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Potential of the Jerivá Fruit (*Syagrus romanzoffiana* C.): Physicochemical and Bioactive Characterization

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ABSTRACT

Background: Jerivá is a native palm tree from Brazil, very abundant in the rural environment and widely observed in the urban area. Its fruits can be consumed in fresh and drink form. Despite this context there are few studies on the species, especially when portraying the nutritional value of its fruit. This research aims to investigate jerivá fruits in three ripening stages.

Methods: The fruits were harvested in a domestic orchard in Campos dos Goytacazes-RJ, in three ripening stages, according to the color: green (green peel), intermediate (yellowish green peel) and ripe (orange peel). The fruits were characterized in terms of physicochemical and bioactive composition.

Result: This fruit has a low source of ascorbic acid in all evaluated stages, but has high levels for yellow flavonoids and total extractable polyphenols when mature (23.07 mg/100 g and 596.95 mg GAE/100 g, respectively). Considering the relevance of this fruit species and the few researches at national level, it is necessary to evaluate the physicochemical and bioactive characteristics of the fruits of Jerivá, in order to quantify particularities regarding the detailed composition, guaranteeing its potential for use.

Key words: Bioactive compounds, Functional foods, Native fruits, Physicochemical, *Syagrus romanzoffiana* C.

INTRODUCTION

Among the species cultivated today, palm trees comprise a single family known as *Arecaceae*, consisting of about 252 genus and approximately 2600 species (Dransfield *et al.,* 2008). These species are widely distributed worldwide, occurring mainly in tropical areas (Svenning *et al.,* 2008; Kier *et al.,* 2005). In Brazil, there are approximately 36 genus and 195 native species, many of which are in serious danger of extinction due to the rapid destruction of theirs natural environments (Giulietti *et al.,* 2005).

Palm trees are of great socioeconomic, food and medicinal importance and are considered the third most important botanical family for humans. They stand out for the wide variety of products used by man such as vegetable oils and extracts, cosmetics (creams and soaps), home utensils such as brooms, pulp for sweets and ice cream, heart of palm, among other purposes (Johnson, 1998; Zambrana *et al.,* 2007; Bonomo and Capeletti, 2014).

Belonging to the *Arecaceae* family, jerivá (*Syagrus romanzoffiana* C.) is an important species of Brazilian flora (Lorenzi *et al.,* 2010). This species is endemic to South America, being well distributed in Brazil in the Northeast and South (Noblick, 2017) and still widely found in the Southeast. Its a palm tree that can reach up to 25 m in height, with inflorescence in hanging cluster and globose fruits with orange and meat pulp when ripe. The fruits have an oval shape. The outside, fleshy, is composed of a sweet mucilage, much appreciated by some animals as parrots or even consumed by man. Inside there is a small chestnut very similar to that of coco-da-baía. It blooms and fruits in different months of the year, depending on the region of occurence (Lorenzi *et al.,* 2010; Galetti *et al.,* 2013; Goudel *et al.,* 2013).

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The postharvest characterization of plant species is important since the identification of genetic materials with promising quality characteristics are acceptable attributes for the commercialization and use of edible portions such as pulp in the elaboration of industrialized and high added value products. Among these attributes stand out the color, texture, flavor, aroma, among others (Chitarra and Chitarra, 2005).

Recent studies have shown that fruits are rich in many bioactive compounds and have high antioxidant capacity and that these chemical components are mostly concentrated in the pulps, peels and seeds of these species (Albuquerque *et al.,* 2016; Vinita and Punia, 2016; Rydlewski *et al.,* 2017; Souza *et al.,* 2018, Stafussa *et al.,* 2018; Bala and Barmanray, 2019; Loizzo *et al.,* 2019; Ribeiro *et al.,* 2019; Ousaaid *et al.,* 2020). Several authors have also associated the beneficial effects on human health of regular consumption of fruits, vegetables and grains with the presence of substances as antioxidant potential, such as

phenolic compounds, vitamin C and E and carotenoids (Rababah *et al.,* 2004; Kim *et al.,* 2007; Schreckinger *et al.,* 2010; Donno *et al.,* 2013; Albuquerque *et al.,* 2016; Loizzo *et al.,* 2019).

Although jerivá fruits show good acceptance in the consumer market due to their attractive sensory characteristics, studies involving their detailed physicochemical and bioactive characterization are scarce, so this characterization is necessary to have previous knowledge of the potential of utilization and value addition of the fruit. Therefore, the knowledge of the physiological development of the fruit, as well as the ideal harvest is fundamental. The present work aimed to characterize jerivá fruits in three ripening stages from Campos dos Goytacazes-RJ.

MATERIALS AND METHODS

Jerivá fruits were harvested from plants in domestic orchards in 2018, located in Campos dos Goytacazes, RJ, located at approximately 11 m altitude, presenting as geographic coordinates 21°18′47″ south latitude and 41°18′24″ west longitude of the Greenwich meridian. According to Köppen classification, the climate of this region is Aw' type, characterized as humid tropical, with average rainfall of 1087 mm, minimum and maximum temperatures of 20 and 26°C, respectively. The fruits were harvested directly in the canopy of the plant, taking as the harvest index the color, divided into three ripening stages, according to the color: green (green peel), intermediate (yellowish green peel) and ripe (orange peel) (Fig 1). Subsequently, they were taken to the Food Processing Laboratory at Darcy Ribeiro North Fluminense State University, Campos dos Goytacazes, RJ, where they were previously selected and separated for the absence of physical damage and washed in running water. Shortly thereafter, the fruits were sanitized by immersion in 1% sodium hypochlorite solution for 15 minutes for further analysis.

For the physical evaluations were used 20 fruits for each stage of maturation, being each fruit considered a repetition, these were evaluated as: Fresh mass (g) of the fruit, that was obtained using semi-analytical balance; longitudinal and transverse diameter (mm) and longitudinal and transverse diameter (DL/DT) ratio, determined with the aid of a manual caliper and pulp yield and of the fruit constituent parts (%). The coloring was measured by reflectance using a Minolta CR-300 model colorimeter with D 65 light source with 8 mm aperture in standard C. I. E (Commission Internacionale de L'Eclaraige). For the objective characterization of color the CIELAB system (L*a*b*) was used. The values of L* (clarity), a* (green-red components) and b* (blue-yellow) were obtained directly from the colorimeter and used to calculate the color tone (H*=arctan b*/a*). For H*, 0 represents pure red; 90 is pure yellow, 180 is pure green and 265 is pure blue (Mcguire, 1992).

For the physicochemical evaluations, the peel was removed and the pulping of the fruits in the three ripening stages, establishing three repetitions for each ripening stage. Then, both edible portions of pulp and rind were homogenized in a blender and filtered in a domestic juicer and the analyzes were carried out.

Soluble solids contents were determined using digital refractometer model DRBS-300 and the results expressed as °Brix (AOAC, 2016). To determine the titratable acidity, the sample was titrated with 0.1 N of NaOH solution and the results in % citric acid (AOAC, 2016). The pH was determined using a digital potentiometer, model pH Meter w3b (AOAC, 2016). The relationship between soluble solids and titratable acidity (SS/AT) was also determined.

Total sugars were determined by the antrona method following the methodology described by Yemn and Willis (1954). The readings were taken in a spectrophotometer at 620 nm and the results expressed in %. The reducing sugars determined according to the methodology described by Miller (1959). The readings were taken in a spectrophotometer at 540 nm and the results expressed in %. Starch content was determined by the dinitrosalicylic acid (DNS) method (AOAC, 2016), with spectrophotometer reading at 540 nm and the results expressed in %.

For the bioactive compounds of the fruit, the following variables were analyzed: Ascorbic acid content by titration with DFI solution (2.6-dichloro-phenol-indophenol 0.02%) until slightly pink, according to Dinesh *et al.* (2015) and the results expressed in mg/100 g; Total carotenoids determined by the Higby (1962). The reading is taken on the spectrophotometer at 450 nm. Results were expressed in mg/100 g; Yellow flavonoids and total anthocyanins determined following Francis (1982) methodology. Spectrophotometer reading at 374 and 535nm for yellow flavonoids and total anthocyanins, respectively and the results were expressed in mg/100 g and total extractable polyphenols determined according to Larrauri *et al.* (1997). The reading was taken by spectrophotometer at a wavelength of 700 nm and the results expressed in mg/100 g.

Results were subjected to analysis of variance (ANOVA) and data averages were compared by Tukey test at 5% probability. The analyzes were performed by the computer program variance analysis system-SISVAR (Ferreira, 2014).

RESULTS AND DISCUSSION

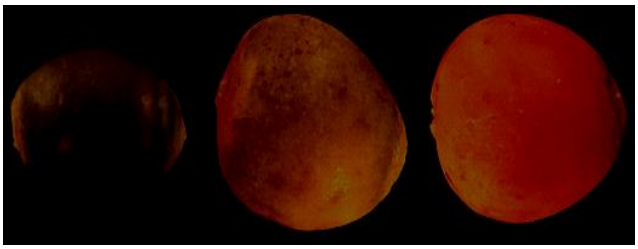
The fruits have an average fresh mass of 7.33 g and longitudinal and transverse lengths of 26.70 and 22.55 mm. Among the green, intermediate and ripe fruits, there was a significant difference for these variables, noting that the green fruits were physiologically developed, but still immature. Significant difference was observed for the variable DL/DT and fresh mass (%) between the maturation stages (Table 1).

The fruit of the jerivá is oval shaped, juicy, sweet and has a single almond per fruit. The peel of the fruit is a thin film, easily peeled off when the fruit is ripe. When green, it has green bark color and when ripe, the bark color turns orange. Considering the pulp, the color changes from white to orange as the fruit ripens. A characteristic aroma is also noticeable in ripe fruits. Commonly palm species present

individual variations for different characteristics such as pulp proportion, seed size and weight and these variations are attributed, among other aspects, to environmental factors including climatic conditions under which the plant develops, stage of fruit ripening and genetic variability. These parameters may constitute basic information that indicates fruit productivity and economic potential as a food resource or as a raw material in the manufacture of pharmaceutical products (Mhanhmad *et al.,* 2011; Goudel *et al.,* 2013). Thus for example, Goudel *et al.* (2013) working with biometric parameters of 400 jerivás fruits from 8 matrices located in Florianópolis, Brazil, determined values of longitudinal and transverse diameter of 21.69 mm and 19.66 mm, respectively, for a fruit mass of 5.61 g. The DL/DT ratio found in this study was 1.20, indicating that the fruit is oval in shape and very close to that obtained by Goudel *et al.* (2013) in his study with the fruit of jerivá. Fresh weight and length are important parameters of fruits quality. Chitarra and Chitarra (2005) reported that cell expansion and consequent weight gain can continue until fruits maturation, when they acquire harvest rates.

The yield of jerivá pulp averaged 20.36%, ranging from 18.71 to 20.31%, indicating the existence of selection for fruits with higher proportion of pulp, evidence of domestication. Comparing with *Mauritia flexuosa* L., whose fruits give rise to buriti, the proportion of pulp is much higher: 19.70% of pulp in jerivá versus 8.53% of usable pulp in buriti (Cândido and Silva, 2017). However, Goudel *et al.* (2013), working with jerivá fruits, found an average value of 59.29%, well above that of the study. Pulp yield is another factor paramount importance in economic exploration (Camilo *et al.,* 2014).

The coloration of the fruits used in the chemical analysis can be seen in Table 2. Cândido and Silva (2017), studied the color parameters of the buriti fruit in different biomes in Brazil and found significant differences in the analyzed parameters. In this study it was possible to observe that the luminosity of the fruits increased when it went from green fruit to intermediate maturation; However, as maturation progressed, the brightness decreased. For the L* luminosity index, there was a statistical difference between the ripening stages and the fruits with intermediate ripening presented the highest averages. Regarding the index a* and b*, there was a significant difference between the treatments. For index b*, the green fruits presented lower intensity of yellow



a) **b)** **c)**

Fig 1: Ripening stages of jerivá fruit: a) green; b) intermediate; c) mature.

Table 1: Results of the determination of the physical characteristics of jerivá fruits harvested in the green, intermediate and ripe maturation stages.

Stages	Physical characteristics				
	DL[1] (mm)	DT[2] (mm)	DL/DT[3]	MF[4] (g)	REND[5] (%)
Green	27.72±1.02[a]	18.88±0.87[c]	1.47±0.08[a]	5.94±0.47[c]	18.71±2.64[b]
Intermediate	26.28±1.04[b]	25.65±0.58[a]	1.02±0.04[c]	7.06±0.95[b]	22.08±2.54[a]
Ripe	26.11±1.06[b]	23.13±1.02[b]	1.13±0.24[b]	8.99±0.81[a]	20.31±2.61[b]
Average	26.70	22.55	1.20	7.33	20.36
CV (%)	3.92	4.00	6.00	10.10	11.33

Mean ± standard deviation; C.V. = Coefficient of variation; [1]DL = Longitudinal diameter; [2]DT = Transverse diameter; [3]DL/DT = Format index; [4]MF = Fresh mass; [5]REND = Pulp yield. Note: Averages followed by the same letter in the columns do not differ significantly by Tukey's test at 5% probability.

Table 2: Results of the colorimetric analysis of jerivá fruits for different maturation stages according to CieLab space.

Maturation stages	CieLab space parameters			
	L*	a*	b*	°Hue
Green	40.81±1.25[b]	-15.73±1.17[c]	24.90±2.08[c]	122.33±1.89[a]
Intermediate	55.69±3.43[a]	3.62±7.27[b]	46.94±6.37[b]	85.51±9.10[b]
Ripe	54.87±2.14[a]	22.47±0.90[a]	50.91±2.46[a]	66.14±1.24[c]
Average	50.46	3.45	40.91	91.33
CV (%)	5.07	128.06	9.37	6.04

Note: Averages followed by the same letter in the columns do not differ significantly by Tukey's test at 5% probability.

color than the intermediates. It can be observed that the index b* presented higher values than the index a*, demonstrating greater intensity of orange color, a positive characteristic for the fruit of jerivá, since today the market seeks fruits with color, more attractive to the consumer. For the °Hue index, the green fruits presented the highest values. Thus, the °Hue, indicative of shade, shows that intermediate fruits with a value of 85.51 °Hue were close to orange yellow, while ripe fruits with a value of 66.14 °Hue were close to orange. The color data confirm the difference in maturity stage between treatments (Fig 2).

There was a significant difference in soluble solids content, with ripe fruit presenting 83.41% more soluble solids when compared to green fruit (Table 3). This accumulation of soluble solids during the ripening process in most fruits is caused by starch degradation. Santos *et al.* (2017), evaluating the pulp quality characteristics of the fruits of five native palm trees of the Brazilian Amazon, found average values for soluble solids well above that of the mentioned study, which is in the order of 5.22 °Brix. Soluble solids content is an important measure for the evaluation of soluble fruit quality and is usually correlated with carbohydrate content and predominant organic acid content. Thus, this variable is of great interest for agroindustrial processing, considering consumers preference for raw materials with the best sweetness. According to Chitarra and Chitarra (2005), fruits when they reach maturity can increase only the soluble solids content due to the cell wall polysaccharide degradation or due to water loss.

According to the data in Table 3, jerivá pulp presented a mean pH value of 5.49, with no statistical difference between the maturation stages. Santos *et al.* (2017) evaluating the pulp pH of the fruits of five native palm trees of the Brazilian Amazon found average values below and above that of the study, whose average value was 5.49. There was no significant difference for titratable acidity between intermediate and ripe fruits, with average values of 0.17 and 0.14%, respectively (Table 3). Santos *et al.* (2017), studying this variable in the buriti fruit pulp, found an average value of 0.56%, which is much higher than that of the aforementioned study. The SS/AT ratio was high, with an average value of 34.98, because, despite the low soluble solids content in green fruits, the acidity of this fruit is low.

Table 3: Physicochemical characteristics of jerivá fruits harvested in the green, intermediate and ripe maturation stages.

Stages	Physicochemical characteristics						
	SS[1] (°Brix)	AT[2] (%)	SS/AT[3]	pH[4]	AST[5] (%)	AR[6] (%)	AMI[7] (%)
Green	1.63±0.06[c]	0.24±0.00[a]	6.95±0.3[c]	5.60±0.05[a]	0.71±0.04[c]	0.36±0.02[c]	0.57±0.01[a]
Intermediate	5.10±0.14[b]	0.17±0.00[b]	29.09±1.1[b]	5.60±0.05[a]	2.08±0.08[b]	0.85±0.03[b]	0.33±0.01[b]
Ripe	9.83±0.14[a]	0.14±0.00[b]	68.90±2.22[a]	5.28±2.39[a]	3.87±0.10[a]	1.43±0.04[a]	0.19±0.01[c]
Average	5.22	0.18	34.98	5.49	2.22	0.88	0.36
C.V. (%)	3.02	6.92	4.01	3.48	4.19	4.36	3.02

Mean ± standard deviation; C.V. = Coefficient of variation; [1]SS = Soluble solids; [2]AT = Titratable acidity; [3]SS/AT = Soluble solids/titratable acidity ratio; [4]pH = Hydrogen potential; [5]AST = Total soluble sugars; [6]AR = Reducing sugars; [7]AMI = Starch. Values followed by repeated letters in the same column do not differ by Tukey's test at the 5% probability level.

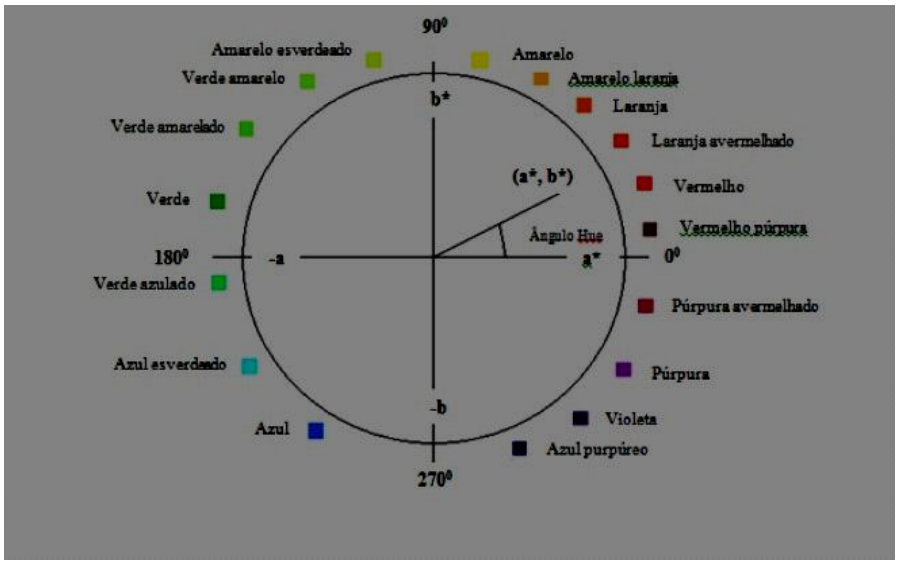


Fig 2: CIELAB diagram with °Hue color sequence and orientation. (Adapted from Chitarra and Chitarra, 2005).

In mature fruit, this ratio was higher than intermediate and green (Table 3). Santos *et al.* (2017), studying this variable in the peach palm fruit pulp, found an average value of 34.80, with the value in the same range as that of the study. It has also been observed that the green fruit has astringent taste, certainly due to the presence of tannins. According to Pereira *et al.* (2006) the SS/AT ratio of fruits is an indicator used to establish the harvest index of some fruits, indicating the sweetness of the fruits for selecting a better raw material, that is, the higher the SS/AT ratio, the sweeter the fruits.

The average soluble sugar content varied from 0.71 to 3.87% for green and mature stages, respectively. The latter stood out for presenting better total soluble sugar content among the evaluated (Table 3). Santos *et al.* (2017), observed levels of 3.58% of total soluble sugars in pulp of ripe bacaba fruits. For reducing sugars, the mature stage presented the highest average content (1.43%), while the green stage presented the lowest value (0.36%) (Table 3). Santos *et al.* (2017), studying this variable in the pulp of palm fruits native to the Brazilian Amazon observed different results. It is also noteworthy that the main sugars present in these palm species, in general, are glucose and fructose (AR) and sucrose (ANR). Reducing sugars contribute almost 100% of the total sugar content in the early stage of fruit development. However, sucrose can reach up to 50% of total sugars in the final maturation phase, with an approximate proportion of glucose (25%) and for fructose (25%) (Long *et al.,* 2004). Sugars are primary products of photosynthesis and it was previously thought that sugars were a fundamental compound correlated with fruit quality and flavor, which determine the caloric value of the fruit. Now, it has been proved that sugars are necessary for building up elements in the cell walls and energy sources in plants, which are used as precursors for aroma compounds and signaling molecules (Wind *et al.,* 2010; Halford *et al.,* 2011).

The results found for starch show that there are significant differences in the average levels of 0.57 to 0.19% for the green and mature stages (Table 3), respectively and superior results have been reported by Santos *et al.* (2017), who studied bacaba and tucumã fruits, found average values obtained for starch content of 8.59 and 10.49%, respectively. According to Kareem *et al.* (2017) the starch is one of the most important product of plant found in main storage organs of plant including roots/tubers, stem, seeds/grains and fruits as it is major source of calories in human diet.

The ascorbic acid content found in jerivá pulp can be considered low for the three ripening stages, between 7.36 and 12.57 mg/100 g of fresh pulp (Table 4). Santos *et al.* (2015), studying the levels of ascorbic acid in different palm species, found higher average levels than the one of the mentioned study. Vitamin C content in foods is also variable due to various factors such as growing region, temperature, light intensity, moisture content, harvesting time and the method of extracting and processing the pulp, which can greatly affect the concentration of ascorbic acid, even though the same variety is used (Rufino *et al.,* 2010).

When analyzing the total carotenoids, there was variation in the average levels between the stages from 0.48 to 1.07 mg/100 g for green and mature, respectively (Table 4). Mambrim and Barrera-Arellano (1997), characterizing palm fruits from the Amazon region, including bacaba and tucumã, found values for total carotenoids of 0.29 and 2.42 mg/100 g, respectively. Santos *et al.* (2015), studying the total carotenoid content in the flesh of the bacca fruit found an average value similar to that of the aforementioned study. It should be noted that the carotenoids content in fruits and vegetables depends on several factors such as: genetic variety, maturity stage, storage, processing and preparation (Capecka *et al.,* 2005). According to Davison *et al.* (1993), carotenoids, have received great attention for their antioxidant properties and their potential is related to reducing the risk of some diseases. Therefore, knowledge of the composition of carotenoids in species still little studied, such as these native palm trees, is fundamental for the appreciation of their potential as a nutraceutical and functional resource.

The mature stage presented the highest average levels for yellow flavonoids and anthocyanins (23.07 and 5.74 mg/100 g, respectively) (Table 4). Corrêa *et al.* (2019) studying bacabeira fruits from the State of Mato Grosso obtained total anthocyanin contents of 37.31 mg/100 g, much higher than the average value found in this study. Santos *et al.* (2015), studying the flesh of bacaba fruits found for yellow flavonoids a content of 36.00 mg/100 g, higher than what we obtained in this work. However, it is noteworthy that flavonoids and

Table 4: Bioactive compounds of jerivá fruits harvested in the green, intermediate and ripe ripening stages.

Stages	Bioactive compounds				
	AC[1] (mg/100 g)	CT[2] (mg/100 g)	FA[3] (mg/100 g)	ANT[4] (mg/100 g)	PET[5] (mg/100 g)
Green	12.57±0.94[a]	0.48±0.87[c]	15.09±0.08[c]	3.99±0.47[b]	163.11±2.64[c]
Intermediate	10.12±0.65[b]	0.67±0.58[b]	20.22±0.04[b]	4.44±0.95[b]	283.84±2.54[b]
Ripe	7.36±0.65[c]	1.07±1.02[a]	23.07±0.24[a]	5.74±0.81[a]	596.95±2.61[a]
Average	10.01	0.74	19.46	4.72	347.97
CV (%)	6.74	5.74	3.13	4.98	5.35

Mean ± standard deviation; C.V. = Coefficient of variation; [1]AC = Ascorbic acid; [2]CT = Total carotenoids; [3]FA = Yellow flavonoids; [4]ANT = Total anthocyanins; [5]PET = Total extractable polyphenols. Values followed by repeated letters in the same column do not differ by Tukey's test at the 5% probability level.

Table 5: Percentage constitution of jerivá fruit at different ripening stages.

Fruit parts	*Maturation stages (%)		
	Green	Intermediate	Ripe
Pulp	18.71±2.64	22.08±2.54	20.31±2.61
Peel	11.90±2.80	12.77±3.71	12.22±1.75
Seed	69.39±3.49	65.15±5.29	67.47±3.85

*Values determined based on the average of 20 fruits.

anthocyanins are a class of substances that occur naturally in fresh fruits and vegetables and because they are excellent compounds with antioxidant potential, their intake is necessary, even in small quantities. The various color nuances of the pulps produced lead us to believe that different concentrations of various flavonoid and anthocyanin types are present.

There was variation in the average levels of total extractable polyphenols (Table 4). The mature stage presented a numerically more expressive average content, standing out positively in relation to the green stage with 596.95 mg/100 g. Corrêa *et al.* (2019) studying bacabeira fruits from the state of Mato Grosso, reported an average value for total extractable polyphenols of 42.07 mg GAE/ 100 g. Santos *et al.* (2015), analyzing the content of total extractable polyphenols in native palm fritters of the Brazilian Amazon observed the most varied results. These discrepancies in the phenolic content results may be due to environmental characteristics, cultivation, genotype, fruit maturation stage, harvest time, among other factors.

Table 5 shows the percentages of the constituent parts of jerivá fruit. It can be observed that the pulp yield is not very high, since the seed represents average value of 67.33% at the three stages of maturation of the fruit.

CONCLUSION

The fruits with the best physical characteristics of fresh mass and longitudinal diameter, both for fresh consumption and for agroindustrial processing are ripe and green, with values of 8.99 g and 27.72 mm, respectively. For physicochemical properties, the stages showed great variability and the fruit in its mature stage presented the highest average values for SS/AT, soluble solids, reducing sugars and totals (68.90, 9.83°Brix, 1.43 and 3.87%, respectively).This fruit has a low source of ascorbic acid in all evaluated stages, but has high levels for total carotenoids, yellow flavonoids and total extractable polyphenols when mature (1.07, 23.07 and 596.95 mg/100 g, respectively).

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Authors' contribution

All authors had direct participation in the execution of the experimental, written and adequate review of the article.

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