03	11.80 bc ± 1.51	18.82 c ± 0.03
CEPEC 2005	0.96 a ± 0.86	3.78 c ± 0.04	12.90 ab ± 1.04	23.17 a ± 0.48
PS 1319	0.36 b ± 0.26	4.33 a ± 0.06	10.20 c ± 0.30	14.83 d ± 0.51

Means followed by same letters in the column do not differ among them according to the Tukey test ($p \leq 0.05$)

Lipids present in the seed represent cocoa butter employed in chocolate production (Efraim et al., 2011). The CEPEC 2005 clone is the most suitable for cocoa butter extraction by presenting a higher concentration of lipids.

The lipid concentration found in this study (2.16 to 5.83%) was lower than the values presented by Martini & Tavares (2005). A review study about the seed reserves of seven species of *Theobroma* relates that for the *T. cacao* species, the percentage of lipids must be between 19.5 and 56.0%. This discrepancy can be associated with the extraction methodology or the sample preparation, being inferred thus that the Bligh-Dyer method might not have been efficient for the extraction of lipids.

Comparing the energy values between pulp and seeds shows that the pulp has fewer calories since the amount of lipids, proteins, and carbohydrates are lower.

The clone CEPEC 2005 presented the more elevated titratable acidity when compared to the CEPEC 2004 and PS 1319 clones, as well as the lower pH and the highest concentration of reducing sugars (% glucose), differing statistically ($p \leq 0,05$) from the others (Table 8).

The Normative Instruction nº 01 of January 2000 establishes for cocoa pulp minimal limits of 14.0 ºBrix for soluble solids, 3.4 for pH, and 0.75 for titratable acidity (% citric acid) (Brasil, 2000). Thus, only the cocoa pulp of the CCN 51 clone agrees with the current Brazilian instruction since it presented all results higher than the limits recommended. Hence, this pulp can be commercialized.

In contrast, the CEPEC 2004 and PS 1319 clones are out of the standards for soluble solids and titratable acidity, and CEPEC 2005 for soluble solids, as they presented values lower than prescribed by the instruction. According to Lima et al. (2011), the cultivar and the cocoa tree genotype are factors that influence the attributes of cocoa quality.

Alexandre et al. (2015), when analyzing cocoa clones in the municipality of São Mateus, state of Espírito Santo, Brazil - found similar values for the variables soluble solids and pH for the CCN 51 clone, which obtained 15,05 ºBrix and 3.24, respectively. For the PS 1319 clone, they found a lower titratable acidity and pH but a higher concentration of soluble solids than in this study.

Titratable acidity and sugar concentration in the pulp are fundamental to stimulate growth and yeast activity in the first phase of the cocoa fermentation process (Pereira et al., 2017). The CCN 51 and CEPEC 2005 clones are the most indicated for the cocoa fermentation process, as they have higher titratable acidity and higher sugar content, besides having a higher concentration of lipids, which generates more cocoa butter. In the case of CEPEC 2005, it must be combined with another clone (PS 1319) to compensate for pulp yield, which is low. Thus, a combination of the CCN 51, CEPEC 2005, and PS 1319 clones is suitable for the cocoa fermentation process.

For the dessert industry, the CCN 51 clone is the most suitable because it presented a higher concentration of soluble solids. For jam production, the CEPEC 2005 clone is the most suitable because it showed the lowest pH. For pulp elaboration, PS 1319 is the most adequate by presenting the highest percentage of pulp yield. The CEPEC 2004 clone can be indicated to produce nibs, destined for fat-restricted diets, as it contains the lower concentration of lipids.

Conclusions

1. The CCN 51 clone presented heavier fruits with higher rind mass, a higher ratio between the rind thickness in its thickest part and the rind thickness in the furrow, as well as a higher number of seeds per fruit.

2. The fruits from the CCN 51 and CEPEC 2004 clones are more oblong, and the fruits from the CEPEC 2005 and PS 1319 clones are more oval. The PS 1319 clone presented the highest pulp yield, with a yellower pulp and orangish seed.

3. The pulp of the clones evaluated have a lower energy value than the seeds. The CEPEC 2005 clone contains the highest concentration of sugar and the lowest pH.

4. The CCN 51 and CEPEC 2005 clones are the most suitable for the cocoa fermentation process. For desserts, jams, pulp, and cocoa nibs, the CCN 51, CEPEC 2005, PS 1319, and CEPEC 2004 clones are the most indicated, respectively.

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