Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 31 March 2024
https://doi.org/10.14295/CS.v15.3721

Umbu physicochemical quality, diversity in the Caatinga biome and promising genotypes for consumption

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Abstract

Umbu (*Spondias tuberosa Arruda*) is a wild fruit species distributed all over the Caatinga biome in the Northeast of Brazil. The objective of this study was to analyze the physicochemical quality variability of umbu genotypes in the Caatinga biome, and to identify the most promising ones for fresh fruit consumption, processing industry and breeding programs. The fruit of 69 umbu genotypes were harvested at the maturity stage known as swollen, presenting full size and beginning of softening. The plants were cultivated in the umbu germplasm bank (UGB) at the Brazilian Agricultural Research Corporation, Embrapa, Petrolina, PE, Brazil. Each genotype was characterized by the global position system (GPS) coordinates to understand the distribution of fruit physicochemical quality in different regions in the Caatinga biome. According to the results, fruit physicochemical quality, such as mass, soluble solids (SS), titratable acidity (TA), and SS/TA ratio are homogeneously distributed all over the Caatinga biome. However, there were three main genotype groups, one characterized by higher fruit mass (52, 55, 57, 60, 65, and 68), other by higher SS (08, 09, 11, 20, 38, 41, and 62), and another by lower AT (02, 03, 07, 08, 16, 24, 27, and 51). Umbu genotypes with the highest mass and SS content can be used for commercial production in order to obtain fruit with desirable trait for the market. In addition, genotypes from all three groups can be used in breeding programs to obtain new genotypes with all desirable traits for fresh fruit consumption and processing industry.

Keywords: Consumer, fruit, in nature consumption, market, processing industry

Introduction

The plant known as umbuzeiro (*Spondias tuberosa* Arruda) belongs to the Anacardiaceae family that is composed by 80 genera and 600 species, among which 13 genera and 68 species are located in Brazil (Kiill et al., 2016). The genus *Spondias* was stablished in 1753 in the study *Genera Plantarum* authored by Linnaeus that aimed to group the "Tropical Plums" (Kiill et al., 2016). In this genus are other species with similar fruit such as cajazeira (*S. mombim*), cirigueleira (*S. purpurea*) and natural occurring hybrids, such as umbu-cajá (*S. mombin* x *S. tuberosa*), and umbuguela (*S. tuberosa* × *S. purpurea*) (Silva et al., 2014).

The umbuzeiro is a xerophyte endemic species of the Caatinga biome, which has an area of about 845 km^2, located in the Semi-arid region in the Northeast of Brazil (Pell et al., 2011; Araújo et al., 2016). Caatinga is an exclusive Brazilian biome composed by highly diverse species adapted to the Semi-arid environmental conditions (Lima Filho, 2011; Mitchell & Dali, 2015; Mertens et al., 2017).

The umbuzeiro fruit, known as umbu, is fleshy and highly appreciated for consumption in the Northeast of Brazil. Umbu mass can range from 2.8 to 120 g, skin color from green to yellow or red, soluble solids from 8 to 15%, acidity from 0.5 to 1.5% of citric acid, and ascorbic acid from 10 to 40 mg 100 g^{-1} (Costa et al., 2015; Dutra et al., 2017; Lima et al., 2018). In 2017, the umbu production was about 7.5 tons, which generated revenues of approximately R$ 7.76 million (IBGE, 2020). Although, umbuzeiro commercial cultivation is currently expanding, only a few cultivars have been launched by the Brazilian Agricultural Research Corporation, Embrapa and most of the umbu production still remains extractivist (Araújo et al., 2016; Barreto & Castro, 2010). In that case, highly heterogeneous fruit reach the market, which hinders price

Received: 07 April 2021
Accepted: 01 August 2023

standardization and postharvest strategies to maintain umbu quality. Therefore, genotype characterization studies are necessary in order to identify those with high potential for commercial purposes, which will guarantee high and homogeneous fruit quality to consumers.

The Embrapa Umbu Germplasm Bank (UGB) currently has 80 genotypes collected all over the Caatinga biome in the states of Pernambuco, Bahia, Rio Grande do Norte and Minas Gerais in Brazil (Oliveria et al., 2016). Preliminary studies have shown high genetic variability in the UGB (Santos et al., 2008) as well the leaf content and the nutrients cycling by the plant (Santos et al., 2020). However, more detailed studies will help selecting the best genotypes with high physicochemical quality and potential for commercial cultivation and consumption, as well as will help providing the most appropriated genetic background for breeding programs to obtain new genotypes with combined desired fruit traits for the fresh market and processing industry. In addition, identification of superior genotypes for commercial production will also provide the opportunity to define ideal crop management practices that can increase fruit productivity and quality, as well as will help developing efficient postharvest protocols to maintain fruit quality to consumers.

The objective of this study was to analyze the variability of fruit physicochemical quality of umbuzeiro genotypes in the Caatinga biome and to identify the most promising ones for fresh fruit consumption, processing industry and breeding programs.

Material and Methods

The Umbuzeiro Germplasm Bank (UGB) is located in the Caatinga Experimental Station, Embrapa, Petrolina, PE, Brazil (9°03'39'' S and 40° 18'49'' W), at an altitude of 365.5 m. The climate of the region is classified as BSh according to the Köppen e Geiger (1928) climate classification (Alvares et al., 2014). The Semi-arid region is highlighted on the Brazilian territory, as shown in (**Figure 1)**. The soil of the experimental area is a Yellow Argisol, with low water retention and poor fertility, highly representative of the Caatinga biome (Oliveria et al., 2006).

Although the UGB has 80 genotypes, only 69 genotypes presented fruit production during the two years of the study. These 69 genotypes were collected all over the Caatinga biome in the states of Pernambuco, Bahia, Rio Grande do Norte and Minas Gerais in Brazil (Oliveira et al., 2016). Each genotype was characterized by the global position system (GPS) coordinates to understand the distribution of fruit physicochemical quality in the Caatinga biome. The UBG followed a randomized block

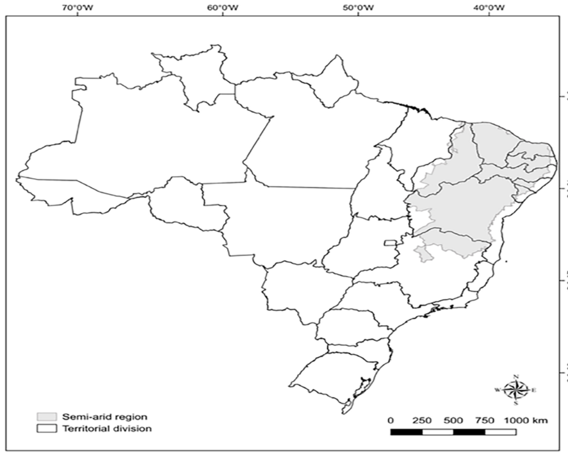

Figure 1. Semi-arid region in Brazilian.

design, where each genotype was represented by two blocks and each block by two plants spaced by 8.0 x 8.0 m (line x row). The plants age ranged from 15 to 20 years old, which represent the average age for high fruit production. Fruit of all genotypes were harvested during two production years at the physiological maturity known as swollen, characterized by full size and beginning of softening. A total of 10 fruit were harvested per block. Fruit harvest was accomplished at the end of the production cycle that took place from January to February in 2017 and in 2019. The air temperature (maximum and minimum), relative humidity (maximum and minimum) and rainfall were monitored during both fruit production cycles with an automatic agrometeorological station equipped with air temperature and relative humidity sensors (HMP45, Campbell Scientific, Logan, Utah, USA), as well as with a rainfall sensor (CS700-L, Hydrological Services Rain Gage, Liverpool, Austrália), data are presented in (**Figure 2**).

After harvest, fruit were analyzed in the Postharvest Laboratory at Embrapa, Petrolina, PE, Brazil. Fruit were analyzed for the longitudinal (LD), transverse

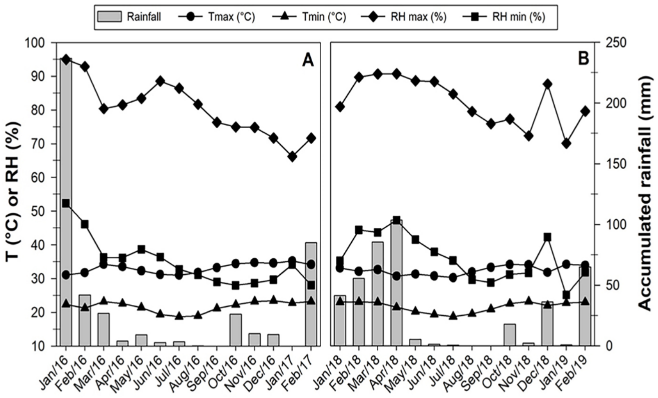

Figure 2. Monthly averages of air temperature (T) (maximum and minimum), relative humidity (RH) (maximum and minimum) and rainfall in the Caatinga Experimental Station, Embrapa, Petrolina, PE, Brazil, along the years preceding umbu harvest from January 2016 to February 2017 (A) and January 2018 to February 2019 (B).

(TD) diameters (cm) and LD/TD ratio. Fruit diameters were measured with a digital caliper (Digimess, SP, Brazil). Fruit were also analyzed for fruit mass (FM), pulp mass (PM), skin mass (SKM), and seed mass (SEM) using a semi-analytical balance (Mars AD500, SP, Brazil). All fruit on each sample were then juiced to determine the soluble solids (SS) content, titratable acidity (TA) and pH. The SS content was determined with a digital refractometer Pal-1 (Atago, SP, Brazil) and the results were expressed in percentage. The TA was determined by titrating 5 mL of juice diluted in 50 mL of distilled water with NaOH at 0.1 N. The titration was accomplished until pH 8.1 using an automatic titrator model 848 Titrino Plus (Metrohm, SP, Brazil) and the results were expressed as percentage of citric acid in the juice. The juice pH was also determined with the automatic titrator model 848 Titrino Plus (Metrohm, SP, Brazil). The SS/TA ratio was calculated by dividing the SS value by the TA value on each sample.

The data were used to obtain a similarity matrix through the average Euclidean distance between the variables. The similarity matrix allowed grouping the genotypes in a dendogram, using the method of mean intergroup linkage, known as Unweighted Pair Group Method using Arithmetic averages (UPGMA). The cutoff region followed the software suggestion (Cruz, 2013; software Genes, version 1990.2019.15, Federal University of Viçosa, MG, Brazil), which takes into account the significance of the clusters according to the method describe by Mogena (1977).

The data were also subjected to the Principal Component Analysis (PCA) using the software Statistica 10.0 (StatSoft, OK, USA) to identify the fruit physicochemical traits that most influence the observed variability, as well as to determine genotype relationship to the components of variation. A class map was developed with the QGIS Software 2.18 (QGIS Development Team, https://qgis.org/en/site/index.html), using the physicochemical quality trais fruit mass, SS, AT and SS/AT, in order to observe the distribution of each genotype in the Caatinga biome, based on these quality parameters.

Results and Discussion

The environmental conditions in the UGB localized in the Caatinga Experimental Station at Embrapa, Petrolina, PE, along the years preceding umbu harvest from January 2016 to February 2017 and January 2018 to February 2019, are shown in Figure 2. In both years, the rainfall was high and decreasing from January to July, no rainfall was observed in August and September, and increasing rainfall was observed from October to February in the following year, when the fruit were harvested (Figure 2). The maximum relative humidity ranged from about 95% to 65%, whereas the minimum relative humidity ranged from about 52% to 25%, in both years (Figure 2). The maximum air temperature ranged from about 35°C to 30°C, whereas the minimum air temperature ranged from about 25°C to 20°C, in both years (Figure 2).

According to the results, the umbuzeiro genotypes showed high variability on fruit physicochemical quality (Supplemental Table 1). The data obtained show that umbu longitudinal diameter ranged from 1.6 to 4.5 cm, transverse diameter ranged from 1.3 to 4.5 cm, DL/DT ratio raged from 0.8 to 1.2, fruit mass ranged from 6.4 to 44.1 g, seed mass ranged from 0.8 to 5.4 g, skin mass ranged from 1.4 to 10.3 g, pulp mass ranged from 2.8 to 33.1 g, titratable acidity ranged from 0.4 to 1.6%, soluble solids ranged from 8.3 to 14.1%, SS/TA ratio ranged from 6.7 to 27.9, pH ranged from 2.2 to 4.0 (Supplemental Table 1).

In our study, the most important physicochemical parameters desired for fresh consumption and processing industry were considered to be fruit mass, SS, TA and SS/TA ratio. These quality parameters were analyzed in umbu genotypes from different regions in order to better understand the geographical distribution of these quality traits in the Caatinga biome (**Figure 3**). The results obtained showed that umbu quality traits are evenly distributed all

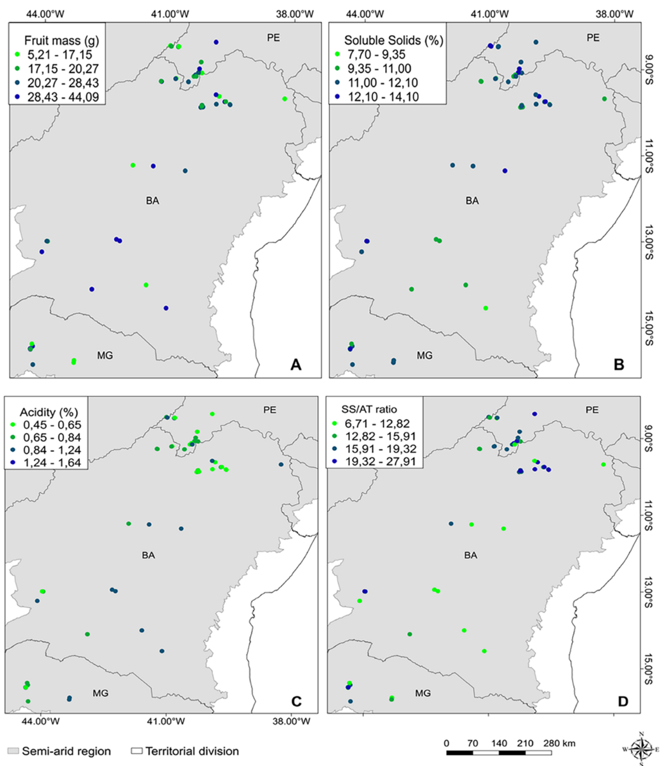

Figure 3. Distribution of umbuzeiro genotypes in the Semi-arid region in Brazil. Each genotype is presented as a colored dot that ranges from light green to dark blue, which means lower to higher fruit mass (A), soluble solids (B), titratable acidity (C), or SS/TA ratio (D), respectively.

over the Caatinga biome, without presenting a specific pattern (Figure 3).

Grouping genotypes in a similarity matrix was accomplished by taking into account the average link between the groups (coefficient of correlation = 0.7509) (**Figure 4**). Observing the genotypes on a descending vertical scale, and taking into account the region of cut, one can see the formation of a larger group containing the genotypes 23 to 13 (Figure 4). Another group can also be observed containing the genotypes 56 to 68 (Figure 4). The remaining genotypes formed small groups or were separated from the others. Both large groups contain genotypes from different origins in the Caatinga biome (Figure 4 and Supplemental Table 1).

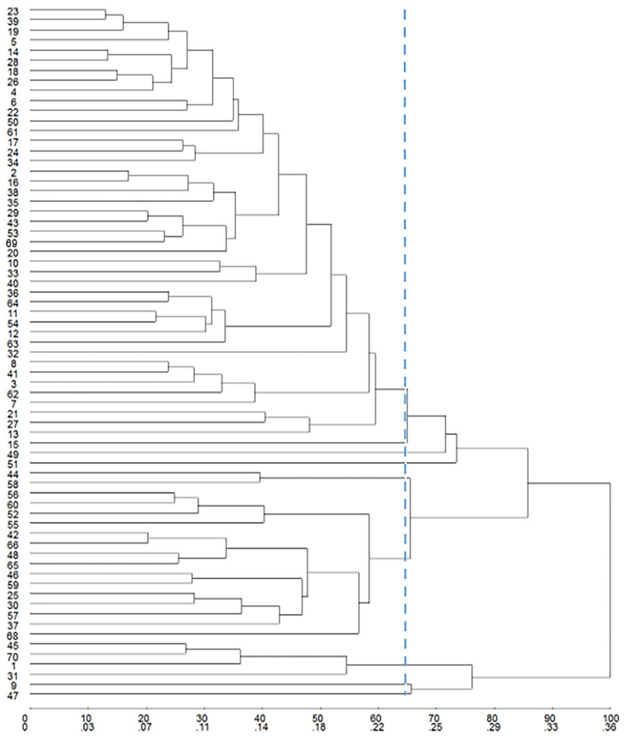

Figure 4. Dendogram of the average Euclidean distance between umbuzeiro genotypes, determined based on the eleven fruit physicochemical quality parameters. Genotypes were grouped according to the method of mean intergroup linkage, known as Unweighted Pair Group Method using Arithmetic averages (UPGMA). Dashed line represents cutoff region suggested by Genes software, which was determined considering the significance of the clusters according to the method of Mogena (1977).

According to the principal component analysis (PCA), it was possible to identify the most influential phenotypic traits characterizing the genotypes. Among 11 components, 7 were discarded based on the Genes software suggestion, following the approach described by Jolliffe (1972). The physicochemical traits were then grouped into 4 components, with a cumulative proportion of 89.28% (**Table 1**). The PCA 1 contributed with 49.13% of the variability, which showed a strong effect on separating genotypes based on LD, TD, LD/TD ratio, FM, PM, SKM and SEM (Table 1 and **Figure 5**A). The PCA 2 contributed with 23.64% of the variability, which showed a strong effect on separating genotypes based on SS content, TA and pH (Table 1 and Figure 5A).

Table 1. Principal component and correlation analyses between variables and each component

Variance components	Principal Components (Factors)			
	1	2	3	4
Eigenvalues	5.4014	2.6005	1.0684	0.7508
Propotion (%)	49.1343	23.6413	9.7130	6.8255
Propotion acumulated (%)	49.1343	72.7457	82.4588	89.2843
Variables	Correlation with Principal Components			
Longitudinal Diameter (DL)	+0.3991	-0.0784	+0.1902	+0.0617
Tranverse Diameter (DT)	+0.4092	-0.0550	-0.1923	-0.0691
LD/TD ratio	-0.1160	-0.0229	+0.8973	+0.2844
Fruit mass	+0.4214	-0.0349	+0.0592	+0.0518
Seed mass	+0.3728	+0.0389	+0.0734	+0.1606
Skin mass	+0.3890	-0.1467	-0.0327	+0.0999
Pulp mass	+0.4094	+0.0155	+0.0767	+0.0178
Titatrable acidity (TA)	+0.0347	-0.5560	-0.0577	+0.3237
Soluble solids (SS)	-0.1236	-0.3348	-0.2816	+0.8335
SS/TA ratio	-0.0890	-0.5735	-0.0454	+0.0131
pH	+0.0065	-0.4644	+0.1459	-0.2684

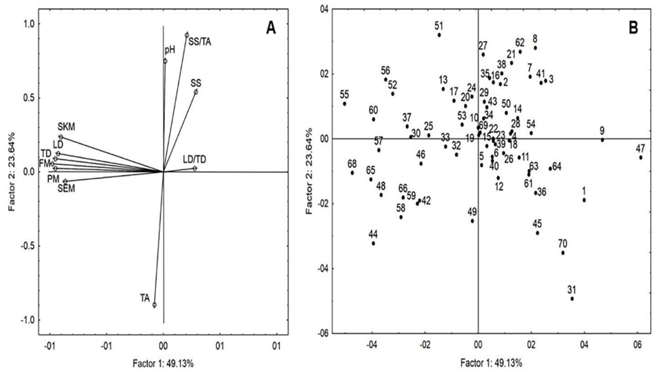

Figure 5. Principal component analysis for eleven fruit physicochemical quality parameters in 69 umbuzeiro genotypes belonging to the UGB at Embrapa, Petrolina, PE, Brazil. The quality parameters presented were longitudinal (LD) and transverse (TD) diameters, LD/TD ratio, fruit mass (FM), pulp mass (PM), skin mass (SKM), seed mass (SEM), soluble solids (SS) content, titratable acidity (TA) and pH.

Geographical distribution of umbu physicochemical quality in the Caatinga biome

The umbuzeiro genotypes analyzed in our study showed a homogeneous distribution of fruit physicochemical traits along the Caatinga biome. In other words, the results showed no specific pattern of geographical genotype groups based on fruit physicochemical quality. Therefore, umbuzeiro genotypes with fruit presenting desirable traits for consumption such as bigger size, higher SS content and lower TA were observed all over the Caatinga biome.

The wide variability on umbu physicochemical quality observed in our study has also been shown in other studies with wild umbu produced in semi-arid conditions (Santos et al., 1999; Santana et al., 2011). These results show a great potential for the selection of umbuzeiro genotypes with desirable traits for the fresh market and processing industry, as well as for breeding programs to obtain new genotypes with combined desirable traits.

Umbu genotypes for fresh consumption, processing industry and breeding programs

According to a study carried out with agro-extractivist communities in the Brazilian Caatinga biome, 34% of people working with wild umbu harvest the fruit based on size, whereas 50% harvest the fruit based on the maturity stage (Araújo et al., 2016). In these communities, 64% of the wild fruit is destined for industrial processing, 32% for the fresh market, and the remaining 4% is used for local consumptions in the community. In this study, umbu consumers were asked to rank the most important traits for consumption. The results showed that 54% of the consumers consider sugar content as the most important trait, 36% consider fruit size as the most important trait, and 10% consider a mixture of other traits important for consumption (Araújo et al., 2016). Accordingly, other studies have shown that SS content and TA play an important role on determining fruit quality for consumptions, but more important is the ratio between SS/AT in the fruit (Baldwin et al., 1998). Although the results obtained in our study show that umbu physicochemical variability is well distributed all over the Caatinga biome, without presenting specific patterns, the results also show a high variability in fruit physicochemical quality among wild umbuzeiro genotypes. Accordingly, fruit mass ranged from 6.4 g to 44.1 g, SS content ranged from 8.3 % to 14.1%, TA ranged from 0.4% to 1.6%, and SS/AT ratio ranged from 6.7 to 27.9. Other studies analyzing the genetic variability of wild umbuzeiros have also shown high variability of the species in the Caatinga biome (Gondim et al., 2013; Yamamoto et al., 2017a; Yamamoto et al., 2017b).

In our study, the cluster analysis shows on a vertical descending scale that the largest group is composed by the genotypes between 23 and 13, which are characterized by higher SS content. The second largest group is formed by the genotypes from 56 to 68 that are characterized by higher fruit mass. Confirming the cluster analysis, the PCA analysis also show a separation of genotypes in different groups based on fruit physicochemical quality. One group contains fruit with higher SS, other group contains fruit with higher mass, and another group contains fruit with lower TA. These results have shown that although all groups have desirable physicochemical quality parameters that could be used for fresh fruit consumption and processing industry, there is no single genotype presenting all desirable quality traits with the highest values for fruit mass and SS, as well as the lowest AT to result in the highest SS/AT ratio. In that case, the genotypes presenting 20% of the highest mass (>36.5 g) were 52, 55, 57, 60, 65, and 68. The genotypes presenting 20% of the highest SS (>12.9%) were 08, 09, 11, 20, 38, 41, and 62. The genotypes presenting 20% of the lowest AT (<0.6%) were 02, 03, 07, 08, 16, 24, 27, and 51. The genotypes with high fruit mass and SS content can be used for commercial production in order to obtain fruit with desirable trait for fresh consumption and processing industry. In addition, breeding programs can explore the observed physicochemical variability among all three groups to obtain new genotypes with all desirable traits for fresh fruit consumption and processing industry.

Conclusions

Fruit physicochemical variability of umbuzeiro genotypes is evenly distributed in the Caatinga biome in the Brazilian semi-arid region.

Cluster and principal components analyses showed three major and distinct umbuzeiro genotype groups based on fruit physicochemical quality, one influenced by mass, other by the SS content, and another by TA. The umbuzeiro genotypes with the highest fruit mass were 52, 55, 57, 60, 65, and 68, genotypes with the highest SS content were 08, 09, 11, 20, 38, 41, and 62, whereas genotypes with the lowest TA were 02, 03, 07, 08, 16, 24, 27, and 51.

Umbu genotypes with high fruit mass and SS content can be used for commercial production in order to obtain fruit with desirable trait for fresh consumption and processing industry.

Umbu genotypes with the highest mass and SS content, and the lowest TA can be used in breeding programs to obtain new genotypes with all desirable traits for fresh fruit consumption and processing industry.

Acknowledgements

The authors would like to thank the Brazilian Agricultural Research Corporation (Embrapa), the United Nations Development Programme and the Financiadora de Estudos e Projetos (FINEP) for the financial support.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Supplemental Table 1. Physicochemical quality of umbu genotypes harvested at the maturity stage known as swollen, characterized by full fruit size and beginning of softening. Averages were calculated with data obtained in two production cycles in 2017 and 2019. Fruit were evaluated for longitudinal diameter (LD), transversal diameter (TD), LD/TD ratio, fruit mass, seed mass, skin mass, pulp mass, titratable acidity (TA), soluble solids (SS), SS/TA ratio and pH. Genotypes were collected all over the Caatinga biome in the states of Pernambuco, Bahia, Rio Grande do Norte and Minas Gerais in Brazil.

UGB	Municipalities	LD (cm)	TD (cm)	LD/TD	Fruit (g)	Seed (g)	Skin (g)	Pulp (g)	AT (%)	SS (%)	SS/AT	pH
01	Juazeiro, BA	2.5	2.3	1.1	7.5	1.4	1.9	4.3	0.8	10.4	13.8	2.4
02	Juazeiro, BA	3.5	3.1	1.1	20.0	2.4	5.1	12.6	0.5	11.3	23.8	3.0
03	Juazeiro, BA	3.1	2.7	1.2	14.2	1.5	4.9	7.8	0.5	12.6	24.2	2.9
04	Juazeiro, BA	3.3	3.1	1.1	18.5	2.0	4.1	12.4	0.7	11.1	17.2	3.0
05	Juazeiro, BA	3.5	3.1	1.1	21.4	2.8	5.2	13.4	0.8	10.3	12.6	3.0
06	Juazeiro, BA	3.4	3.1	1.1	20.0	2.3	5.7	12.0	0.7	10.8	16.2	2.5
07	Juazeiro, BA	3.1	2.9	1.1	15.9	2.1	4.6	9.3	0.4	12.0	27.9	2.7
08	Juazeiro, BA	3.1	3.0	1.1	15.7	1.7	4.7	9.4	0.5	13.5	25.5	3.4
09	Afrânio, PE	2.4	2.2	1.1	6.4	1.3	2.1	3.1	0.7	13.6	18.7	2.5
10	Afrânio, PE	3.9	3.2	1.2	22.7	3.0	5.8	13.9	0.8	12.5	15.6	3.0
11	Afrânio, PE	3.1	3.0	1.1	17.5	2.4	3.8	11.3	1.0	13.1	13.8	2.8
12	Petrolina, PE	3.1	3.1	1.0	18.1	2.7	5.1	10.3	1.0	11.6	12.0	2.8
13	Petrolina, PE	3.8	3.6	1.1	26.5	3.1	7.4	16.0	0.7	11.6	15.7	3.8
14	Petrolina, PE	3.5	2.9	1.2	17.2	2.6	3.9	10.7	0.6	11.4	19.3	2.9
15	Juazeiro, BA	3.2	3.9	0.8	15.3	2.3	5.6	7.5	0.8	12.1	14.8	2.8
16	Juazeiro, BA	3.4	3.2	1.1	20.3	2.3	5.7	12.2	0.5	11.8	22.3	3.1
17	Juazeiro, BA	3.9	3.5	1.1	25.0	3.4	6.0	15.7	0.6	10.9	17.5	3.4
18	Casa Nova, BA	3.2	3.0	1.1	16.9	2.3	4.5	10.0	0.6	10.1	16.5	3.0
19	Casa Nova, BA	3.6	3.3	1.1	22.2	2.8	5.2	14.2	0.7	11.6	15.9	2.9
20	Casa Nova, BA	3.6	3.5	1.0	25.1	2.7	6.5	15.9	0.7	13.0	20.3	2.7
21	Santa Maria da Boa Vista, PE	3.4	3.1	1.1	17.4	1.9	5.2	10.3	0.6	12.1	19.2	4.0
22	Petrolina, PE	3.2	3.2	1.0	18.9	2.3	5.9	10.8	0.7	10.7	17.1	2.8
23	Juazeiro, BA	3.5	3.1	1.1	18.8	2.8	5.5	10.5	0.7	11.2	15.9	2.8
24	Petrolina, PE	3.8	3.3	1.2	22.4	2.7	6.2	13.4	0.5	10.2	20.3	3.2
25	Casa Nova, BA	3.8	3.6	1.1	29.3	3.2	7.5	18.7	0.7	10.5	15.1	3.0
26	Casa Nova, BA	3.4	3.0	1.1	17.9	2.4	4.5	11.1	0.7	10.1	15.6	2.8
27	Lagoa Grande, PE	3.5	3.4	1.0	21.2	3.0	5.1	13.1	0.5	10.9	24.2	3.7
28	Uauá, BA	3.4	3.0	1.2	17.9	2.3	4.3	11.3	0.6	11.0	17.8	2.9
29	Uauá, BA	3.1	3.1	1.0	22.5	3.1	6.5	13.0	0.6	11.8	19.7	3.1
30	Afrânio, PE	3.8	4.0	1.0	31.4	4.0	6.0	21.4	0.7	10.3	15.3	3.0
31	Uauá, BA	2.6	2.3	1.1	7.5	2.0	2.7	2.8	1.6	11.0	6.7	2.2
32	Uauá, BA	3.4	3.3	1.0	23.4	4.6	5.9	13.0	0.7	10.5	15.9	2.6
33	Uauá, BA	3.9	3.5	1.1	27.3	3.2	6.6	17.5	0.8	11.9	14.6	2.7
34	Uauá, BA	3.7	3.2	1.1	23.1	2.2	4.3	16.6	0.6	10.4	17.6	3.2
35	Uauá, BA	3.3	3.6	0.9	19.3	2.3	5.3	11.7	0.6	12.0	24.3	3.1
36	Uauá, BA	3.0	2.8	1.1	12.8	2.5	3.6	6.7	1.1	11.8	11.2	2.8
37	Uauá, BA	4.4	3.7	1.2	31.5	3.9	8.3	19.3	0.8	11.4	15.0	2.9
38	Uauá, BA	3.4	3.2	1.1	20.0	2.6	4.9	12.5	0.6	12.9	21.5	3.3
39	Petrolina, PE	3.4	3.1	1.1	19.7	2.5	5.1	12.1	0.8	11.3	14.8	3.0
40	Petrolina, PE	3.8	3.3	1.2	20.1	2.1	3.9	14.2	1.0	11.9	12.4	3.0
41	Juazeiro, BA	3.2	2.9	1.1	14.7	1.9	3.6	9.3	0.6	12.9	22.1	3.2
42	Juazeiro, BA	3.7	3.7	1.0	30.6	4.0	6.4	20.2	1.1	11.3	9.9	2.7
43	Uauá, BA	3.2	3.4	1.0	20.9	2.8	5.1	13.0	0.6	11.9	20.5	3.0
44	Anajé, BA	4.1	4.0	1.0	35.6	5.1	6.5	24.0	1.1	8.3	7.3	2.6
45	Brumado, BA	2.9	2.9	1.0	12.2	1.4	3.6	7.2	1.0	10.4	10.1	2.2
46	Guanambi, BA	3.9	3.8	1.0	31.7	2.4	6.6	22.7	0.7	9.8	14.2	2.5
47	São Gabriel, BA	1.6	1.3	1.3	8.7	0.8	1.4	6.4	0.7	11.5	16.2	2.9
48	América Dourada, BA	4.1	4.1	1.0	36.1	4.9	6.9	24.3	1.1	11.7	11.0	2.4
49	Miguel Calmon, BA	3.7	3.3	1.1	22.1	3.5	4.9	13.7	1.2	12.3	9.9	2.3
50	Santana, BA	3.3	3.1	1.1	17.4	2.8	4.1	10.6	0.7	11.2	17.0	3.4
51	Santana, BA	4.3	3.7	1.2	28.4	3.5	6.6	18.3	0.5	12.7	25.9	3.4
52	Parnamirim, PE	4.2	3.9	1.1	37.3	4.3	7.2	25.8	0.6	12.1	19.6	3.0
53	Petrolina, PE	3.5	3.4	1.0	25.3	2.7	6.1	16.6	0.7	11.2	16.1	3.2
54	Caiçara, RN	3.0	2.9	1.0	14.9	2.3	3.7	8.9	0.8	12.8	15.2	3.2
55	Lagoa Grande, PE	4.4	4.2	1.0	44.1	4.6	10.3	29.2	0.7	12.7	17.6	2.7
56	Januária, MG	4.0	3.8	1.1	36.3	5.4	8.9	22.1	0.6	11.9	20.9	3.1
57	Januária, MG	4.1	3.9	1.1	37.3	4.7	7.6	25.1	0.7	10.1	14.0	2.8
58	Januária, MG	4.3	3.6	1.2	32.3	5.2	5.7	21.3	1.1	9.0	8.6	2.7
59	Januária, MG	3.9	3.9	1.0	31.8	2.6	6.2	23.0	1.0	10.4	10.4	2.4
60	Januária, MG	4.1	4.0	1.0	37.3	5.2	8.7	23.4	0.7	11.4	16.8	2.8
61	Januária, MG	3.1	2.8	1.1	14.4	2.3	3.0	9.1	0.8	10.0	12.8	3.0
62	Januária, MG	3.3	3.0	1.1	18.0	2.9	4.5	10.6	0.6	14.1	25.2	3.2
63	Janaúba, MG	2.9	2.9	1.0	12.1	3.5	3.2	5.4	0.9	11.7	12.6	3.0
64	Janaúba, MG	2.9	2.7	1.1	12.1	1.5	3.4	7.2	0.9	11.9	13.5	2.8
65	Santa Maria da Vitória, BA	4.3	4.1	1.1	37.2	5.0	7.5	24.7	1.1	11.3	10.5	2.8
66	Ibipitanga, BA	3.9	3.9	1.0	32.0	4.1	7.1	20.8	1.1	10.2	9.5	2.8
67*	Ibipitanga, BA	-	-	-	-	-	-	-	-	-	-	-
68	Lontra, MG	4.5	4.5	1.0	42.9	3.2	6.6	33.1	0.9	9.9	10.6	2.9
69	Lontra, MG	3.2	3.2	1.0	24.2	2.6	5.2	16.4	0.7	11.5	17.4	2.8
70	Paulo Afonso, BA	2.7	2.4	1.1	9.1	1.5	2.9	4.7	1.2	9.8	9.7	2.3

*The BGU67 genotype did not produce fruit in 2017 and 2019.