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

Bianca M. Reges, Anielly M. Maia, Diogenes H. A. Sarmento, Mayara S. Silva, Sandra M. L. dos Santos & Marlene N. Damaceno

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

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.
**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 (Medaur 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 Plant (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, totaling 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, totaling 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 (ºBrix) through the measurement in an Abbe Refractometer Optronics® digital refractometer; and reducing sugars through a measure at 540 nm in a Femto 600 plus® spectrophotometer using the 3.5-dinitrosalicylic (DNS) acid method with a 1% standard glycoside curve (Miller, 1959).

The results were submitted to variance analysis, and the means were compared among them through the Tukey test at p ≤ 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 (Vanegotn 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 same 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 b ± 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   | 256.44 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 same 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 b ± 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 | 2.10 a ± 0.12 |

Means followed by same letters in the same 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 - 17.93º). The Hue* angle is situated between 69.33 and 81.26º, demonstrating that the pulp is yellower, as it is close to the 90º 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 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 (g) | PMS (g) | PTM (g) | PY (%) |
|-----------|---------|---------|---------|--------|
| CCN 51    | 167.00 ± 39.03 | 21.50 ± 11.32 | 21.50 ± 4.74 | 3.13 ± 1.24 |
| CEPEC 2004| 105.95 ± 29.09 | 15.39 ± 8.37  | 10.53 c ± 3.43 | 3.13 ± 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 ± 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)

### Table 5. Instrumental color (CIE Lab) of cocoa ground seeds 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| 58.82 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. 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) |
|-----------|----------|--------------|---------------|-------|-------------|---------------|-----------------------------|
| 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 |

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) |
|-----------|----------|--------------|---------------|-------|-------------|---------------|-----------------------------|
| CCN 51    | 43.33 b ± 1.95 | 5.46 a ± 0.71 | 1.95 b ± 0.03 | 27.71 a ± 0.45 | 20.71 a ± 0.80 | 15.40 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 | 19.91 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)
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 ≤ 0,05) from the others (Table 8).

The Normative Instruction nº 01 of January 2000 establishes for cocoa pulp minimal limits of 14.0 °Brix 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 °Brix 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 2005 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.

## Acknowledgements

The authors acknowledge the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES, the Fundação Cearense de Desenvolvimento Científico e Tecnológico - FUNCAP, the Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq, and the Instituto Federal de Educaçã, Ciência e Tecnologia do Ceará - IFCE for their financial support. The authors also individually thank CAPES (first author), CNPq (second author) and CAPES / PNPD (fifth author) for the scholarships granted.

## Literature Cited

Alexandre, R. S.; Chagas, K.; Marques, H. I. P.; Costa, P. R.; Cardoso Filho, J. Caracterização de frutos de clones de cacaueres na região litorânea de São Mateus, ES. Revista Brasileira de Engenharia Agrícola e Ambiental, v.19, p.785-790, 2015. https://doi.org/10.1590/1807-1929/agriambi.v19n3p785-790

AOAC - Association of Official Analytical Chemists. Official methods of analysis of association of official analytical chemists. 17.ed. Washington: AOAC, 2000. 1080p.
Theobroma cacao L.

Features of the raw seed to chocolate: Volatile profile of Blanco de Criollo in different phases of the processing chain. Microchemical Journal, v.133, p.474-479, 2017. https://doi.org/10.1016/j.microc.2017.04.024

Batista, N. N.; Ramos, C. L.; Ribeiro, D. D.; Pinheiro, A. C. M.; Schwam, R. F. Dynamic behavior of Saccharomyces cerevisiae, Pichia kluyveri and Hanseniaspora uvarum during spontaneous and inoculated cocoa fermentations and their effect on sensory characteristics of chocolate. IWT - Food Science and Technology, v.63, p.221-227, 2015. https://doi.org/10.1016/j.iwt.2015.03.051

Beg, M. S.; Ahmad, S.; Jan, K.; Bashir, K. Status, supply chain and instability of raw cocoa beans are affected by fermentation. Food Chemistry, v.228, p.484-490, 2017. https://doi.org/10.1016/j.foodchem.2017.06.007

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Cultivo de cacau orgânico. Salvador: Serviço Brasileiro de Pesquisa Agropecuária, 2012. 490 p.

Ullrich, M. S.; Kuhnert, N. Degradation of cocoa proteins into reducing sugar. Analytical Chemistry, v.31, p.426-428, 1959. https://doi.org/10.1021/ac60147a030

Moreira, L. F. Characterization of the polpa of fruits of genotypes of cacao (Theobroma cacao L.) produced in the vale of Jaguaribe - Ceará. Limeiro do Norte: IFCE, 2017. 70p. Dissertação Mestrado

Oddoye, E. O. K.; Agyentu-Badu, K. C.; Gyedu-Akoto, E. Cocoa and its by-products: Identification and utilization. In: Watson, R. R.; Preedy, V. R.; Zádari, S. Chocolate in health and nutrition. Totowa: Humana Press, 2013. Chapter 3. p.23-37. https://doi.org/10.1007/978-1-61779-803-0_3

Martini, M. H.; Tavares, D. de Q. Reservas das sementes de sete espécies de Theobroma: revisão. Revista Instituto Adolfo Lutz, v.64, p.10-19, 2005.

McGuire, R. G. Reporting of objective color measurements. HortScience, v.27, p.1254-1255, 1992. https://doi.org/10.21273/HORTSCI.27.12.1254

Medauro, C. C.; Galvão, Í. M.; Carvalho, L. C. C.; Silva, S. de A. Spatial-temporal variability of leaf chlorophyll and its relationship with cocoa yield. Revista Brasileira de Engenharia Agrícola e Ambiental, v.22, p.164-169, 2018. https://doi.org/10.1590/1807-1929/agriambi.v22n3p164-169

Menezes, A. G. T.; Batista, N. N.; Ramos, C. L.; Silva, A. R. de A. e; Efraim, P.; Pinheiro, A. C. M.; Schwam, R. F. Investigation of chocolate produced from four different Brazilian varieties of cocoa (Theobroma cacao L.) inoculated with Saccharomyces cerevisiae. Food Research International, v.81, p.83-90, 2016. https://doi.org/10.1016/j.foores.2015.12.036

Miller, G. L. Use of dinitrosalicylic acid reagent for determination of reducing sugar. Analytical Chemistry, v.31, p.426-428, 1959. https://doi.org/10.1021/ac60147a030

Moreira, L. F. Caracterização da polpa dos frutos de genótipos de cacau (Theobroma cacao L.) produzidos no vale do Jaguaribe - Ceará. Limeiro do Norte: IFCE, 2017. 70p. Dissertação Mestrado

Nyadnanu, D.; Assuah, M. K.; Adomako, B.; Asiama, Y. O.; Adu-Amponsah, Y. Thickness of the cocoa pod husk and its moisture content as resistance factors to Phytophthora pod rot. International Journal of Agricultural Research, v. 6, p. 310-322, 2011. https://doi.org/10.1923/j.ijar.2011.310.322

Oliveira, M. L. de; Luz, E. D. M. N. Identificação e manejo das principais doenças do cacau no Brasil. Ilhéus: CEPLAC/CEPEC/SEFIT, 2005. 132p.

Pereira, G. V. de M.; Alvarez, J. P.; Carvalho Neto, D. P. de; Soccol, V. T.; Tanobe, V. O. A.; Roger, H.; Goês-Neto, A.; Soccol, C. R. Great intraspecies diversity of Pichia kudriavzevii in cocoa fermentation highlights the importance of yeast strain selection for flavor modulation of cocoa beans. IWT - Food Science and Technology, v.84, p.290-297, 2017. https://doi.org/10.1016/j.lwt.2017.05.073

Ramos, C. L.; Dias, D. R.; Miguel, M. G. C. P.; Schwam, R. F. Impact of different cocoa hybrids (Theobroma cacao L.) and S. cerevisiae UFLA CA11 inoculation on microbial communities and volatile compounds of cocoa fermentation. Food Research International, v.64, p.908-918, 2014. https://doi.org/10.1016/j.foodres.2014.08.033

Santos, C. O. dos; Bispo, E. da S.; Santana, L. R. R.; Carvalho, R. D. S. de. Use of “cocoa honey” (Theobroma cacao L.) for diet jelly preparation: Alternative technology. Revista Brasileira de Fruticultura, v.36, p.640-648, 2014. https://doi.org/10.1590/0100-2945-042/13

Santos, R. O. dos; Franco, L. B.; Silva, S. A.; Sodré, G. A.; Menezes, A. A. Spatial variability of soil fertility and its relation with cocoa yield. Revista Brasileira de Engenharia Agrícola e Ambiental, v.21, p.88-93, 2017. https://doi.org/10.1590/1807-1929/agriambi.v21n2p88-93

Sodré, G. A.; Venturini, M. T.; Ribeiro, D. O.; Marrocos, P. C. L. Extrato da casca do fruto do cacau como fertilizante potássico no crescimento de mudas de cacau. Revista Brasileira de Fruticultura, v.34, p.881-887, 2012. https://doi.org/10.1590/S0100-29452012000300030

Vanegtern, B.; Rogers, M.; Nelson, S. Black pod rot of cacao caused by Phytophthora palmivora. College of Tropical Agriculture and Human Resources, v.108, p.2-5, 2015.