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ORIGINAL ARTICLE

Characterization and genetic divergence of araçá-boi based on physicochemical and colorimetric traits of fruits

Caracterização e divergência genética do araçá-boi com base em características físico-químicas e colorimétricas de frutos

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ABSTRACT: The araçá-boi (*Eugenia stipitata* McVaugh), a native fruit from the Amazonian Forest, has great potential for fruit pulp production. Araçá-boi cultivation could diversify the incomes of small farmers and contribute to food security. However, little is known about the physicochemical, physiological, and agronomic aspects of araçá-boi, making its cultivation and expansion limited. This study aimed to characterize the physicochemical and colorimetric traits of fruits of araçá-boi and to access the genetic diversity among the studied accessions. Eight fruits of 33 accessions were collected for evaluation. The experiment was carried out at the Instituto Federal do Espírito Santo – Campus Itapina, located in Colatina-ES, in the year of 2015. Seven physicochemical traits and eight chromaticity parameters of fruits were measured. Grouping methods, such as Tocher optimization, hierarchical grouping, and principal component analysis (PCA), were applied to study the genetic diversity. It was observed phenotypic variability for all the evaluated traits. The three grouping methods were efficient for representing the genetic divergence among the accessions. The accessions 28 and 25 are interesting for clonal seedlings, for presenting good averages of fruit mass (FM), pulp mass (PM) and a relatively high total soluble solid (TSS) content. To develop a base population, besides accessions 28 and 25, the accession 33, which presented the highest TSS and accession 1 or 21, with high averages of FM and PM should be included in crossings to obtain a base population aiming to start a breeding program of araçá-boi.

RESUMO: *O araçá-boi (*Eugenia stipitata *McVaugh), fruteira nativa da Floresta Amazônica, possui grande potencial para produção de polpa de frutas. O cultivo de araçá-boi pode diversificar a renda de pequenos agricultores e contribuir para a segurança alimentar. No entanto, pouco se sabe sobre os aspectos físico-químicos, fisiológicos e agronômicos do araçá-boi, limitando seu cultivo e sua expansão. Este trabalho teve como objetivo caracterizar as características físico-químicas e colorimétricas de frutos de araçá-boi e acessar a diversidade genética entre os genótipos estudados. Oito frutos de 33 genótipos foram coletados para avaliação. O experimento foi realizado no Instituto Federal do Espírito Santo – Campus Itapina, localizado em Colatina-ES, no ano de 2015. Foram avaliadas sete características físico-químicas e oito parâmetros de cromaticidade dos frutos. Métodos de agrupamento, como otimização de Tocher, agrupamento hierárquico e análise de coordenadas principais, foram aplicados para estudar a diversidade genética. Foi observada variabilidade fenotípica para todas as características avaliadas. Os três métodos de agrupamento foram eficientes para representar a variabilidade genética entre os genótipos. Os genótipos 28 e 25 são interessantes para propagação clonal, por apresentarem boas médias de massa de fruto (MF) e massa de polpa (MP) e relativamente alto teor de sólidos solúveis totais (TSS). Para o desenvolvimento de uma população de base, além dos genótipos 28 e 25, o genótipo 33, que apresentou os maiores TSS, e os genótipos 1 ou 21, com médias elevadas de MF e MP, devem ser incluídos nos cruzamentos para obter uma população base visando iniciar um programa de melhoramento de araçá-boi.*

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1 Introduction

The fruit production in Brazil is important for the economy, once the country is the third biggest fruit producer in the world. However, there is a need to diversify the Brazilian fruit production sector, in order to diversify small farmers profits and to contribute enhancing food security (Mayes et al., 2012). Once that about 95% of the world's food production is based on a few crops (FAO, 2018). Furthermore, the consumer exigencies for fruits with new aroma, flavors, and textures are constantly increasing (Kader, 2008).

Several native fruit trees have potential and need to be studied with the aim to diversify this economic sector. The araçá-boi (*Eugenia stipitata* McVaugh), a native fruit from the Amazon Forest, produces globose berry fruits, with thin and velvety skin, canary yellow color when ripened, which weight may vary from 30 to 800 g. The fruits have round or flattened shape, with longitudinal diameter ranging from 5 to 10 cm and transversal diameter ranging from 5 to 12 cm. Its pulp is juicy, acid, with light yellow coloration, slightly fibrous, possessing from 4 to 10 oblong seeds with the length varying from 0.5 to 1.0 cm (Sacramento et al., 2008).

The araçá-boi cultivation is economically promising because it can grow in low fertility soil, begin fruit production early, and have high yield, associated with high percentage of pulp (Mendes & Mendonça, 2012). According to Falcão et al. (2000), the fruits of araçá-boi own an unique pleasant flavor and it is useful for juice, jelly, compote, custard, and candy. It is barely consumed *in natura* because of its high acidity.

Information about physicochemical and physiological characteristics, harvest time, and the yield of araçá-boi is scarce. This fruit has great potential for juice and pulp production. Besides the fruit yield, physicochemical traits such as shape, size, diameter, color, acidity, and sweetness of fruits, among others, should be considered for the selection of superior plants. Since the market price of fruits is highly influenced by these traits, which are directly related to product quality (Chitarra & Chitarra, 2005).

The knowledge about the accessions available in a gene bank is a central point for its better use in a breeding program. The diversity analysis aims to identify genitors to obtain hybrids with greater heterotic effect and that provides greater segregation in recombination, allowing the appearance of transgressive genotypes (Cruz & Carneiro, 2003).

Predictive methods for heterosis use morphologic, physiologic, or molecular differences, quantified in some dissimilarity measure, which express the degree of genetic divergence between the genitors. Commonly used methods for studying the genetic divergence are the Euclidean and the Mahalanobis distances. These methods are based on multivariate statistics, allowing the combination of multiple information of trait sets. However, there is a critic for using the Euclidean Distance because it does not take into consideration the residual variances and covariances that exist between the measured traits, this method is suitable for analyzing accessions without an experimental design and without replicates (Cruz & Carneiro, 2003). Several studies of genetic divergence performed in native fruits used the Average Euclidean Distance as measure of dissimilarity between the studied accessions (Lourenço et al., 2013; Silva et al., 2013; Oliveira et al., 2014).

The dissimilarity estimates attend to the breeder's objectives, but a simple visual interpretation of the results sometimes can be unworkable because generally several accessions are characterized and a high number of estimates are obtained. To make it easier and simpler breeders use grouping methods, such as Tocher optimization method or hierarchical grouping methods, such as the Unweighted Pair Group Method using Arithmetic averages (UPGMA). Furthermore, the Principal Component Analysis with projection of distances on bidimensional plots is of great use in plant breeding, because it summarizes a whole data set in a few components, which explain most of the variation in a given group of individuals (Cruz & Carneiro, 2003).

This work aimed to study the genetic divergence of 33 accessions of araçá-boi, available at the Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo (IFES) – Campus Itapina, based on physicochemical and colorimetric traits of fruits.

2 Materials and Methods

The experiment was conducted at the Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo – Campus Itapina, located in Colatina County, Northwest of Espírito Santo State in 2015. The region climate is the Aw of Köppen, raining about 1.170 mm per year. The IFES – Campus Itapina holds an orchard with 86 accessions, with approximately 17 years old plants with 14 years of productive life. Observation of these plants indicates good adaptation to the region, although with variation related to yield, quantitative, and qualitative aspects of fruits.

The araçá-boi flowers and yields almost all over the year. Thus, it was harvested 8 fruits per accession during the productive season between August and October of 2015. Initially, all 86 accessions would be essayed, but only 33 accessions produced 8 fruits during the evaluating time and were used for statistical analysis.

The fruit harvest was made twice or three times a week, according to ripen fruit availability. The fruits were collected in the early morning and packed in plastic bags to avoid transpiration losses and transported properly to the Applied Biology Laboratory of IFES – Campus Itapina for physicochemical and colorimetric analysis.

Measurements of longitudinal and the transversal length (expressed in mm) of fruits were analyzed by using a digital pachymeter with precision of 0.01 mm. The fruit mass (FM) and fresh pulp mass (FMP) were measured by using a semi-analytical scale. For FMP the fruits were half-cutted and only the seeds were removed. The percentage of fresh pulp mass (PFPM) was determined by dividing FMP by FM.

The fruit pulp was processed in an industrial blender and a sample was used to measure the total soluble solid (TSS) content, expressed in ^{o}Brix, determined using a digital refractometer with an automatic control of temperature and the potential of hydrogen (pH) measured using a digital pH meter (Oaklon, WD-35614-22).

To perform the colorimetric analysis the same 8 fruits of each accession were used. The external part (skin) and internal part (pulp) were analyzed by choosing three equidistant points to obtain an average value. This was made before physicochemical destructive analyzes. The colorimetric parameters were recorded using space coordinate (Hunter, 1987), chromaticity "a" and "b", luminosity "L", and *hue* angle (expressed in hº) (Konica Minolta Chroma Meter Mod. CR-400). The chromaticity parameters are demonstrated in Figure 1:

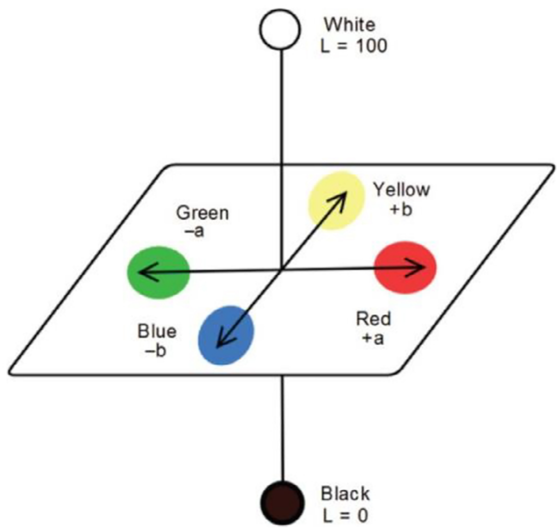


Figure 1. Hunter Color parameters: chromaticity "a" and "b", luminosity "L" and hue angle "hº". Source: Afonso et al. (2017).

Figura 1. Parâmetros colorimétricos de Hunter: cromaticidade "a" e "b", luminosidade "L" e ângulo hue "hº". Fonte: Afonso et al. (2017).

The relationship between the accessions were verified through the multivariate analysis of genetic divergence, expressed by the grouping of Tocher optimization method and in a dendrogram, constructed using the Unweighted Pair Group Method using Arithmetic averages (UPGMA), where the matrix of genetic dissimilarity between the accessions was obtained using the Average Euclidean Distance. Principal Component Analysis (PCA) expressed in a bidimensional biplot (2D) was also verified. To verify correlation between traits, the Pearson correlation and the Mantel test based on 5.000 simulations were employed. All analyzes were performed using the software GENES (Cruz, 2006) and plots were made through R programing language (R Core Team, 2013).

3 Results and discussion

The 33 accessions presented variation for all the evaluated traits. Considering the trait fruit mass (FM), the highest mean was observed for accession 1 (190.48 g) and the lowest for accession 12 (89.82 g), whereas the average was 131.56 grams. Falcão et al. (2000) studying the araçá-boi phenology found similar values for maximum (180 g), minimal (95 g), and average (135 g) fruit mass.

The accession 1 also showed the highest mean (150.40 g) for fresh mass of pulp (FMP) and the accession 3 showed the lowest (70.58 g). Falcão et al. (2000) found an average pulp weight of 104.9 grams, which is close of that observed in this study (105.43 g).

The araçá-boi fruits presented longitudinal length varying from 47.66 (accession 3) to 65.53 cm (accession 21), and the average was 56.28 cm. The pH of araçá-boi fruits in general is very low and it is related to the acidity content of the fruit. In this study, the pH varied from 2.66 (accession 25) to 3.42 (accession 1). The average pH was 3.06. It was higher than 2.6 observed by Garzón et al. (2012) and lower than 4.0 analyzed by Canuto et al. (2010).

Considering the total soluble solids, the accession 33 showed 8.11 ºBrix and the accession 12 showed 3.56 ºBrix. Canuto et al. (2010) and Garzón et al. (2012) studying araçá-boi, identified 4.5 e 4.6 ºBrix, respectively. These results are lower than the average total soluble solids observed here (5.08 ºBrix). The total soluble solids content is related with sugar and content of organic acids, and it characterizes as an important feature for *in natura* commercialized products, since the consumer prefers sweeter fruits (Barrett et al., 2010). The accession 33 showed interesting values of TSS for *in natura* consumed fruits and juice pulp production, however it presented a very low fresh pulp mass per fruit (83.13 g), compared to accession 1, which presented 150.40 grams per fruit. The wide variation in this trait ensures that exist genetic variability among the accessions, and provides support for selecting accessions with high total soluble solids content.

The luminosity parameter "L" measured in the fruit skin revealed that the accessions varied from 62.56 (accession 25) to 70.52 (accession 14), with average of 66.34. This parameter ranges from 0 (black) to 100 (white), according to Figure 1, demonstrating that the fruits have a mechanism to accentuate light reflection, in account of cuticle thickness, relative to serosity of the fruit or presence of hairiness.

The reflection observed on the skin is related to the skin thickness, structure responsible to accumulate wax. It is reasonable that higher values of parameter "L" will be related to thicker layer of wax, improving the protection against water loss, therefore, increasing the post-harvest quality.

According to Rossato & Kolb (2010) the increase of cuticle thickness has as one of its functions to reflect the luminosity, in order to maintain optimal levels of leaf temperature, and thus, favor the physiological processes.

In relation to fruit hairiness, the araçá-boi fruits own a considerable number of trichome and it is positively associated with light reflection index, thus, both characteristics, hairiness and cuticle thickness, contribute simultaneously for the parameter "L".

In the pulp, the "L" revels that some accessions present higher reflection in comparison with others, it might be related with less darkening of the pulp. The darkening of the pulp, in some fruits, is a serious problem for the post-harvest, as observed in peach (Brackmann et al., 2007). The accession 26 presented the highest (71.96) and accession 16 the lowest (60.47) mean, while the average was 66.26.

The parameter "a" when positive indicates a leaning to red pigmentation and this evaluation allowed the identification of fruits with more red pigmentation than others. The "a" of fruit skin varied from -0.83 (accession 25) to 7.07 (accession 6), with average of 3.29. The red pigmentation is correlated with an increasing of secondary metabolites (antioxidants), such as xanthophyll, and other variations of carotenoids. This is an important nutritional aspect of fruits, which tend to have higher levels of antioxidants compounds (Schmidt et al, 2017). Torres et al. (2009) associated the increases of "a" values in tomato ripening. The fruit color change from green to red in tomatoes is due to chlorophyll degradation and lycopene synthesis during the ripening. Analyzing the parameter "a" of the pulp, it was possible to observe that most accessions presented negative values, where the average was -1.30.

In the fruit skin the content of carotenoids can be estimated by the parameter "b". Thus higher or lower values correspond to higher or lower content of carotenoid, respectively. Ruiz et al. (2005) studying the color parameters "a", "b", and "hº" in apricot, identified the relationship between the parameter "b" and the individual and total carotenoid content, in both, skin and pulp. The highest "b" value was observed in accession 28 (41.72) and the lowest in accession 25 (34.65).

Considering the pulp, the variation of the parameter "b" was used to analyze the yellow intensity and it indicates higher carotenoid content in some accessions, as shown in accessions 32 (28.45) and 8 (26.47). This carotenoid content indicates the fruits with better nutritional standard, once they have desirable compounds with antioxidant function. The minimum "b" value was observed in accession 16 (22.47) and the average was 24.63.

The quadrant of colors used in this work for the parameter "hº" interpretation, revealed that the araçá-boi fruits are located in the 90º quadrant, demonstrating that they are yellow/red. Some accessions exceed the 90º quadrant, presenting a greenish coloration (yellow/green quadrant), although, yellow coloration was predominant by the proximity to axis 90º (yellow). In the pulp, the parameter "hº", corroborating with the carotenoids concentration, demonstrates that most of the accessions placed between the 90º quadrant (yellow color axis) and the 180º quadrant (green color axis), always very close to the yellow color.

The study of phenotypic correlation based on Pearson correlation and Mantel test revealed significant correlation at 1 and 5% of probability (Table 1). According to Carvalho et al. (2004), the correlation coefficients follow a magnitude of values, where values equal to zero, there is an absence of linear correlation; values from zero to 0.30, it is weak; 0.30 to 0.60, it is average; 0.60 to 0.90, it is strong; and from 0.90 to 1.00, it is very strong correlated.

The trait FM showed very strong correlation with LL, TL, and PM (Table 1). These results demonstrate that these tree traits have high influence over the main trait FM. Very strong correlation between LL with TL (0.90) and PM (0.90), and TL with PM (0.97) were observed.

Considering the trait TSS, negative correlation was observed for all other physicochemical traits (Table 1), highlighting the negative and strong correlation between TSS and pH of -0.88. This situation may be a problem for the breeder to select simultaneously accessions with high TSS content and high fruit mass or fresh pulp mass. Performing a correlation analysis of traits in papaya fruits, Quintal (2009) also verified negative correlation between the TSS content with other morpho-agronomic traits of importance for papaya breeding.

The trait PFPM presented only a single weak correlation with TSS of 0.29. Considering the correlation of physicochemical with colorimetric measurements, it was observed average significant correlations at 1% of probability between the parameter "a" measured in the skin with pH (0.49) and TSS (-0.43). This parameter was also negatively strongly correlated (-0.99) with the "hº" measured in the fruit skin.

Table 1. Phenotypic correlation of physicochemical traits in 33 accessions of araçá-boi, Colatina-ES, 2015

Tabela 1. Correlação fenotípica de características físico-químicas de 33 acessos de araçá-boi, Colatina-ES, 2015

	LL	TL	PM	pH	TSS	PFPM	"L" skin	"a" skin	"b" skin	"hº" skin	"L" pulp	"a" pulp	"b" pulp	"hº" pulp
FM	**0.90	**0.98	**0.96	0.18	-0.20	-0.09	0.31	-0.07	**0.49	0.09	-0.25	**-0.38	0.05	**0.38
LL	-	**0.90	**0.90	-0.08	-0.05	0.05	0.33	-0.19	**0.46	0.22	-0.21	**-0.46	0.03	**0.45
TL		-	**0.97	0.17	-0.22	-0.02	0.22	-0.05	**0.44	0.07	-0.23	-0.34	0.07	0.34
PM			-	0.10	-0.11	0.17	0.25	-0.11	**0.46	0.11	-0.19	**-0.40	0.10	**0.40
pH				-	**-0.88	-0.28	0.21	**0.49	0.12	**-0.48	-0.29	0.29	-0.33	-0.27
TSS					-	0.29	-0.17	**-0.43	-0.03	**0.42	0.27	*-0.37	*0.36	*0.36
PFPM						-	-0.17	-0.12	-0.09	0.10	0.26	-0.17	0.18	0.17
"L" skin							-	0.05	**0.60	-0.05	-0.32	0.05	-0.06	-0.03
"a" skin								-	0.28	**-0.99	-0.31	*0.35	-0.18	-0.34
"b" skin									-	-0.27	**-0.54	-0.16	-0.08	0.17
"hº" skin										-	0.30	*-0.36	0.16	*0.35
"L" pulp											-	-0.22	*0.36	0.21
"a" pulp												-	0.00	**-1.00
"b" pulp													-	-0.04

**,*: Significant at 1 and 5% of probability by the Mantel test based on 5.000 simulations. FM: fruit mass; LL: longitudinal length; TL: transversal length; PM: pulp mass; pH: Potential of hydrogen; TSS: total soluble solids content; PFPM: percentage of fresh pulp mass; "L" skin, "a" skin, "b" skin, and "hº" skin: colorimetric parameters measured in fruit skin; "L" pulp, "a" pulp, "b" pulp, and "hº" pulp: colorimetric parameters measured in fruit pulp.

The parameter “b” measured in the fruit skin had average correlation with FM (0.49), LL (0.46), TL (0.44), and PM (0.46). A negative correlation of -0.54 and a positive correlation of 0.60 were observed between this parameter with the parameter “L” measured in the fruit pulp and the parameter “L” measured in the fruit skin, respectively.

For the parameter “h°” measured in the fruit skin, an average correlation was observed with TSS (0.42) and negative average correlation with pH (-0.48). Analyzing the parameter “a” measured in the fruit pulp, significant negative correlations were observed with FM (-0.38) and LL (-0.46). In the same way that observed in the fruit skin, this parameter had negative strong correlation with the parameter “h°” (-0.99) measured in the fruit pulp. This observation indicates that in both skin and pulp measurements, the parameters “a” and “h°” are correlated in opposite directions. Furthermore, the parameter “h°” measured in the fruit pulp had average correlations with FM (0.38), PM (0.40), and LL (0.45).

The clustering analysis done through the Tocher Optimization method based on the Average Euclidean Distance, allowed the formation of eight groups. Five groups had only one accession each (Table 2). The group II and III consisted of two and four accessions, respectively. The remaining 22 accessions were grouped together, representing 66.67% of the characterized accessions (Table 2).

Table 2. Representation of the grouping by the Tocher Optimization method based on the Average Euclidean Distance, estimated from seven physicochemical traits and eight colorimetric parameters of 33 accessions of araçá-boi, Colatina-ES, 2015

Tabela 2. Representação do agrupamento pelo método de Otimização de Tocher baseado na Distância Euclidiana Média, estimada a partir de sete características físico-químicas e oito parâmetros colorimétricos de 33 genótipos de araçá-boi, Colatina-ES, 2015

Groups	Accessions	(%)
I	1, 21, 4, 20, 30, 19, 11, 24, 15, 6, 16, 13, 7, 31, 18, 2, 26, 22, 29, 10, 14, 9	66.67
II	17, 23, 33, 5	12.12
III	8, 27	6.06
IV	25	3.03
V	28	3.03
VI	3	3.03
VII	32	3.03
VIII	12	3.03
Total	33	100.00

Formation of groups with only one accession characterizes good level of genetic divergence between the accessions. Oliveira et al. (2014) studying 30 accessions of cagaiteira (*Eugenia dysenterica* DC.), which belongs to the same genus of araçá-boi, found similar results with the formation of 9 groups, where four groups consisted of only one accession. The study of 18 accessions of muricizeiro (*Byrsonima dealbata* Griseb) allowed the formation of four groups, with three groups consisting of only one accession and the remaining accessions in one group (Lourenço et al., 2013).

The PCA dispersion of physicochemical traits using two components represented 84.06% of the total variation between the accessions (Table 3). According to Cruz & Carneiro (2003), when the two main components explain more than 80% of the total variation, the bidimensional plot (2D) is efficient for studying the genetic divergence among accessions.

Table 3. Eigenvalues associated with seven physicochemical traits of 33 accessions of araçá-boi, Colatina-ES, 2015

Tabela 3. Autovalores associados a sete características físico-químicas de 33 genótipos de araçá-boi, Colatina-ES, 2015

Principal component	Square (%)	% Accumulated
Dim1	55.1695	55.1695
Dim2	28.8952	84.0648
Dim3	12.3277	96.3925
Dim4	2.5915	98.9839
Dim5	0.7644	99.7484
Dim6	0.2228	99.9712
Dim7	0.0288	100.00

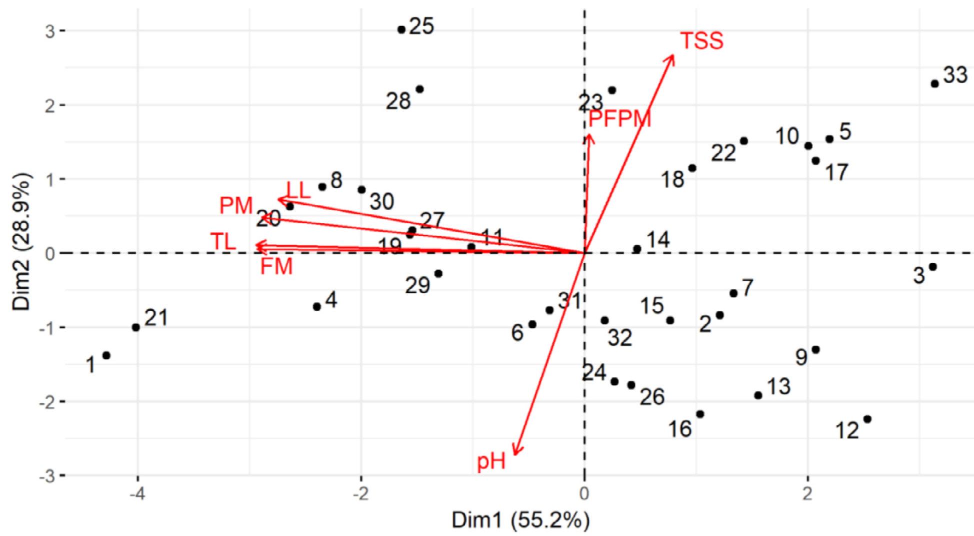
Dim: dimension

The PCA results and the correlation of physicochemical traits were presented in a biplot (Figure 2). It was observed concordance with the Tocher Optimization method, mainly by the appearance of groups with isolated accessions.

The biplot is a simple and fast way to visualize the dispersion of accessions and the correlation of traits simultaneously. The red vectors (arrows) show how much weight each trait has on that principal component. In other words, the traits FM, TL, PM, and LL have a strong influence on the principal component 1 (Dim1), while the traits TSS and pH are the ones with more influence on the principal component 2 (Dim2) (Figure 2). In addition, the vectors point in what direction the dispersed accessions show the higher means for that particular trait.

The correlation of the physicochemical traits can be analyzed looking at the angles between vectors (Figure 2). The smaller the angle between vectors, it means that the corresponding traits are more positively correlated. In the same way, the vectors pointing to opposite directions mean that the corresponding traits are negatively correlated. If the vectors meet each other at 90°, it indicates they have no linear correlation.

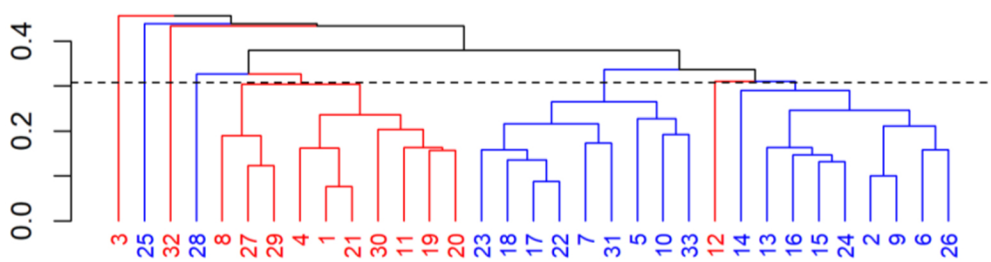
Other methods for studying the genetic divergence among accessions include the hierarchical grouping methods. In this study the Unweighted Pair Group Method using Arithmetic averages (UPGMA) was used, based on the Average Euclidean Distance as measure of dissimilarity, to obtain a dendrogram (Figure 3). It was clear to observe concordances with the two preview methods for representing the genetic divergence. The accessions 28, 12, 32, 25, and 3 were grouped separately as observed in Tocher optimization method (Table 2), while in the PCA, only the accession 32 was not grouped separately (Figure 3). Concordance with the three methods was also observed by Lourenço et al. (2013) and Oliveira et al. (2014).



Dim: dimension

Figure 2. Biplot of Principal Component Analysis and correlation of seven physicochemical traits of 33 accessions of araçá-boi, Colatina-ES, 2015

Figura 2. *Biplot* da Análise de Coordenadas Principais e correlação de sete características físico-químicas de 33 genótipos de araçá-boi, Colatina-ES, 2015



Cophenetic correlation coefficient = 0.72.

Figure 3. Representative dendrogram of the genetic divergence among 33 accessions of araçá-boi, obtained by the Unweighted Pair Group Method using Arithmetic averages (UPGMA), using the Average Euclidean Distance as measure of dissimilarity

Figura 3. Dendrograma representativo da divergência genética entre 33 genótipos de araçá-boi, obtidos pelo método de Agrupamento Médio Entre Grupos (UPGMA), utilizando a Distância Euclidiana Média como medida de dissimilaridade

The clusters I (accession 3), II (accession 25), III (accession 32), IV (accession 28), and VII (accession 12) grouped only one accession each (Figure 3). The accession in cluster IV presented good means of FM, PM, PFPM, and a relatively high mean of TSS (6.80 ºBrix), becoming an interesting accession with high FM and TSS, as it is known that these traits are negatively correlated (Table 1). In the same way, the accession 25 (Cluster II) is also interesting. The accession 12 (Cluster VII) showed the lowest mean of FM. In the cluster V, ten accessions (8, 27, 29, 4, 1, 21, 30, 11, 19, and 20) with higher measures of FM, LL, TL, and PM was observed. The cluster VI comprised nine accessions (23, 18, 17, 22, 7, 31, 5, 10, and 33) with lower means of FM, LL, TL, and PM. Furthermore, the PFPM and TSS of these accessions ranged between 0.81 to 0.86 and 5.09 to 8.11 ºBrix, respectively. The group VIII with nine accessions (14, 13, 16, 15, 24, 2, 9, 6, and 26) showed average measures of FM, LL, TL, and PM, with TSS ranging from 4.15 to 5.44 ºBrix. It was not so clear to observe the differences of the accessions in distinct groups, when analyzing the colorimetric parameters of fruits.

The cophenetic correlation coefficient (CCC) represents the reliability between the dissimilarity matrix and the dendrogram. The UPGMA method expressed a CCC of 0.72 ($P \leq 0.01$), being the highest value compared to other hierarchical grouping methods and satisfactory to represent the genetic distances of the araçá-boi accessions. Oliveira et al. (2014) observed a CCC of 0.65 using the UPGMA method for studying the genetic divergence of 30 accessions of *E. dysenterica*.

The information contained in the employed grouping methods combined with quantitative and qualitative data are important for allowing the selection of candidate plants to be included in a plant breeding program, highlighting the importance to proceed the analyzes related to pre-breeding.

The results reveal the existence of sufficient genetic variability among the characterized accessions of araçá-boi. Indicating that the selection of divergent and promising accessions for future breeding programs is possible. Since a broad genetic base guarantees greater potential of selection gain for obtaining new genetic material. In the case of the araçá-boi crop, this can be achieved through the selection of superior plants for clonal seedling propagation, as well as to carry out hybridizations, among the genetically most distant accessions to obtain hybrids, taking advantage of the heterosis phenomenon (Falconer, 1989).

4 Conclusions

The 33 accessions of araçá-boi available at the IFES – Campus Itapina, in Colatina-ES, showed phenotypic variability for all physicochemical and colorimetric characteristics evaluated.

All three grouping methods used, the Tocher optimization, UPGMA, and PCA expressed in 2D biplot, were efficient for representing the genetic divergence between the accessions, showing high concordance of grouping patterns.

The accessions 28 and 25 are interesting for clonal seedlings, because they present good averages of FM and PM, combined with relatively high TSS content. Furthermore, they are genetically distant and together with accession 33, which has the lowest FM, but the highest TSS content, which should be included in crossings to obtain a base population aiming to start a breeding program of araçá-boi. Accessions 1 or 21 are also recommended to contribute in the base population, for showing high averages of FM and PM, and being significatively distant from accession 25.

This study shows that the orchard available at the IFES – Campus Itapina holds accessions of araçá-boi with good genetic variability for characteristics of interest for the juice and pulp industry, as well for starting a breeding program.

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