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Selection of cupuassu tree clones for fruit quality

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ABSTRACT: This study aimed to evaluate the potential of cupuassu tree genotypes based on the physical characterization of the fruit and the physical-chemical properties of the pulp. We used cupuassu tree clones from a field trial installed in the municipality of Tomé Açu, Pará, Brazil. The data obtained from the characterization were submitted to univariate and multivariate analysis of variance by the methods of principal components, correlation networks and established the divergence between the genotypes. The results showed that clone 46 had the highest seed and pulp masses, as well as fruits that excelled in average length, when compared to clones 32 and 61. Regarding vitamin C contents, clones 46, 61, 63 were superior compared to the other genotypes studied. These same clones, along with the 32 presented values higher than the quality reference standard proposed by the legislation in force. Thus, the tested clones presented characteristics suitable both for the pulp market (46, 61 and 64) and for the cupulate industry (32, 42 and 46), with pulp quality indexes higher than those determined by the Brazilian legislation.

Key words: chemical composition; clonal selection; fruit quality; native fruit tree; *Theobroma grandiflorum*

Seleção de clones de cupuaçuzeiro visando qualidade de fruto

RESUMO: Este estudo visou avaliar a potencialidade de genótipos de cupuaçuzeiro embasando-se na caracterização física do fruto e físico-química da polpa. Foram empregados clones de cupuaçuzeiro oriundos de um ensaio de campo instalado no município de Tomé Açu, Pará, Brasil. Os dados obtidos com a caracterização foram submetidos à análise de variância univariada e multivariada pelos métodos de componentes principais, redes de correlações e estabelecida a divergência entre os genótipos. Os resultados demonstraram que o clone 46 apresentou as maiores massas de semente e polpa, além de frutos que se destacaram no comprimento médio, quando comparados aos clones 32 e 61. Em relação aos teores de vitamina C, os clones 46, 61, 63 foram superiores em relação aos demais genótipos estudados. Esses mesmos clones, juntamente com o 32 apresentaram valores superiores ao padrão de referência de qualidade proposto pela legislação vigente. Dessa forma, os clones testados apresentaram características adequadas tanto para mercado de polpa (46, 61 e 64) quanto para a indústria de cupulate (32, 42 e 46), com índices de qualidade de polpa superiores aos determinados pela legislação brasileira.

Palavras-chave: composição química; seleção clonal; qualidade do fruto; frutífera nativa; *Theobroma grandiflorum*

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Introduction

The Amazon biome concentrates the largest biodiversity of flora and fauna in the world (Costa et al., 2013). Among the elements present in the flora one can observe different species of fruit trees with unique sensory and nutritional characteristics (Souza et al., 2020), which represent a great potential for human consumption, being able to prevent some diseases (Alves et al., 2019). The scientific knowledge of these fruit trees is the most efficient method to develop sustainable growing systems, which enable financial returns to the producer, use by the agro-industry, consumer satisfaction, and conservation of natural resources.

Among these fruits, cupuassu, the fruit of the cupuassu tree [*Theobroma grandiflorum* (Wild ex Spreng) Schum], Malvaceae, is one of the most relevant, with great socioeconomic and cultural importance in the northern region of Brazil, due to the multiple uses of the pulp and almonds (Franklin & Nascimento, 2020). Cupuassu is characterized as a drupaceous berry, with smooth skin, green color covered by brown hairs, with dimensions varying from 10 to 30 cm in length and 9 to 15 cm in diameter, weighing on average 1200 g and producing around 30 seeds per fruit (Souza et al., 2017).

The butter, obtained from the almonds, is used in the pharmaceutical and cosmetic industries due to its antioxidant properties, and has potential for use in the food industry, through the production of “cupulate”, a product similar to chocolate. The pulp, the foundation of the cupuassu production chain, is appreciated by consumers for its pleasant aroma and striking flavor, and is used to prepare juice, ice cream, cream, and jelly, among others (Franklin & Nascimento, 2020). The physical-chemical characteristics are related to the quality of the pulps, which present great variation among individuals. Santos et al. (2010), found titratable acidity values ranging from 1.28 to 2.31% citric acid, different from that obtained by Canuto et al. (2010), who quantified titratable acidity at 3.50%. Pugliese et al. (2013), observed protein contents ranging from 0.7 to 1.2 % and vitamin C contents from 1.8 to 17.0 mg per 100g of pulp. In this sense, fruit contains essential elements, such as vitamins, minerals, and bioactive substances that help regulate the body’s functions (Costa et al., 2017), matching the positive correlation that has been observed between the increased consumption of fruit in the human diet, and the growing consumer concern about health (Yahia et al., 2017).

The studies on genetic improvement of the cupuassu tree started in the 1980s, aiming to develop genotypes with superior fruit production characteristics and resistance to vassoura de bruxa (*Moniliophthora perniciosa* Stahel Aime & Phillips-Mora), the main disease that plagues this crop. In 2002 the first cultivars were released by Embrapa Amazônia Oriental, named BRS Coari, BRS Codajás, BRS Manacapuru and BRS Belém, clonal cultivars that presented characteristics of disease resistance and high fruit production (Alves & Cruz, 2003). In 2012, the seminal cultivar BRS Carimbó was made available, obtained by crossing 16 genotypes that combine resistance and productivity characteristics (Alves et al., 2017).

Before deciding which genotype to use, the grower must have access to all possible information on the planting material, including the physical and physicochemical fruit characteristics of the materials on the market. In addition, this information is used in the breeding program to guide the choice of parents to be used in future hybridizations, as well as to direct the breeding for a particular trait of interest. For this reason, studies such as those focused on in the present research become fundamental for the continuous evolution of the sustainability of the cupuassu tree production chain. From the point of view of pulp quality several studies with other crops have been conducted, among which, Viana et al. (2015) selected papaya genotypes through physicochemical and sensory characteristics. Chavarría-Perez et al. (2020) selected sweet passion fruit genotypes through physical and physicochemical characteristics of the fruit.

This study aimed to evaluate the physical characteristics of the fruit and the physical-chemical properties of the fruit pulp of six cupuassu tree genotypes in order to identify the most promising ones to support improvement programs, as well as to identify market niches.

Materials and Methods

The following cupuassu tree clones were used: 32, 42, 46, 61, 63 and 64, from a clonal trial installed in the physical base of Embrapa Amazônia Oriental, located in Tomé-Açu, Pará, Brazil (02˚26’08’’ S; 48˚09’08’’ W). These clones were in the final evaluation phase, 15 years after establishment in the field. Four plants of each genotype were sampled and five fruits were collected from each plant, totaling 20 fruits of each genotype. The harvest took place in February and March, when the fruit was completely ripe, that is, when the fruit naturally detached from the tree. After harvesting, the fruits were taken to the fruit analysis laboratory of Embrapa Amazônia Oriental in the same municipality.

Initially, a visual evaluation of the physical and sanitary integrity of the fruits was performed. Then the fruits were washed and immediately peeled and pulped by hand. Next, bark, seeds, placenta, and pulp were separated for mass measurement. After the pulp masses were obtained, they were fractioned and packed in plastic bags, stored and frozen in a freezer (-18 °C) to be used in the physicochemical studies.

The length and diameter of the cupuassu tree fruits, as well as the thickness of the skin, were determined using a digital pachymeter. The number of seeds was quantified in all fruits of the six genotypes. The total mass and the components of the fruit: peel, pulp, placenta and seeds, were determined on a digital scale. The estimates of the studied characteristics were presented at the level of averages per fruit.

The physical-chemical analyses of the pulp were performed in the Laboratory of Plant Nutrition, at the Universidade Estadual do Norte Fluminense Darcy Ribeiro. The soluble solids content (SS), expressed in °Brix, was determined by direct reading in a digital refractometer. For the pH of the pulp using a digital pH meter.

For titratable acidity and vitamin C analysis, 10 g of pulp were diluted in 100 mL of deionized water and homogenized using a mixer. Titratable acidity (TA) was obtained by titration with 0.1 N sodium hydroxide, expressed as g of citric acid in 100 g of pulp, and vitamin C (mg of ascorbic acid 100 g of pulp) by titration with 2,6-dichlorophenol-indofenol solution, sodium salt (AOAC, 2016). The Ratio was estimated by the SS/TA ratio.

The humidity of the samples was determined by drying the material in an oven at 105 °C until constant mass. Ash was determined after calcination of the samples in a muffle furnace at 550 °C, following methodology described by AOAC (2016).

Protein was determined by quantifying nitrogen (N) by the Nessler method and using a factor of 6.25 to transform into crude protein content. Reducing sugars were quantified by the Somogyi-Nelson method.

The data were analyzed following an entirely randomized design, using a fixed linear model (Equation 1):

$$Y = \mu + G_i + \varepsilon_{ijk} \quad (1)$$

where: Y is the phenotypic data; μ corresponds to the average; G_i is the effect of genotypes; and, is the random effect of the non-controllable factors, that is, the residuals. When a significant difference in the effect of genotypes was detected by the F test, Tukey average grouping test was applied at 5% probability.

In order to study the interrelationship between the variables used, the correlations between each pair of variables were estimated, using the estimator (Equation 2):

$$r_{XY} = \frac{Cov(X,Y)}{\sqrt{V(X)V(Y)}} \quad (2)$$

After the estimations, the significance of the coefficients was checked using Student t-test. The significant correlations were represented in a correlation network.

The relationship between characters and genotypes was best explained by conducting multivariate principal component analysis (PCA). These components were acquired by obtaining the eigenvalues and eigenvectors from the correlation matrix, made after standardizing the variables. Biplot graphs were then constructed for the set of variables and treatments. All analyses and graphs were prepared in R statistical software (R Core Team, 2014).

Results and Discussion

With the exception of the number of seeds, the other physical characteristics of the fruit showed differences among the genotypes (Table 1), attesting to the presence of variability among them.

Fruit length (FL) and diameter (FD) values ranged from 19.0 to 23.8 cm and from 10.7 to 13.2 cm, respectively. Clone 46 showed higher FL compared to clones 32 and 61. As for FD, clones 46 and 63 expressed the highest averages, differing from the other genotypes (Table 1). These characteristics are important for *in natura* cupuassu market, since larger fruits become more attractive to consumers because, it is implied that they are heavier and this characteristic is correlated with higher pulp mass (Alcoforado et al., 2019).

Regarding peel thickness (PT), clone 63 differed statistically from the other genotypes evaluated, with an average of 1.1 cm, while clone 32 had the thinnest bark (Table 1). In some fruit trees, it is interesting that the fruits have lower PT indicating higher pulp yield, for example fruits of passion fruit culture (Cavalcante et al., 2018). On the other hand, for the cupuassu tree a balance point must be found, since the ripe fruit detaches from the plant and falls to the ground. Therefore, fruits with less peel thickness can suffer cracks allowing the entrance of microorganisms that deteriorate the pulp.

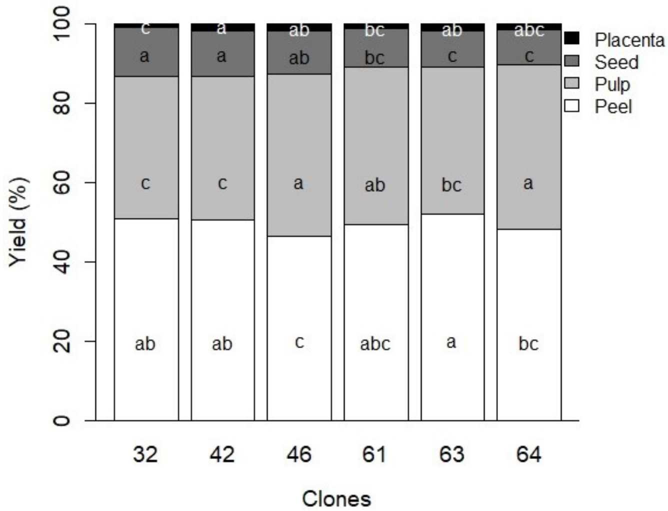
Clone 32 showed the lowest value of peel mass (PM) (570.6 g), being one of the smallest fruits and lowest total mass among the genotypes evaluated (Table 1). The average values for placenta mass (PM2) ranged from 12.5 to 35.2g per fruit, and followed the trend of SM, with clones 46, 63, 42 and 64 differing from clone 32, which in turn exhibited the lowest PM2 averages. Clone 46 was also superior in seed mass (SM), pulp mass (PM1), as well as for total average fruit mass (TF). These results were reflected in the average yields of these variables, in which this genotype was the big highlight (Figure 1). The fruits of genotype 46 presented 51.7% of its mass composed of PM1 and SM, interesting characteristics for the producer, who searches for genotypes with double aptitude, both for pulp and seeds.

The physical constitution of cupuassu tree fruits is, on average, 45% peel, 37% pulp, 15% seeds, and 3% placenta

Table 1. Fruit length (FL), fruit diameter (FD), peel thickness (PT), peel mass (PM), seed mass (SM), pulp mass (PM1), placenta mass (PM2), and total fruit mass (TF), in six cupuassu tree genotypes.

Clones	FL	FD	PT	NS	PM	SM	PM1	PM2	TF
		(cm)					(g)		
32	19.0b	10.7b	0.8c	31.7	570.6c	138.1c	404.2e	12.5d	1125.4e
42	21.4ab	11.8b	1.0b	32.3	771.9b	169.4b	548.6d	28.7ab	1518.6cd
46	23.8a	13.1a	0.9b	34.6	925.3a	215.9a	813.8a	35.2a	1990.1a
61	20.7b	11.3b	1.0b	33.6	729.4b	139.4c	581.8cd	19.1cd	1469.6d
63	21.8ab	13.2a	1.1a	31.9	939.3a	162.7bc	669.4bc	29.0ab	1800.4ab
64	21.8ab	11.7b	1.0b	30.8	822.5ab	147.1bc	701.2b	25.6bc	1696.4bc

In the same column, followed by different letters, differ by Tukey test (p ≤ 0.05).



Yields followed by different letters differed from each other by Tukey test at 5% probability, within each part of the fruit among the genotypes.

Figure 1. Yield (%) of peel, pulp, seed and placenta of fruits from six cupuassu tree genotypes.

(Souza et al., 2017). In this sense, improvement seeks to increase the yields of pulp and seeds in the total mass of the fruit, at the expense of the percentage of skin and placenta, since they are the main economic products of the crop (Alves et al., 2020). In this trial, clones 46, 61 and 64 stood out in terms of pulp yield, and may be promising genotypes for the production of fruit for pulp extraction, while they can be used in future breeding work as gene donors to improve this trait. For the production of almond derivatives, clones 32, 42 and 46 can be pointed out as promising genotypes for producers seeking this market niche (Figure 1).

On average, the genotypes studied presented 84.2% of humidity in the fruit pulp. This moisture content ranged from 83.0 to 85.9% in genotypes 32 and 64, respectively (Table 2), similar to Pugliese et al. (2013) who found moisture contents ranging from 83 to 90%, in fresh and commercial pulps.

Clone 46 showed higher ash content (3.6%) when compared to clone 32 (2.3%) (Table 2). This characteristic is considered a general measure of quality and is often used as a criterion in the identification of foods. It is also known as inorganic matter, corresponding to the amount of minerals present in food. The average value for this trait is higher than those observed by Pugliese et al. (2013) (1.2 %) and Sousa et al. (2020) (0.3 %).

Clones 42, 63, and 64 had protein contents above 7%, higher than the trial average (Table 2). These results were

Table 2. Moisture (%), ash (%), protein (%) and reducing sugar (%) contents in the pulp of six cupuassu tree genotypes.

Clones	Moisture	Ash	Protein	Reducing sugar
			(%)	
32	83.0 c	2.3b	6.9c	7.8a
42	83.3bc	3.3a	7.5a	7.3a
46	83.8bc	3.6a	6.9c	7.6a
61	84.3abc	3.2a	7.0bc	7.9a
63	85.2ab	3.0ab	7.4ab	6.1b
64	85.9a	3.4a	7.6a	6.3b

Averages, in the same row, followed by different letters, differ by Tukey test ($p \leq 0.05$).

higher than those reported by Pérez-Mora et al. (2018) who, found values around 5%. Cupuassu pulp is rich in protein, containing almost all essential amino acids except tryptophan, as well as some non-essential ones like asparagine and glutamine (Ramos et al., 2020). Obtaining genotypes with higher protein contents results in more nutritious derived products for consumers.

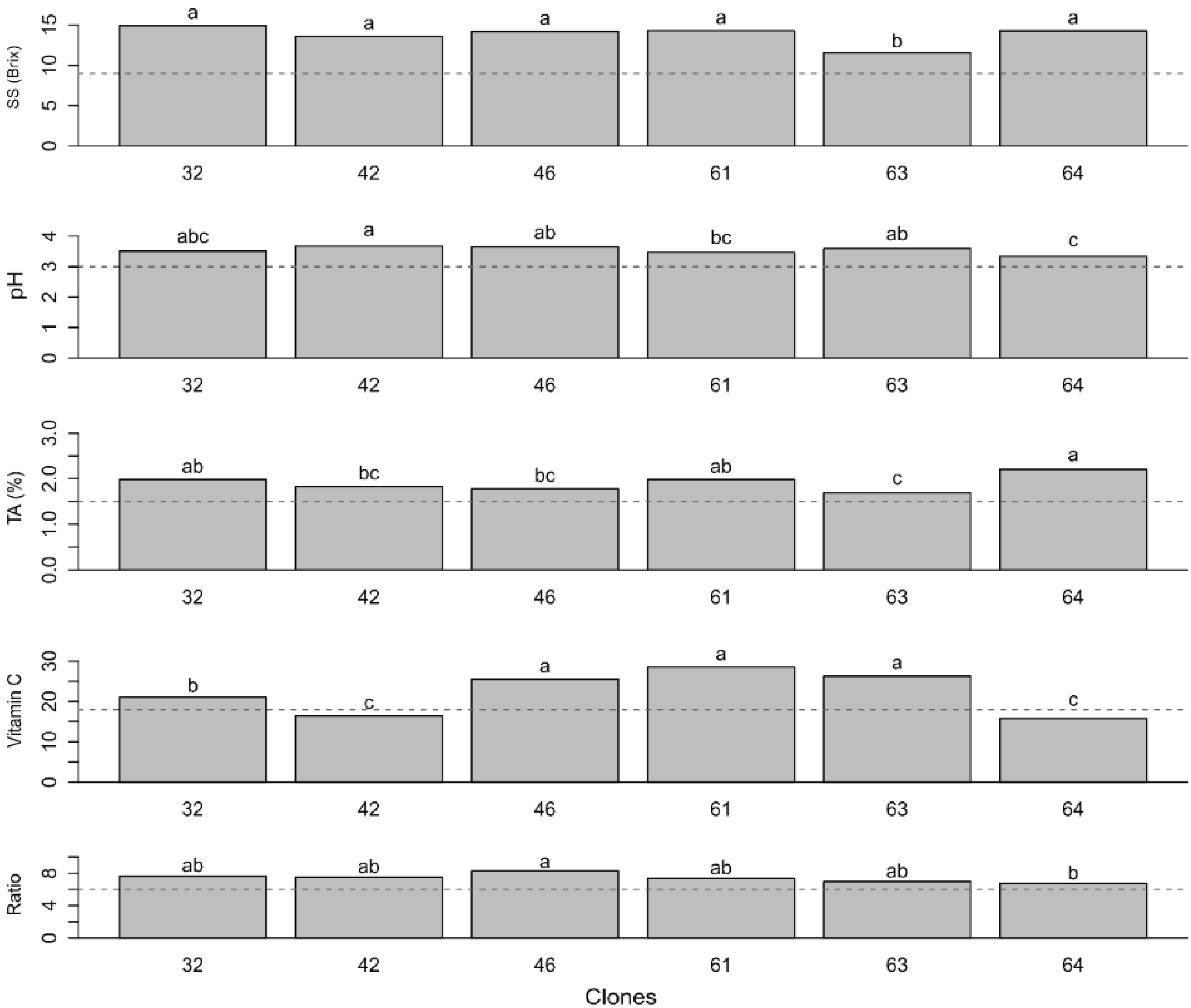
Regarding the reducing sugar contents, clones 32, 42, 46 and 61 stood out. It is important to point out that the reducing sugar content is an important characteristic in the indication of fruits destined to the juice industry, because it allows a better yield in the industrial processing. In addition to this use, fruits with higher levels of reducing sugars (glucose and fructose) are preferred for consumption *in natura*, since, these sugars confer better sensory properties, nutritional values and acceptance by consumers (Pérez-Mora et al., 2018). In the present study we observed higher results than those observed by Santos et al. (2010) in which the values ranged from 1.3 to 3.8% in different commercial cupuassu pulps. Therefore, considering only this variable, fruits from genotypes 32, 42, 46 and 61 would be the most indicated to meet the demand for fresh consumption.

Another important physical-chemical characteristic for the pulp market is the soluble solids (SS), which are related to the content of organic sugars and organic acids in the pulps. Thus, for the industry, the higher the fruit soluble solids value, the less pulp is needed for juice concentration. For this characteristic, all genotypes showed high values, differing only from clone 63, which showed the lowest SS value (11.5 °Brix) (Figure 2). It is worth noting that all values exceed the minimum quality standards required by Brazilian standards for cupuassu pulp (9.0 °Brix), proposed by the Ministério da Agricultura, Pecuária e Abastecimento (Brasil, 2018).

Clone 64 had the most acidic pulps, with the lowest pH value (Figure 2). This characteristic ensures the preservation of the pulp by interfering with the incidence of microorganisms, without the need for high heat treatments that, in a way, reflect on the nutritional quality of the pulp (Alexandre et al., 2015). The pulp of this genotype also shows higher titratable acidity. There is a clear relationship between the variables, where the genotype with the highest titratable acidity was the one with the lowest pH, while clone 63, with the lowest titratable acidity, also had the lowest soluble solids values, probably due to the relationship of the organic acids.

The divergent results of titratable acidity, as well as other physicochemical characteristics, stem from the difference not only between genotypes, but also the ripening stage of the fruit (Bojacá et al., 2019). This is proven when we take into account the results found here, and others in the literature, such as Santos et al. (2010), who measured titratable acidity values in cupuassu pulp samples ranging from 1.28 to 2.31% citric acid; Canuto et al. (2010) observed averages of 3.50% citric acid; and Costa et al. (2013), who obtained titratable acidity of 2.27% in citric acid in cupuassu pulp.

Ascorbic acid (AA), also known as vitamin C, is a water-soluble compound that is essential for a number of metabolic



The dotted line (..........): is MAPA pulp quality standard. Averages followed by different letters, differed by the Tukey test at 5% probability among the genotypes.

Figure 2. Average soluble solids (SS), hydrogen potential (pH), titratable acidity (TA), vitamin C (VIT C) and RATIO (ratio soluble solids/titratable acidity) of fruit pulp from six cupuassu tree genotypes.

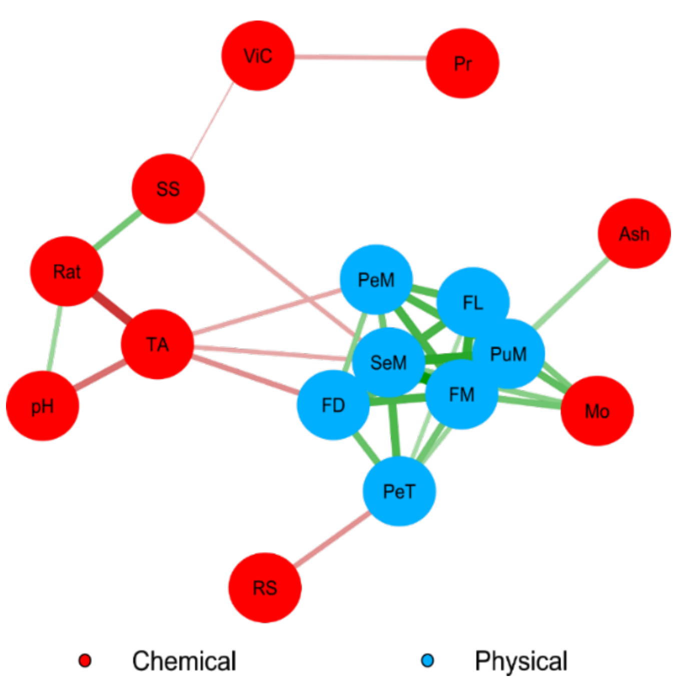
reactions, including iron absorption. The degradation of AA in foods depends on factors such as oxygen, light, water activity, temperature, and storage time (Figueiredo et al., 2020). In the materials evaluated in this study, the vitamin C values varied between 15.7 and 28.5 mg 100g^{-1} pulp. Clones 42 and 64 were below the standard value, while, clones 32, 46, 61 and 63 showed values above this quality reference standard proposed by current legislation (18.0 mg 100g^{-1}) (Brasil, 2018) (Figure 2). Therefore, these materials are interesting for the composition of products that have ascorbic acid as a commercial motto.

In this sense, Santos et al. (2010) analyzing seven commercial brands of industrialized cupuassu pulp, observed averages ranging from 4.95 to 15.26 mg of ascorbic acid per 100 g of cupuassu pulp. Sousa et al. (2011) found a value of 14.47 mg 100g^{-1} of ascorbic acid in cupuassu pulp residues. Pugliese et al. (2013) analyzed fresh and commercial pulps and observed average values ranging from 1.8 to 17 mg 100g^{-1} pulp, respectively. It is observed that this characteristic is very variable among the aforementioned studies, possibly due to the sensitivity of ascorbic acid, given its ease of degradation compared to the other vitamins. For this reason, the AA content is considered an index for maintaining the nutritional quality of foods, because if the presence of the element is verified in adequate amounts, it is understood that the percentage of retention of the other vitamins will be similar or higher (Sucupira et al., 2012).

The values of the ratio between soluble solids and titratable acidity (Ratio) ranged from 6.73 to 8.37. A certain standardization was observed in this characteristic, with differences only between clones 46 and 64. The Ratio determines the flavor of the fruit pulp, since it relates the soluble sugars, responsible for the sweetness, and the amount of free acids present in the pulp. Therefore, the higher this ratio, the sweeter the pulp. In pulps from different cocoa (*Theobroma cacao* L.) genotypes, Alexandre et al., (2015) observed SS/TA ratio values ranging from 6.46 to 9.1, soluble solid contents ranging from 12.97 to 16.55 °Brix, titratable acidity with values from 1.57 to 2.12% of citric acid and pH from 3.19 to 3.45. Also for cocoa, Bojacá et al. (2019) found soluble solids values ranging from 14.4 to 20.39 °Brix, titratable acidity ranging from 1.30 to 1.59% citric acid, and pH ranging from 3.4 to 3.6.

High correlation was observed among the physical characteristics and low correlation among the physicochemical ones (Figure 3). Such a result suggests the existence of linked or pleiotropic genes controlling the physical traits and the absence of these genes for the physicochemical ones (Montesinos-López et al., 2019). This hinders indirect selection for characters that are more difficult to measure, while maintaining the need for processing of the fruit components to obtain the physicochemical characters. It is important to evaluate correlations in more than one population or generation to define the true nature of the relationships (Cruz et al., 2014). Since the results observed in the present study are in line with those obtained by Alcoforado et al. (2019), there are strong indications that this is the pattern observed for the species.

The first two Principal Components (PC) provided an explanation of 76.1% (48.9% in Component 1 and 27.2% in Component 2) of the variance of the data (Figure 4), indicating that the representation of the diversity of the genotypes can be explained by these two PC (Cruz et al., 2014). Similar results were observed by Araújo et al. (2002) studying the physical characteristics of the fruits of 22 cupuassu tree genotypes, in which the first two principal components explained about 76% of the total variation of the characteristics. In the present study, the first principal component (PC1) correlated with most of the physical characteristics of the fruit, while the second component (PC2) was related to most of the physicochemical characteristics of the pulp. Therefore, it is observed that most of the variability is explained by the physical characteristics of the fruits, and therefore, there is a smaller contribution of this variation attributed to the physicochemical characteristics of the pulp.



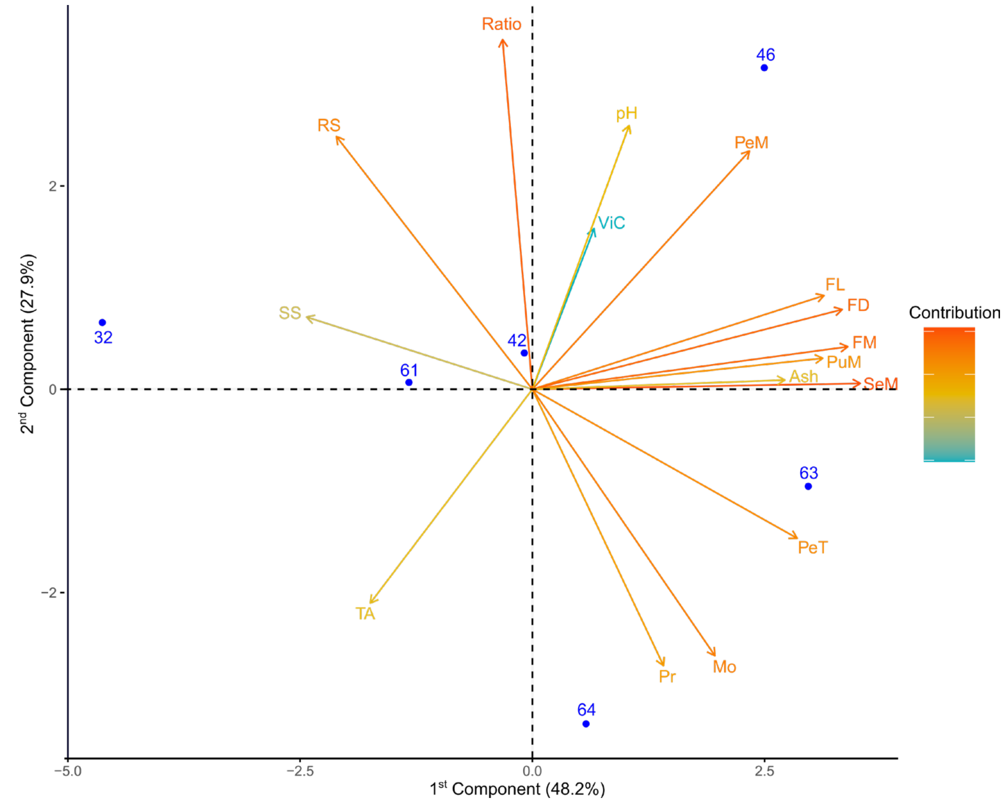
[†] Average fruit length (cm): FL; Average fruit diameter (cm): FD; Peel thickness (cm): PeT; Total fruit mass (g): FM; Pulp mass (g): PuM; Peel mass (g): PeM; Seed mass (g): SeM.
[‡] Soluble solids (ºBrix): SS; Vitamin C (mg ascorbic acid (AA)/100g pulp): ViC; Total acidity (g citric acid (CA)/100g pulp): TA; Proteins (%): Pr; Moisture (%): Mo; pH: Ratio; Ash (%): Ash; Reducing sugar (g glucose/100 g pulp): RS.

Figure 3. Network of correlations between physical[†] and physicochemical[‡] characters of cupuassu tree fruits.

It was observed that the physical characteristics such as peel mass, total fruit mass, fruit length, and seed mass; and the physicochemical characteristics Ratio and moisture content contributed the most to the composition of the components. Also according to this analysis, the variables, vitamin C, yields of pulp, placenta and peel, soluble solids, total acidity, pH, and ash had no relevant contribution to the composition of principal components. However, it is worth noting that this observation cannot be considered common sense for the species, since the materials used in the study are the fruit of a long process of improvement, which may have contributed to divergence among the clones for these characteristics.

The relationships observed in Figure 3 are corroborated by principal component analysis (Figure 4). The most economically important fruit characteristics, such as length, diameter, fruit mass, flesh mass, and seed mass (Figure 4) were positively correlated with each other. Among the physicochemical characteristics, the Ratio showed a positive correlation with soluble solids. Therefore, among the cupuassu tree genotypes studied, soluble solids contributed more to the SS/TA ratio than the titratable acidity content. Some physical characteristics, including fruit length, diameter, and mass, were negatively correlated with titratable acidity, showing that the larger the fruit, the less acidic its flesh. This result converges with two aspects of cupuassu tree improvement: obtaining genotypes with large fruits and with less acidic pulp.

The six genotypes analyzed were separated into three groups, demonstrating considerable divergence among them (Figure 4). The representation of clone 32 in the first quadrant indicates that this genotype presented, among the analyzed characteristics, higher values of soluble solids, reducing sugars, and seed yield. Importantly, these characteristics are desired for almond production and pulp quality. On the other hand, it presented small fruits and consequently lower pulp mass values. Clone 46 represented in the second quadrant indicates that characteristics such as seed mass, length, fruit mass and diameter are the standouts for this material. Clones 63 and 64 represented in the fourth quadrant showed higher values for bark thickness, protein and moisture content and tended to have lower values for reducing sugar and seed yield. The genotypes 42 and 61 were in the intermediate region for the analyzed characteristics.



† Average fruit length (cm): FL; Average fruit diameter (cm): FD; Peel thickness (cm): PeT; Total fruit mass (g): FM; Pulp mass (g): PuM; Peel mass (g): PeM; Seed mass (g): SeM.
‡ Soluble solids (ºBrix): SS; Vitamin C (mg ascorbic acid (AA)/100g pulp): ViC; Total acidity (g citric acid (CA)/100g pulp): TA; Proteins (%): Pr; Moisture (%): Mo; pH: Ratio; Ash (%): Ash; Reducing sugar (g glucose/100 g pulp): RS.

Figure 4. Biplot obtained with the values of the first two principal components, showing the dispersion of six cupuassu tree genotypes and the physical characteristics of the fruits† and physicochemical characteristics of the pulps‡.

Conclusions

The tested materials present adequate characteristics both for the pulp market (46, 61 and 64) and for the utilization of almonds (32, 42 and 46), with pulp quality indexes higher than those determined by the Brazilian legislation.

The genotypes studied have complementary comparative advantages. Clone 32, stands out for its pulp quality, with comparatively high reducing sugar content, soluble solids, titratable acidity and Ratio, despite having the smallest fruit.

Clone 42 has a medium-sized fruit with moderately acidic flesh, low vitamin C content, and high protein and ash contents.

The 46 has the fruit with the highest yield, that is, components of greater mass, besides having the pulp with the highest Ratio, being the most suitable for commercialization *in natura*.

The 61 stands out with the highest vitamin C content among the genotypes studied, as well as high titratable acidity and reducing sugar content, despite having a smaller fruit mass.

The 64 has an average fruit, with pulp poor in vitamin C, but rich in minerals and proteins, besides having the highest titratable acidity and lowest pH.

Clone 63 has a large fruit, but with most of its weight occupied by the rind.

From the principal component analyses, the physical characteristics of the fruit are more determinant in establishing variability among genotypes than the physicochemical variables of the pulp.

Compliance with Ethical Standards

Author contributions: Conceptualization: MEV, MSMF, IJMV; Data curation: RMA; Formal analysis: SFSC, MV; Funding acquisition: MSMF; Investigation: MEV, RMA, MSMF, SFSC, DAP; Methodology: MEV, MSMF, IJMV, DAP; Project administration: RMA; Resources: RMA, MV; Supervision: MSMF, IJMV; Visualization: MEV; Writing - original draft: MEV; Writing - review & editing: RMA, MSMF, IJMV, SFSC, DAP, MV.

Conflict of interest: The authors declare there is no conflict of interest for this research.

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