Fruit quality and genetic diversity of *Spondias dulcis* accessions[1]

Pedro Henrique Magalhães de Souza[2], Victoria Azevedo Monteiro[2], Cláudia Dayane Marques Rodrigues[2], Francielly Rodrigues Gomes[3], João Alison Alves Oliveira[4], Danielle Fabíola Pereira da Silva[2]*

10.1590/0034-737X202269020008

ABSTRACT

Among the less exploited Brazilian native fruit trees, the *Spondias dulcis* (cajá-manga) has many uses, being their fruits appreciated in fresh consumption and its pulp used in popsicles, ice-creams, and jellies production. However, there is a lack of research on this species, being necessary more studies. This work aimed to characterize the physical and chemical quality and the genetic diversity of *Spondias dulcis* fruits harvested in different accessions in the municipality of Jataí – GO. The experiment was carried out in a completely randomized design with six treatments (accessions), ten replications with ten fruits per plot, totaling a sample of 600 fruits. The fruits were evaluated for pulp and peel color, pulp yield, soluble solids content, titratable acidity, soluble solids content/titratable acidity ratio, and vitamin C content. The fruits from accessions M4 and M5 presented physical and chemical characteristics higher than the other plants. The evaluated accessions presented genetic variability, being the methodology employed efficiently to indicate this variability, in which the accession M2 was the most divergent.

Keywords: cajá-manga; native fruit trees; multivariate analysis.

INTRODUCTION

Brazil has one of the worlds' greatest fructiferous biodiversity, in which the species from the *Anacardiaceae* Family such as mango, cashew fruit, ciriguela, and cajá-manga (*Spondias dulcis*) stand out (Moura *et al*., 2013; Vasconcelos *et al*., 2017). Among the less exploited commercial species, there are the fruits from the genus *Spondias*, which have the *S. dulcis* L. species, that are regionally known as cajá-manga, taperebá or cajarana and, in general, are exploited in an extractivist way in almost the entire Brazilian territory, especially across the regions North, Northeast and Midwest (Mitchell & Daly, 2015).

Despite the good acceptance by the consumers and of bringing benefits to human health, the *S. dulcis* fruit is not marketed on a large scale due to its high perishability and short postharvest shelf-life. The fruit sales occur only during the harvest seasons since these fruits come from extractivism in areas of the natural occurrence of the species, which can lead to their disappearance in the future (Lima *et al*., 2019). Furthermore, the plants are propagated by seeds which causes non-uniformity and long vegetative periods, this occurs because *S. dulcis* seeds have physical and physiological dormancy, features that are very undesirable for commercial crops (Martins *et al*., 2019).

The evaluation of the physical characteristics of fruits has great importance when it comes to the determination of the genetic variability of a species that can subsidize breeding programs, as well as its relationship with environmental factors (Nascimento *et al*., 2014). Genetic diversity is an important parameter evaluated by plant breeders in the initial phase of a breeding program. Several methods are available to evaluate it in plant populations, based on the ability to detect differences among genotypes, costs, ease of use, consistency, and replicability of results (Morales *et al*., 2011). The quantification of genetic diversity can be performed through agronomic, morphological, and molecular traits (Silva *et al*., 2012).

Submitted on May 22nd, 2021 and accepted on June 23rd, 2021.

[1] This work is part of the first author master's degree dissertation.

[2] Universidade Federal de Jataí, Jataí, Goiás, Brazil. pedrrromagalhaes@gmail.com; vicmonteiro44@gmail.com; mclaudiadayane@gmail.com; daniellefpsilva@gmail.com
[3] Universidade Estadual Paulista 'Júlio de Mesquita Filho', Faculdade de Ciências Agrárias e Veterinárias, Jaboticabal, São Paulo, Brazil. fram_rodgomes@hotmail.com
[4] Instituto Federal de Educação Ciência e Tecnologia do Norte de Minas Gerais, Almenara, Minas Gerais, Brazil. joao.alison@yahoo.com.br
* Corresponding author: fram_rodgomes@hotmail.com

Multivariate analysis techniques can be used at the discrimination of accessions in germplasm banks, aiming to evaluate the genetic diversity among those accessions and select the most important descriptors (Rodrigues *et al*., 2010). Among the several techniques of multivariate statistics, there are the analyses of correlations and clustering methods (Cruz *et al*., 2012). The clustering methods are important for plant breeding because they allow estimating the distance between genotypes, avoiding the conservation of duplicates in germplasm banks and helping in the choice of parents for future crosses aiming a greater gain by heteroses (Passeri-Lima *et al*., 2020).

Thus, there is the need to evaluate the physical and chemical characteristics of *S. dulcis* fruits associating the environment with productivity, and obtaining the ideal crop places of this species, besides researches of the existent diversity among fruits. Therefore, this work aimed to characterize the physical and chemical quality of *S. dulcis* as well the genetic diversity among the fruits harvested on different accessions in the municipality of Jataí – GO.

MATERIAL AND METHODS

For the characterization of fruit quality and genetic diversity, the fruits of cajá-manga (*S. dulcis*) were harvested from accessions of a natural occurrence in the urban zone from the municipality of Jataí – GO – Brazil. The main soil type in the urban area is classified as purple oxisol (Scopel *et al*., 2002). According to Köppen-Geiger's classification, the climate is from Aw type, with the dry season from May to September and the rainy season from October to April (Melo & Dias, 2019).

The accessions were randomly chosen based on the minimum distance of 3.5 km. Fully ripe fruits were harvested by hand with the aid of a stick 4.5 m high and sent to the laboratory of fruticulture from the Federal University of Jataí in plastic boxes (55 x 25 x 36 cm). The fruits from the accessions were selected for the absence of mechanical damages or injuries caused by pests and diseases, then, the selected fruits were sanitized in a sodium hypochlorite solution per five minutes.

The fruits were characterized for their physical and chemical characteristics. The pulp and peel color were given by the CIELab coordinates L* (Lightness), b* (Yellowness), C* (Chroma), and h° (hue angle), determined through reflectometry with a colorimeter Konica Minolta© measuring at the midpoint in opposite surfaces of the fruits. The pulp yield was obtained with the assistance of a precision scale through the quotient between fruit weight and pulp weight after the pulp extraction by hand, and the results were expressed in percentage (%).

The soluble solids concentration (SSC) was evaluated from the juice obtained after the pulp extraction by hand and measured in a handheld refractometer (Atago, Japan), whose results were expressed in °Brix. The titratable acidity (TA) was obtained through titration in a NaOH solution using phenolphthalein as an indicator, and these results were given in g of citric acid/100 mg of fresh fruit. The SSC/TA ratio was given through the quotient between these two characteristics. The ascorbic acid content (vitamin C) was obtained through titration with Tillman reagent (2,6-dichlorophenolindophenol sodium solution at 0,1%) (Merck Eurolab, Belgium), and the results were given in mg of ascorbic acid/100 mg of fresh fruit. The methodology employed to determine the pulp chemical characteristics was performed based on the procedures described by the Instituto Adolfo Lutz (IAL, 2008).

The experiment was carried out in a completely randomized design, composed of six treatments (Accessions M1; M2; M3; M4; M5 and M6) with ten replications of ten fruits per plot, totaling a sample of 600 fruits. The data were checked by the normality and homoscedasticity test and subjected to the analysis of variance. The averages were compared by Tukey's test at 1% of significance level ($p < 0.01$). The data analyses were performed in the RBio statistical program (Bhering, 2017).

A phenotypical correlation was performed using multivariate analysis, based on the Guerra & Liveira's (1999) classification, in which a correlation coefficient is considered very strong when it ranges from ± 0.91 to ± 1.00; strong when it ranges from ±0.71 to ±0.90; medium when it ranges from ± 0.51 to ± 0.70; and weak when it ranges from ±0.31 to ±0.50.

A multivariate analysis was performed estimating the mean Euclidean distance generated through the six accessions. The cut-off point used to determine the number of clusters at the Unweighted Pair-Group Method using Arithmetic Averages (UPGMA) method was based on the relative size of the six fusion levels (distances). The cophenetic coefficient of correlation (CCC) between the matrix of genetic dissimilarity and the matrix of the cophenetic values was calculated, aiming to verify the clustering consistency. The data were analyzed at the statistical program GENES (Cruz, 2016). The dendrogram was established using the "Statistic" program version 5.0.

RESULTS AND DISCUSSION

The accessions M5, M4 and M3 stood out for the pulp yield with 88.10, 85.5 and 83.4%, respectively, presenting the highest pulp yield among the accessions evaluated, and the lowest values of pulp yield were observed in the accessions M1, M2 and M6 (Table 1).

The pulp yield of fruits from the accessions evaluated in the present work are higher than the values found to *S.*

dulcis by Chaves-Neto & Silva (2019) for fruits harvested in Paraíba state, and by Damiani *et al*. (2011) for fruits harvested in the municipality of Nova Veneza – GO, which presented 73.79 and 73.58% of pulp yield, respectively. Costa *et al*. (2015) and Menezes *et al*. (2017) evaluating *Spondias tuberosa* fruits, obtained 65.08 and 74.30% of pulp yield, respectively. Marques *et al*. (2018) evaluating fruits in the municipality of Boa Vista – RO, obtained fruits of *Spondias mombin* with pulp yield ranging from 55.10 to 77.51%, and Dutra *et al*. (2017) also evaluating fruits of *S. mombin*, but from the municipalities of Macarani and Caraíbas – BA, reported 71.97 and 73.54% of pulp yield, respectively.

The fruits must present at least 40% of pulp yield to be used by processing industries in the elaboration of juices, wines, jellies, and sweets (Lago-Vanzela *et al*., 2011). The results obtained in the present work indicate the great potential of the municipality of Jataí – GO to produce *S. dulcis* fruits with a high pulp yield, an important characteristic, especially for processing industries.

The accession M4 presented the highest titratable acidity (TA), which was 1.21 g of citric acid/100 mg of fresh fruit, and the lowest titratable acidity content was observed in fruits harvested from the accessions M1 (1.09 g of citric acid/100 mg of fresh fruit), M3 (1.07 g of citric acid/100 mg of fresh fruit) and M5 (1.08 g of citric acid/100 mg of fresh fruit) (Table 1). These results are higher than those found by Aroucha *et al*. (2012), who obtained 1.03 g of citric acid/100 mg of fresh fruit for *S. dulcis* fruits harvested in the municipality of Mossoró – RN.

It is worth noting that even with the significant differences among the accessions, these results obtained in the present work are following the TA content required by the processing industries for *S. mombin* fruits, which is the acidity higher than 0.90% of citric acid (Brasil, 2016). Considering the high acidity observed in the evaluated fruits, they could attend the demand of the industries since the high acidity content in the pulp can reduce the need to add citric acid in the juice production and inhibits microorganism's development, which can decrease the production costs (Lima *et al*., 2002; Brasil, 2016).

For soluble solids concentration (SSC), the fruits from accession M2 presented the lowest content, which was 9.67 °Brix, the other accessions showed no significant differences with the values ranging from 10.48 to 11.48 °Brix (Table 1). These results corroborate Aroucha *et al*. (2012), which produced fruits of *S. dulcis* with a soluble solids concentration of 11.78 °Brix. On the other hand, Jayarathna *et al*. (2020) evaluating fully ripen *S. dulcis* fruits, obtained 7.52 °Brix for soluble solids concentration.

For the fruit's good acceptance, especially in fresh consumption, it is required a high soluble solids concentration, being this characteristic a way to determine the fruit quality according to its ripening stage (Trevisan *et al*., 2010; Cremasco *et al*., 2016). The six accessions produced fruits with SSC higher than the minimum value required for *Spondias dulcis* by the Standards of Identity and Quality of pulp fruit (PIQ's) established by the Brazilian legislation, which is 9.0 °Brix at the temperature of 20 °C (Brasil, 2016).

The fruits from accession M1 presented the higher soluble solids content/titratable acidity ratio (SSC/TA), 18.12, and show no significant difference from the accessions M3 and M5 (Table 1). These results corroborate Chaves-Neto & Silva (2019) for fruits of *S. dulcis* produced in Paraíba state, which presented 16.70 of SSC/TA. The lowest value was reported by Damiani *et al*. (2011) in the municipality of Nova Veneza – GO, which presented an SSC/TA of 10.98 for *S. dulcis*.

The SSC/TA is one of the most important characteristics to indicate the fruit flavor since it is related to the balance of sugars and acids, thus, the highest SSC/TA implies in sweeter fruits, which is also related to its ripening stage (Schneider *et al*., 2020; Guimarães *et al*., 2020). Comparing the SSC/TA found in the present work to the minimum values required for *S. dulcis* and umbu (*S.*

Table 1: Pulp yield (PY), titratable acidity (TA), soluble solids concentration (SSC), soluble solids concentration/titratable acidity ratio (SSC/TA), and vitamin C (VitC) of *S. dulcis* fruits harvested from six accessions in the municipality of Jataí – GO

Accession	PY (%)	TA (g of citric acid /100 mg)	SSC (°Brix)	SSC/TA	VitC (mg of ascorbic acid /100 mg)
M1	78.40 b	1.09 c	11.16 a	18.12 a	64.43 a
M2	80.35 b	1.16 b	9.67 b	9.86 c	60.33 b
M3	83.40 a	1.07 c	10.71 a	16.16 a	64.79 a
M4	85.50 a	1.21 a	11.43 a	10.73 b	58.87 b
M5	88.10 a	1.08 c	11.48 a	15.27 a	63.25 a
M6	81.50 b	1.14 b	10.48 a	12.48 b	67.70 a
F-value	0.52*	8.33*	6.89*	9.30*	2.59*
CV (%)	4.66	19.92	7.4	24.52	18.95

Averages followed by the same letter in the column show no statistical differences ($P < 0.01$) according to the Tukey's test.

tuberosa) by the Standards of Identity and Quality of pulp fruit (PIQ's) established by the Brazilian legislation (Brasil, 2016), which is 10 and 6.43, respectively, it can be observed that the fruits from the six accessions presented a higher SSC/TA, indicating the potential for its exploitation by the processing industries.

The accessions M1, M3, M5 and M6 showed no difference between them and present the highest vitamin C content, which was 64.43; 64.79; 63.25 and 67.70 mg of ascorbic acid/100 g of fresh fruit, respectively (Table 1). These results are higher than those reported by Kohatsu *et al*. (2011), which obtained fruits of *S. dulcis* with 54.2 mg of ascorbic acid/100 g of fresh fruit. Bohra & Waman (2017) also reported a lower content of ascorbic acid for fruits of *S. dulcis* fully mature produced in South Andaman – India, which is 35.49 mg of ascorbic acid/100 g of fresh fruit. The *S. dulcis* pulp is rich in antioxidants compounds, high levels of carotenoids, tannins and vitamin C (Tiburski *et al*., 2011). The ascorbic acid oxidation reactions depend on temperature levels and the ripening stage, decreasing with maturity (Jayarathna *et al*., 2020).

Regarding the pulp color, the accession M1 produced fruits with the highest values of coordinates lightness (L*), chromaticity (C) and yellowness (b*), and the highest values of the coordinate hue angle (h°) of the pulp were obtained in fruits from the accessions M3 and M4 (Table 2). For the peel color, the highest L* coordinate value was obtained in fruits from the accession M1, the highest C coordinate was observed in fruits from accessions M1 and M3, the highest h° was obtained in fruits from the accession M2, and the highest b* coordinate were obtained in the peel of fruits from the accessions M1 and M3 (Table 2). Hue angle values closest to 90° indicates that both the pulp and the peel presented an intense yellow color (Pereira *et al*., 2019).

The L* coordinate of pulp and peel is indicative of lightness intensity. During the ripening, the coordinates L* and b* tends to decrease, which implies in fruits with darker colors (Nuncio-Jáuregui *et al*., 2014). Marques *et al*. (2018) evaluating *S. mombin* fruits produced in Roraima, reported L* values of 50.36 for peel and 50.04 for pulp.

As greater is the C coordinate value, as vivid and strong the color will be (Manasa *et al*., 2019). These results found in the present work corroborate the results obtained by Marques *et al*. (2018) evaluating fruits of *S. mombin* in Roraima – Brazil. Fruits with vivid and strong colors tend to be better accepted by the consumers in fresh consumption (Souza *et al*., 2017).

The hue angle (h°) is the angular component of the representation of the product color (Nuncio-Jáuregui *et al*., 2014). H° values closest to 90° are indicative of the maturity stage, which is more attractive to the consumers (Pereira *et al*., 2019). This characteristic is important to the processing industries since fruits at an advanced ripening stage produce more chemical reactions, turning the fruits with an intense yellow color and having no need to add several dyes in the juice processing (Mitchell & Daly, 2015).

Table 2: Color coordinates of pulp and peel of *S. dulcis* fruits harvested from six accessions in the municipality of Jataí – GO

Accession	Pulp			
	L*	**C**	**h°**	**b***
M1	58.49 a	29.74 a	78.99 b	28.40 a
M2	46.20 b	14.55 c	79.98 b	13.58 c
M3	46.23 b	13.32 c	84.57 a	13.56 c
M4	42.86 c	10.13 d	86.39 a	8.27 d
M5	45.40 b	13.15 c	77.47 b	13.21 c
M6	46.98 b	17.52 b	77.90 b	17.20 b
F-value	41.44*	45.93*	5.87*	58.93*
CV (%)	5.64	19.79	5.99	17.94
Accession	**Peel**			
	L*	**C**	**h°**	**b***
M1	57.03 a	19.87 a	89.01 c	19.37 a
M2	43.50 c	9.42 c	100.41 a	8.43 d
M3	53.24 b	19.05 a	93.07 b	18.49 a
M4	42.51 c	11.23 c	94.80 b	10.00 c
M5	46.45 c	16.10 b	88.37 c	16.25 b
M6	44.25 c	11.77 c	92.11 b	11.50 c
F-value	26.59*	19.38*	22.45*	44.86*
CV (%)	7.60	21.59	3.15	15.62

Averages followed by the same letter in the column show no statistical differences (P < 0.01) according to the Tukey's test.

The b* represents the yellow tone of color, whereas the higher is the value, the more intense is the yellow color (Manasa *et al*., 2019). The yellow color occurs due to the activation of the biosynthetic pathways associated with the pigments of phenolic origin (Maldonado-Astudillo *et al*., 2017).

Regarding the pulp chemical characteristics, it can be observed that the titratable acidity presented a negative and significative strong correlation with the soluble solids content/titratable acidity ratio (-0.96), indicating that one characteristic increases as the other decreases, whereas the soluble solids concentration presented a negative and significative strong correlation with the pulp hue angle (-0.98), which also indicates that one characteristic is inverse to another and can indicate that the color change during the ripening is related with the increase of soluble solids concentration (Table 3).

For the pulp color, the coordinates L* C and b* presented a positive and significative strong correlation with the soluble solids content/titratable acidity ratio (0.92, 0.98 and 0.99, respectively) and presented a negative and significative strong correlation with the titratable acidity (-0.89, -0.98 and -0.99), which indicates the changes that occur during the ripening process, besides, the lightness presented a positive and significative correlation with the yellowness (0.91), and for the peel color, the L* coordinate presented a positive and significative correlation with the coordinates C and b* (0.99 and 0.98, respectively), also, the coordinate C presented positive and significative correlation with the b* coordinate (0.99) (Table 3).

The knowledge of the association between characteristics has great importance for breeding programs, especially if the selection presents problems due to its low heritability or it is from difficult measurement and identification, and the correlations are considered for choosing the breeding methods when strategies of simultaneous selection for the characteristics evaluated are formulated (Giles *et al*., 2016). The high correlations obtained in the present work indicate the possibility to present gains from the indirect selection of one feature in the loss of another, which can generate a high potential due to the greater heritability of the characteristics evaluated (Chaves-Neto *et al*., 2018).

It can be observed in the UPGMA dendrogram the formation of two groups, being the group I composed by the accession M2 and group II composed by the accessions M1, M3, M4, M5 and M6, based on the distances index within the dendrogram with a cophenetic correlation coefficient (CCC) of 0.78 and cut-off point of 0.68, corresponding to 85% of distance (Figure 1).

The clustering by the UPGMA method was suitable for genetic diversity representation and the formation of groups between the accessions because it presented a

Table 3: Phenotypic correlation coefficients among 13 variables from *S. dulcis* fruits harvested from six accessions in the municipality of Jataí – GO

Variable	PY[/13]	TA	SSC	SSC/TA	VitC	Lpe	Cpe	hpe	bpe	Lpu	Cpu	hpu
TA[/1]	-0.24^{ns}	-	-	-	-	-	-	-	-	-	-	-
SSC[/2]	0.63^{ns}	-0.55^{ns}	-	-	-	-	-	-	-	-	-	-
SSC/TA[/3]	0.34^{ns}	-0.96**	0.69^{ns}	-	-	-	-	-	-	-	-	-
VitC[/4]	0.20^{ns}	-0.48^{ns}	0.52^{ns}	0.53^{ns}	-	-	-	-	-	-	-	-
Lpe[/5]	0.19^{ns}	-0.52^{ns}	0.38^{ns}	0.69^{ns}	0.37^{ns}	-	-	-	-	-	-	-
Cpe[/6]	0.20^{ns}	-0.43^{ns}	0.39^{ns}	0.62^{ns}	0.44^{ns}	0.99**	-	-	-	-	-	-
hpe[/7]	-0.73^{ns}	0.11^{ns}	-0.32^{ns}	-0.23^{ns}	-0.53^{ns}	-0.40^{ns}	-0.48^{ns}	-	-	-	-	-
bpe[/8]	0.24^{ns}	-0.50^{ns}	0.42^{ns}	0.68^{ns}	0.52^{ns}	0.98*	0.99*	-0.53^{ns}	-	-	-	-
Lpu[/9]	0.02^{ns}	-0.89**	0.41^{ns}	0.92*	0.41^{ns}	0.80^{ns}	0.72^{ns}	-0.07^{ns}	0.75^{ns}	-	-	-
Cpu[/10]	0.20^{ns}	-0.98**	0.60^{ns}	0.98**	0.43^{ns}	0.61^{ns}	0.52^{ns}	-0.05^{ns}	0.57^{ns}	0.93^{ns}	-	-
hpu[/11]	-0.67^{ns}	0.69^{ns}	-0.98**	-0.80^{ns}	-0.54^{ns}	-0.43^{ns}	-0.42^{ns}	0.36^{ns}	-0.46^{ns}	-0.53^{ns}	-0.72^{ns}	-
bpu[/12]	0.28^{ns}	-0.99**	0.64^{ns}	0.99**	0.48^{ns}	0.60^{ns}	0.52^{ns}	-0.13^{ns}	0.57^{ns}	0.91**	0.99^{ns}	0.70^{ns}

[/1]Titratable acidity; [/2]Soluble solids concentration; [/3]Soluble solids concentration/titratable acidity ratio; [/4]Vitamin C content; [/5]Peel L* coordinate; [/6]Peel C* coordinate; [/7]Peel hue angle; [/8]Peel b* coordinate; [/9]Pulp L* coordinate; [/10]Pulp C* coordinate; [/11]Pulp hue angle; [/12]Pulp b* coordinate; [/13]Pulp yield. ns – non-significant; ** and * - statistically significant at 1% ($P < 0.01$) and 5% ($P < 0.05$) probability levels, respectively.

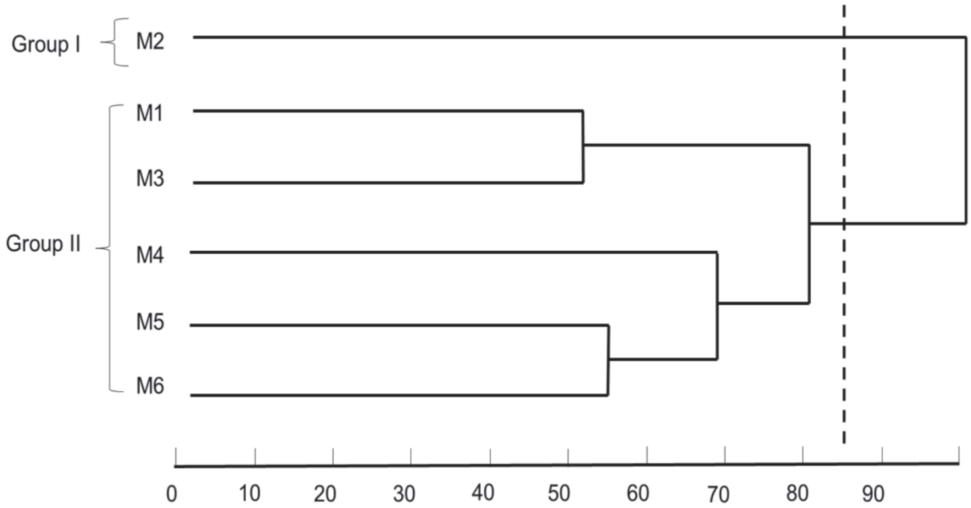

Figure 1: Dendrogram generated by UPGMA method from the dissimilarities through the Euclidean distance among 13 variables of fruits from six accessions.

CCC of 0.78. The CCC measures the adjustment between the dissimilarity matrix and the simplification matrix due to the clustering method, and it is applied to increase the conclusion reliability at dendrograms interpretations (Cruz *et al*., 2012).

The closest to the unity is the CCC value, the better will be the representation of the similarity matrix in the dendrogram (Monteiro *et al*., 2010). That information allows inferring because the evaluated characteristics revealed a good adjustment between the distance graphic representation e its original matrix, which reinforces the results' reliability.

CONCLUSIONS

The fruits from the accessions M3, M4, M5 and M6 presented the greatest pulp yield.

The lowest titratable acidity content was obtained in fruits from the accessions M1, M3 and M5, which indicates the great potential of these fruits for fresh consumption.

The highest vitamin C content was obtained in fruits from the accessions M1, M3, M5 and M6.

The accessions evaluated presented genetic variability, being the employed methodology efficient to show this variability.

The accession M2 stood out as the more divergent.

ACKNOWLEDGMENTS, FINANCIAL SUPPORT AND FULL DISCLOSURE

The authors are grateful to the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the financial support.

The authors state that there are no conflicts of interest.

REFERENCES

Aroucha EMM, Souza CSM, Souza AEDD, Ferreira RMDA & Arroucha-Filho JC (2012) Qualidade pós-colheita da Cajarana em diferentes estádios de maturação durante armazenamento refrigerado. Revista Brasileira de Fruticultura, 34:391-399.

Bhering LL (2017) RBio: A tool for biometric and statistical analysis using the R platform. Crop Breeding and Applied Biotechnology, 17:187-190.

Bohra P & Waman AA (2017) *Spondias dulcis* L.: An Important Acidulant Species In Bay Islands. International Journal of Forest Usufructs Management, 18:25-29.

Brasil (2016) Portaria Nº 58, de 01 de Setembro de 2016. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. DOU 01/09/2016, Seção 1, p.2.

Chaves-Neto JR, Andrade MGS, Schunemann APP & Silva SM (2018) Compostos fenólicos, carotenoides e atividade antioxidante em frutos de cajá-manga. Boletim Centro de Pesquisa de Processamento de Alimentos, 36:55-68.

Chaves-Neto JR & Silva SM (2019) Caracterização física e físico-química de frutos de *Spondias dulcis* Parkinson de diferentes microrregiões do Estado da Paraíba. Colloquium Agrariae, 15:18-28.

Costa FR, Rêgo ERD, Rêgo MMD, Neder DG, Silva SDM & Schunemann APP (2015) Análise biométrica de frutos de umbuzeiro do semiárido brasileiro. Bioscience Journal, 31:682-690.

Cremasco JPG, Matias RPG, Silva DFP, Oliveira JAA & Bruckner CH (2016) Postharvest quality of eight peaches cultivars. Comunicata Scientiae 7:334-342.

Cruz CD (2016) Genes Software-extended and integrated with the R, Matlab and Selegen. Acta Scientiarum. Agronomy, 38:547-552.

Cruz CD, Regazzi AJ & Carneiro PCS (2012) Modelos biométricos aplicados ao melhoramento genético. Viçosa, UFV. 514p.

Damiani C, Silva FAD, Amorim CCDM, Silva STP, Bastos IM, Asquieri ER & Vera R (2011) Néctar misto de cajá-manga com hortelã: caracterização química, microbiológica e sensorial. Revista Brasileira de Produtos Agroindustriais, 13:301-309.

Dutra FV, Cardoso AD, Morais OM, Viana AES, Melo TL & Cardoso Júnior NS (2017) Características físicas e químicas de acessos de umbuzeiros (*Spondias tuberosa* Arr. Cam). Revista de Ciências Agrárias, 40:140-149.

Giles JAD, Oliari LSO, Rocha ACB, Schmildt ER, Silva W & França JM (2016) Correlações entre características físicas, químicas e físico-químicas de frutos de cirigueleira. Revista Agro@mbiente on-line, 10:30-35.

Guerra NB & Livera AV (1999) Correlação entre o perfil sensorial e determinações físicas e químicas do abacaxi cv. 'Pérola'. Revista Brasileira de Fruticultura, 21:32-35.

Guimarães ARD, Leão KV, Mapeli AM & Schneider LC (2020) Physical and chemical characterization of cajarana fruits (*Spondias dulcis Parkinson*). Brazilian Journal of Development, 6:6693-6701.

IAL - Instituto Adolfo Lutz (2008) Métodos físico-químicos para análise de alimentos. São Paulo, Instituto Adolfo Lutz. 1020p.

Jayarathna PLI, Jayawardena JAEC & Vanniarachchy MPG (2020) Identification of Physical, Chemical Properties and Flavor Profile of *Spondias dulcis* in Three Maturity Stages. International Research Journal of Advanced Engineering and Science, 5:208-211.

Kohatsu DS, Zucareli V, Brambilla WP & Evangelista RM (2011) Qualidade de frutos de cajá-manga armazenados sob diferentes temperaturas. Revista Brasileira de Fruticultura, 33:344-349.

Lago-Vanzela ES, Ramin P, Umsza-Guez MA, Santos GV, Gomes E & Silva RD (2011) Chemical and sensory characteristics of pulp and peel'cajá-manga'(*Spondias cytherea* Sonn.) jelly. Food Science and Technology, 31:398-405.

Lima EDPA, Lima CDA, Aldrigue ML & Gondim PJS (2002) Caracterização física e química dos frutos da umbu-cajazeira (*Spondias* spp) em cinco estádios de maturação, da polpa congelada e néctar. Revista Brasileira de Fruticultura, 24:338-343.

Lima KPD, Medeiros ESD, Fernandes FA, Silva VFD & Morais ARD (2019) Ajuste de modelos não lineares para descrição do fruto cajá-manga. Sigmae, 8:221-226.

Maldonado-Astudillo YI, Aliatejacal IA, Núñez-Colín AC, Jiménez-Hernández J & López-Martínez VL (2017) Chemical and phenotypic diversity of mexican plums (*Spondias purpurea* L.) from the states of guerrero and morelos, mexico. Revista Brasileira de Fruticultura, 39:e-610.

Manasa B, Jagadeesh SL, Thammaiah N & Nethravathi (2019) Colour measurement of ripening mango fruits as influenced by pre-harvest treatments using L* a* b* coordinates. Journal of Pharmacognosy and Phytochemistry, 8:2466-2470.

Marques CS, Guimarães PVP, Smiderle OJ & Durigan MFB (2018) Qualidade agroindustrial de frutos de taperebazeiros (*Spondias mombin* L.) cultivados em áreas urbanas de Boa Vista, Roraima. Revista Eletrônica Ambiente, Gestão e Desenvolvimento, 11:296-307.

Martins CC, Silva GZ, Durigan LD & Vieira RD (2019) Pregerminative treatments of yellow mombin (*Spondias mombin* L.) seeds. Ciência Florestal, 29:363-370.

Melo BM & Dias DP (2019) Microclima e conforto térmico de remanescentes florestais urbanos no município de Jataí – GO. Revista da Sociedade Brasileira de Arborização Urbana, 14:01-15.

Menezes PHS, Souza AAD, Silva ESD, Medeiros RD, Barbosa NC & Soria DG (2017) Influência do estádio de maturação na qualidade físico-química de frutos de umbu (*Spondias tuberosa*). Scientia Agropecuaria, 8:73-78.

Mitchell JD & Daly DC (2015) A revision of *Spondias* L. (Anacardiaceae) in the Neotropics. PhytoKeys, 55:01-92.

Monteiro ER, Bastos EM, Lopes ECA, Gomes RLF & Nunes JAR (2010) Diversidade genética entre acessos de espécies cultivadas de pimentas. Ciência Rural, 40:288-293.

Morales RGF, Resende JTV, Faria MV, Silva PR, Figueiredo AST & Carminatti R (2011) Divergência genética em cultivares de morangueiro, baseada em caracteres morfoagronômicos. Revista Ceres, 58:323-329.

Moura FT, Silva SM, Schunemann APP & Martins LP (2013) Frutos do umbuzeiro armazenados em diferentes estádios de maturação. Revista Ciência Agronômica, 47:131-133.

Nascimento RSM, Cardoso JA & Cocozza FM (2014) Caracterização física e físico-química de frutos de mangabeira (*Hancornia speciosa* Gomes) no oeste da Bahia. Revista Brasileira de Engenharia Agrícola e Ambiental, 18:856-860.

Nuncio-Jáuregui N, Calín-Sánchez A, Carbonell-Barrachina A & Hernández F (2014) Changes in quality parameters, proline, antioxidant activity and color of pomegranate *(Punica granatum* L.) as affected by fruit position within tree, cultivar and ripening stage. Scientia Horticulturae, 165:181-189.

Passeri-Lima RH, Moreira LB, Lopes HM, Pereira MB, Menezes BRS & Marinho DV (2020) Divergência genética entre tipos especiais de arroz a partir de técnicas multivariadas. Revista de Ciências Agroveterinárias, 19:299-304.

Pereira LD, Souza LKF, Ferreira KB, Valle KD & Silva DFP (2019) Biofilmes comestíveis na conservação pós-colheita de cajá. Revista Engenharia na Agricultura, 27:285-292.

Rodrigues HCA, Carvalho SP, Carvalho AA, Carvalho Filho JLS & Custódio TN (2010) Avaliação da diversidade genética entre acessos de mamoneira (*Ricinus communis* L.) por meio de caracteres morfoagronômicos. Revista Ceres, 57:773-777.

Schneider LC, Leão KV, Machado LL & Guimarães ARD (2020) Caracterização física e química de frutos de bacupari, *Salacia crassifolia* (Mart. ex Schult.) G. Don, provenientes do município de Barreiras–BA. Brazilian Journal of Development, 6:13942-13953.

Scopel I, Katzer RT, Silva MR, Melo NA & Peixinho DM (2002) Evolução do uso da terra na microbacia do córrego do açude, em Jataí-GO. Boletim Goiano de Geografia, 22:31-46.

Silva DFP, Siqueira DL, Rocha A, Salomão LCC, Matias RGP & Struiving TB (2012) Diversidade genética entre cultivares de mangueiras, baseada em caracteres de qualidade dos frutos. Revista Ceres, 59:225-232.

Souza ASD, Soares KMDP, Góis VAD & Freire BCF (2017) Qualidade microbiológica e físico-química de polpas de umbu-cajá e cajá comercializadas em Mossoró. Higiene alimentar, 31:42-46.

Tiburski JH, Rosenthal A, Deliza R, Godoy RLD & Pacheco S (2011) Nutritional properties of yellow mombin (*Spondias mombin* L.) pulp. Food Research International, 44:2326-2331.

Trevisan R, Piana CDB, Treptow RDO, Gonçalves ED & Antunes LEC (2010) Perfil e preferências do consumidor de pêssego (*Prunus persica*) em diferentes regiões produtoras no Rio Grande do Sul. Revista Brasileira de Fruticultura, 32:90-100.

Vasconcelos LHC, Evangelista ZR, Campos AJD & Teixeira IR (2017) Diferentes embalagens na conservação pós-colheita de Cajá-Manga. Revista Espacios, 38:01-10.