AGRONOMY (AGRONOMIA)

Fruit characterization of genotypes of bread-fruit tree of municipalities in the Recôncavo Baiano, Brazil

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ABSTRACT: The breadfruit tree (*Artocarpus altilis*) is an exotic species found in tropical regions of the world, serving the cultivation of small farmers. This study aimed to evaluate the variability of breadfruit, genotypes located in four districts of the Recôncavo Baiano region (Cruz das Almas, Governador Mangabeira, São Felipe and Sapeaçu) through a characterization of the fruits. Were identified and georeferenced 32 genotypes. For each genotype, eight fruits were collected, which were evaluated for: fruit weight, length and diameter of the fruit pulp thickness, pulp yield length and diameter of the floral axis, weight of the pulp, the shaft and the shell. The pulps were homogenized for physical-chemical and chemical analysis (pH, titratable acidity, the total sugar, reducing sugar and non-reducing sugar, ashes, starch and protein). The data were submitted to descriptive statistical analysis and multivariate cluster analysis. The results showed variability among genotypes, with the formation of four main groups of genetic dissimilarity. Multivariate analysis was efficient to discriminate genotype CA5 and CA9 as the most divergent. The characteristics that contribute most to the formation of groups were full starch and yield of pulp.

Key words: *Artocarpus altilis*; diversity; variability

Caracterização de frutos de genótipos de fruteira-pão de municípios do Recôncavo Baiano

RESUMO: A fruteira-pão (*Artocarpus altilis*) é uma espécie exótica encontrada nas regiões tropicais do mundo, que atende ao cultivo de pequenos agricultores. O presente trabalho teve por objetivo avaliar a divergência de genótipos de fruteiras-pão, localizadas em quatro municípios da região do Recôncavo Baiano (Cruz das Almas, Governador Mangabeira, São Felipe e Sapeaçu) por meio da caracterização dos frutos. Foram identificados e georreferenciados 32 genótipos. Para cada genótipo, foram coletados oito frutos, os quais foram avaliados quanto a: peso do fruto, comprimento e diâmetro do fruto, espessura e peso da polpa, rendimento de polpa, comprimento e diâmetro do eixo floral, peso do eixo e da casca. As polpas foram homogeneizadas para análises físico-químicas e químicas (pH, acidez titulável, açúcar total, açúcar redutor e açúcar não redutor, cinzas, amido e proteína). Os dados foram submetidos à análise estatística descritiva e análise multivariada de agrupamento. Os resultados revelaram divergência entre os genótipos, havendo a formação de quatro grupos principais de dissimilaridade genética. A análise multivariada foi eficiente em discriminar o genótipo CA5 e CA9 como os mais divergentes. As características que mais contribuem para a formação dos grupos são amido e rendimento de polpa.

Palavras-chave: *Artocarpus altilis*; diversidade; variabilidade

Introduction

The breadfruit (*Artocarpus altilis* (Park) Fosberg) is a plant native to the Indo-Malaysia region, being cultivated in the islands of the Asian archipelago and in tropical regions around the world. In Brazil, it occurs frequently in the Amazon region and in the states of Bahia, Paraíba, Alagoas, Sergipe, Pernambuco and Ceará (Sacramento et al. 2009).

This plant has fast growth, a leafy crown and can reach the height of 15 to 30 m, and more than 1.5 m in diameter of the stem. The leaves are 40 to 75 cm long and 26 to 46 cm wide. It is a monoic plant, the female inflorescence is provided with several unicarpellate flowers, involving a globular receptacle, giving rise to subglobose or ovoid chapters, with the perianth attached to the base (Sacramento et al. 2009).

There are two varieties of breadfruit, namely with seed (*A. altilis* var. *Seminifera*) and without seed (*A. altilis* var. *Apyrena*). The breadfruit can be propagated by grafting, making possible the production of seedlings (Santana et al., 2014). The seedless breadfruit pulp is more used in natura, has a high content of carbohydrate, water, vitamins B1, B2, C, calcium, phosphorus, iron, low fat and can be used as a dried fruit. Its flour can be used in breads, and it is also a good source of starch. The breadfruit is a great food, acting as an intestinal regulator (Latchoumia, 2014). It can be used as anti-inflammatory, anti-diabetic, anti-bacterial and estrogen regulation (Somashekhar et al 2013) and also as antioxidant (Amarasinghe et al. 2008).

A work conducted by Jones et al. (2011) revealed a high degree of phenotypic diversity in breadfruit varieties in Hawaii, also obtaining great genotypic variation in relation to characteristics such as protein and mineral content. Ragone (2011) indicated the existence of variety with quality protein, superior to that of potato, wheat, rice and pea.

The selection of genotypes is of great relevance in order to acquire superior materials, seeking to obtain agronomic traits of interest (Pimentel et al., 2013). The characterization generates information about the genotypes, such as botanical and genetic characteristics (Costa et al. 2007)

Thus, aiming at the knowledge of the breadfruit in the conditions of the Recôncavo Baiano region, this work had the objective of identifying the existing variability in breadfruit trees located in four cities of the region through phenotypic characteristics of the fruit.

Material and Methods

The work was carried out in 2014, with the trees already placed at the collection sites. We evaluated 32 genotypes of breadfruit var. *apyrena* located in the cities of Cruz das Almas, Governador Mangabeira, São Felipe and Sapeaçu, in the region of Recôncavo Baiano, located between 12° 23' and 13° 24' S and 38° 38' and 40° 10' O, with an average air humidity of 81%, a mean monthly rainfall of 95.2 mm and average temperatures of 20.1-28.7° C, which gives it characteristics of tropical climate.

Eight fruit were collected for each genotype at the maturation stage "almost ripe", in which the peel is less rough and yellow-greenish. The external physical measures evaluated were length, diameter and weight of the fruit. The fruits were peeled using a knife, removing 1 to 2 mm of peel, cut in half in the longitudinal direction and evaluated for pulp thickness (cm), length (cm) and diameter of the floral axis (cm), pulp mass (kg), floral axis mass (kg) and peel mass (kg) and pulp yield (%), calculated by the equation: pulp mass/fruit mass x 100. The pulps were homogenized for physical-chemical and chemical analyzes, namely pH, with pHgameter; titratable acidity (%), expressed as ascorbic acid; total sugars (%); reducing sugars (%) and non-reducing sugars (%); starch content (%), as recommended by Instituto Adolfo Lutz (1985), ash content (%) and total protein content (%) by the method of Semi-micro Kjeldahl. The chemical and physicochemical analyzes were performed in triplicate.

Data were analyzed by descriptive statistics, using SAS - Statistical Analysis System (Sas institute, 1989), obtaining centrality and dispersion measures, namely minimum, mean and maximum values, amplitude, coefficient of variation and standard deviation. The multivariate analysis was performed and, as a measure of dissimilarity, the mean Euclidean distance was calculated, and the UPGMA-Unweighted pair-group method using arithmetic averages (Johnson & Wichern 2007) was used to form the groupings. The relative contribution rates for dissimilarity were calculated by the method of Singh (1981). The analyzes were performed by the statistical programs Genes (Cruz, 2013) and the dendrograms were obtained by the Statistica program (Statsoft 2005).

Results and Discussion

The analysis of the physical characteristics of the fruit indicated the existence of variation among the evaluated genotypes. The coefficients of variation presented an amplitude of 7.03% for the diameter of the fruit at 24.37% for the mass of the floral axis (Table 1).

The fruit mass varied from 0.69 kg to 1.35 kg, with a mean of 0.98 kg, with SF20 as the best for this variable. Studies in the literature indicate a wide variation for this characteristic. Sacramento et al. (2009) reported a variation of 1 kg to 3 kg, and Nunes et al. (2011) found a mass of 0.73 kg, working with the breadfruit in Venezuela. The fruit mass is the most important characteristic of the fruit because it is the consumable part for the variety used, *apyrena*, which does not produce seed.

The fruit presented a rounded shape, with averages of 12.70 cm for length, with CA12 as the superior one, and 12.34 cm for diameter, with highlight to SF20. Jones et al. (2013) obtained 16.8 cm for the length and 14.0 cm for the diameter of the fruit, indicating variation also for the shape of the fruit.

The thickness of the pulp showed a small variation, from 4.48 to 5.15 cm, with a coefficient of variation of 8.98%. For this attribute, the CA12 genotype was superior to the others.

However, there was a wide variation for the pulp mass, from 0.51 to 1.13 kg, in which the SF20 genotype obtained the best mean. These values are below those observed by Jones et al. (2011) in Hawaii (average of 0.951 kg). For pulp yield, the variation was from 60.71% to 90.98%, with a mean of 77.15%. Jones et al. (2011) found a pulp yield around 83%.

The variation of the floral axis length was from 5.00 to 9.90 cm, with a mean of 7.51 cm, and the diameter ranged from 2.00 to 4.04 cm, mean of 3.20 cm. These values were lower than that observed by Jones et al. (2013), who verified averages of 10.4 cm and 4.2 cm, respectively. For the breadfruit, the ideal fruit is that with a smaller floral axis and a greater thickness of the pulp, since it is the edible part of the fruit. The mean mass of the floral axis was 70 g and the mean mass of the peel was 120 g (Table 1).

The results of the descriptive analysis concerning the chemical and physical-chemical characteristics of the fruit indicate the existence of genetic variability. (Table 2). The mean pH was 6.07, close to the value found by Akanbi et al. (2009), of 6.51, values indicating greater possibility of deterioration by development of microorganisms. Only one genotype (CA5) presented pulp with pH of 4.5. The titratable acidity (TA) ranged from 0.08 to 0.29% ascorbic acid, with an average of 0.15%. The total sugar ranged from 6.86 to 28.5%, with an average of 12.43%. For the reducing sugar, the amplitude found was 2.04 to 12.25%, also obtaining the highest coefficient of variation (CV = 55.71%), the non-reducing sugars varied from 2.75 to 16.25%, with an average of 7.53%.

The average starch content (25.55%) in the evaluated genotypes is in the range of the levels observed by Siviero & Schott (2011), from 24.97% to 33.37%, in cultivars of the cassava of the collection of Embrapa Acre (CMEA), but it is higher than those reported by Leonel & Cereda (2002) on sweet potato (14.72%), yam (20.43%) and *mandioquinha-salsa* (15.75%). The evaluated genotypes presented variation

Table 1. Mean values for the physical characteristics of fruit of 32 genotypes of breadfruit var. *apyrena* from four cities of the Recôncavo da Bahia region, 2014.

Genotype	FM	FD	FL	PL	PY	PM	AL	AD	AM	PM
CA 1	1.25	13.00	15.00	5.00	75.28	0.94	7.66	2.75	0.05	0.11
CA 2	0.71	12.00	11.00	4.32	77.46	0.55	6.00	2.75	0.04	0.09
CA 3	1.20	11.00	13.00	4.33	63.33	0.76	6.60	3.00	0.05	0.11
CA 4	0.70	11.00	10.33	4.00	87.14	0.61	6.00	3.00	0.05	0.07
CA 5	1.12	12.50	12.66	4.42	60.71	0.68	7.66	3.25	0.07	0.12
CA 6	0.86	12.07	12.00	4.65	81.89	0.71	7.66	3.00	0.04	0.08
CA 7	1.15	12.00	12.00	5.00	64.00	0.73	5.00	2.00	0.04	0.09
CA 8	1.22	13.50	14.50	5.00	90.98	1.11	9.00	3.00	0.07	0.12
CA 9	0.81	11.97	12.46	4.21	77.78	0.63	7.60	3.27	0.12	0.06
CA10	0.94	12.55	12.85	4.52	76.60	0.72	7.62	3.56	0.07	0.12
CA 11	1.09	13.22	13.50	5.12	87.16	0.95	7.90	3.28	0.07	0.15
CA 12	1.14	14.60	13.62	5.15	78.25	0.89	8.12	3.35	0.07	0.15
GV 13	0.89	12.61	12.40	4.68	78.65	0.70	7.45	3.01	0.06	0.12
GV 14	0.85	11.82	12.70	4.48	75.28	0.61	6.96	3.25	0.05	0.13
GV 15	0.72	11.68	11.10	4.12	77.46	0.58	6.37	2.95	0.04	0.09
GV 16	0.92	12.70	12.38	4.26	63.33	0.67	7.36	3.26	0.07	0.14
GV 17	0.91	12.66	11.70	4.68	87.14	0.76	6.71	3.10	0.05	0.10
GV 18	0.90	11.87	12.37	4.53	60.71	0.74	6.50	2.75	0.05	0.10
SF 19	1.24	13.68	13.71	5.06	81.89	1.02	8.07	3.68	0.06	0.13
SF 20	1.35	13.25	15.43	4.65	64.00	1.13	9.90	3.87	0.08	0.11
SF 21	0.93	11.68	11.62	4.23	90.98	0.75	7.93	3.65	0.06	0.10
SF 22	0.90	11.87	12.37	4.53	77.78	0.74	6.81	2.75	0.05	0.10
SF 23	1.12	12.67	13.68	4.25	76.60	0.91	8.41	3.35	0.07	0.11
SF 24	1.28	13.13	13.90	4.87	87.16	0.93	8.45	3.35	0.08	0.15
SF 25	1.00	13.15	13.42	4.80	78.25	0.81	8.58	4.03	0.07	0.11
SA 26	0.77	11.07	11.50	3.45	75.28	0.60	7.25	3.45	0.06	0.10
SA 27	1.01	12.16	13.87	4.30	77.46	0.77	8.68	3.11	0.08	0.12
SA 28	0.95	12.16	12.37	4.35	63.33	0.64	7.90	3.67	0.08	0.13
SA 29	1.03	12.77	13.34	4.45	87.14	0.82	8.20	3.51	0.07	0.13
SA 30	1.02	12.58	12.76	4.36	60.71	0.70	7.93	3.23	0.07	0.11
SA 31	0.69	10.92	11.43	3.88	81.89	0.51	7.08	2.78	0.06	0.10
SA 32	0.73	11.00	11.26	3.77	64.00	0.53	7.02	3.41	0.07	0.11
Mean	0.98	12.34	12.70	4.48	90.98	0.76	7.51	3.20	0.07	0.12
Maximum	1.35	14.60	15.44	5.15	77.78	1.13	9.90	4.04	0.12	0.16
Minimum	0.69	10.93	10.33	3.45	76.60	0.51	5.00	2.00	0.04	0.07
SD	0.19	0.87	1.18	0.40	87.16	0.16	0.98	0.40	0.02	0.02
CV (%)	19.03	7.03	9.30	8.98	78.25	21.07	13.10	12.48	24.37	18.92

SD = Standard Deviation; CV = Coefficient of Variation; FM = Fruit mass (kg); FD = Fruit diameter (cm); FL = Fruit length (cm); PL = Pulp thickness (cm); PY = Pulp yield (%); PM = pulp mass (kg); AL = Axis length (cm); AD = Axis diameter (cm); AM = Axis mass (kg); PM = Peel mass (kg).

Table 2. Mean values of the chemical and physico-chemical characteristics of fruit of 32 breadfruit tree genotypes from four cities of Recôncavo da Bahia region, Brazil, 2014.

Genotype	pH	TA	TS	RS	NRS	ST	AS	P
CA 1	5.86	0.14	9.92	2.60	7.32	18.64	0.97	2.65
CA 2	5.98	0.12	9.51	2.38	7.13	23.15	1.30	2.91
CA 3	6.08	0.12	9.49	2.19	7.30	28.56	1.64	2.52
CA 4	5.85	0.12	9.46	3.18	6.25	16.81	1.00	2.18
CA 5	4.51	0.25	10.30	3.72	6.58	15.65	0.92	4.15
CA 6	6.20	0.10	8.67	2.73	5.94	20.51	1.27	2.62
CA 7	6.18	0.08	9.91	2.04	7.87	20.95	0.95	2.79
CA 8	6.45	0.08	7.97	3.02	4.95	26.17	1.12	2.26
CA 9	6.80	0.13	12.54	2.54	10.00	24.87	2.35	2.16
CA10	6.51	0.21	11.76	2.69	9.07	28.05	1.84	2.62
CA 11	6.14	0.12	10.48	2.54	7.94	26.83	1.70	2.13
CA 12	6.46	0.17	13.79	3.00	10.79	23.90	2.67	2.59
GV 13	6.09	0.17	19.24	12.10	7.14	34.50	1.22	1.99
GV 14	6.86	0.18	28.50	12.25	16.25	28.30	1.16	2.18
GV 15	6.34	0.16	17.20	9.01	8.19	30.10	1.10	2.44
GV 16	5.99	0.19	15.54	9.10	6.44	26.80	1.07	3.03
GV 17	6.33	0.20	17.60	5.64	12.20	29.20	0.83	2.90
GV 18	6.09	0.18	23.20	8.75	14.82	28.80	1.08	2.38
SF 19	5.72	0.13	11.45	5.82	5.63	22.00	0.58	2.34
SF 20	5.73	0.16	11.22	6.41	4.81	21.80	0.73	2.27
SF 21	5.60	0.10	9.70	4.89	4.81	21.50	0.70	2.17
SF 22	5.50	0.17	14.13	5.80	8.33	17.40	0.27	2.84
SF 23	5.80	0.10	17.60	5.27	12.33	21.81	0.28	3.50
SF 24	5.42	0.19	13.13	5.20	7.93	18.00	0.87	2.55
SF 25	6.31	0.15	10.73	3.03	7.70	34.59	0.60	2.36
SA 26	6.14	0.08	6.86	4.11	2.75	27.00	0.50	2.05
SA 27	6.14	0.08	6.86	4.11	2.75	27.00	0.50	2.17
SA 28	6.35	0.12	12.17	4.84	7.33	30.00	0.58	2.49
SA 29	6.56	0.08	6.90	3.56	3.34	36.30	0.58	2.91
SA 30	6.27	0.14	7.54	2.76	4.78	25.71	0.64	2.46
SA 31	5.81	0.29	10.51	6.00	4.51	26.50	1.06	2.79
SA 32	6.27	0.10	10.37	4.20	6.17	32.60	0.68	2.57
Mean	6.07	0.15	12.43	4.92	7.53	25.55	1.04	2.56
Minimum	4.51	0.08	6.86	2.04	2.75	15.65	0.27	1.99
Maximum	6.58	0.29	28.5	12.25	16.25	36.30	2.67	4.15
SD	0.45	0.05	4.76	2.74	3.09	5.40	0.54	0.44
CV (%)	7.35	35.85	38.31	55.71	40.97	21.15	51.29	17.24

SD = Standard Deviation; CV = Coefficient of Variation; pH = hydrogenation potential; TA = Titratable acidity (%); TS = Total sugar (%); RS = Reducing sugar (%); NRS = Non-reducing sugar (%); ST = Starch (%); AS = Ash (%); P = Protein (%).

for this characteristic, with plants presenting fruit with 15.65 to 36.30% of starch, SA29 being the highlight for this attribute, being therefore a good source of food. Lima et al. (1999), working with manioc (cassava) var. *Gold* and var. *Sedinha*, obtained averages of 26.64% and 27.75%, respectively.

The ash content ranged from 0.27 to 2.76%, with an average of 1.04%, a variation compatible with that observed in the literature, as Nwokocha & Williams (2011) found an average of 0.99%. However, it is below the levels found by James & Nwabueze (2013), of 2.85%, working with the breadfruit in Nigeria, and Appiah et al. (2011), with 2.37%.

Values for protein content ranged from 1.99 to 4.15%, with CA5 having the highest percentage, above that presented by Nwokocha & Williams (2011), of 1.39%. Protein is an important nutrient for health, making the breadfruit a complete food.

The evaluation of the diversity among the fruit tree genotypes, based on the physical, chemical and physicochemical characteristics of the fruit allowed to obtain the dendrogram presented in Figure 1, whose cophenetic correlation coefficient (CCC) between the matrices of genetic distances and the matrices of clusters were positive and significant, with a value of 0.66.

The grouping method allowed that the 32 genotypes evaluated were divided in four groups. Group 1 presented only one genotype (CA5), from Cruz das Almas, indicating the high genetic divergence it has in relation to the others, characterized by a high value for titratable acidity (0.25% ascorbic acid) and for protein (4.15%). Group 2 was composed of only one genotype (CA9), from Cruz das Almas, with a high value for pH (6.80) and ash content (2.35%).

Group 3 was composed of 22 genotypes: CA2, CA3, CA4, CA6, CA7 and CA10, from Cruz das Almas; GV14, GV15, GV16, GV17 and GV18, from Governador Mangabeira; SF21, SF22 and SF25, from São Filipe; and SA26, SA27, SA28, SA29, SA30, SA31 and SA32, from the city of Sapeaçu.

These genotypes presented similar averages for physical and physicochemical parameters. Group 4 was composed of the genotypes CA1, CA8, CA11 and CA12, from Cruz das Almas, and SF19, SF20, SF23 and SF24, from São Felipe, which presented similar averages for pH, reducing sugar, starch, protein, weight, diameter and fruit length, pulp thickness, length and diameter of the floral axis.

The lowest genetic distance between the evaluated genotypes was 0.13 between SA30 and SA27 (Group 3), both from Sapeaçu, indicating that these have agronomic characteristics with approximate values, as presented in Tables 1 and 2. Due to the geographic proximity of these genotypes, they may be related to each other. The greatest distance was between the genotypes SF20 (Group 4), from
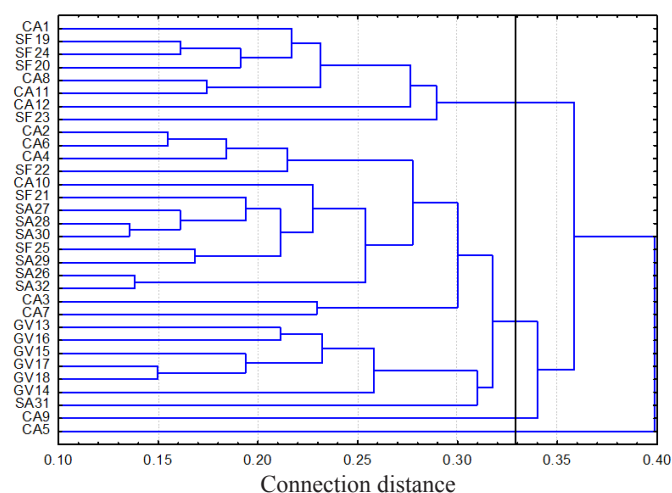
São Felipe, and CA4 (Group 3), from Cruz das Almas, with a distance of 0.53 (Figure 1).

Among the analyzed variables, the most important differences were pulp yield (40.38%), followed by starch (23.01%) and total sugar content (19%) (Table 3).

Conclusions

There is phenotypic divergence among the evaluated breadfruit tree genotypes, with the formation of four groups of dissimilarity.

The yield characteristics of pulp and starch contributed the most to the divergence between the evaluated genotypes of breadfruit.

Figure 1. Dendrogram of dissimilarity among 32 genotypes of breadfruit (var. *Apyrena*), located in the Recôncavo of Bahia region, for the physical, chemical and physicochemical characteristics of the fruit. Cophenetic correlation coefficient (CCC) = 0.66%.

Table 3. Relative contribution of the traits for genetic divergence among the 32 genotypes of breadfruit trees from cities of Recôncavo da Bahia region, 2014.

Characters	Valor (%)
Pulp yield (%)	40.38
Starch (%)	23.01
Total sugar (%)	19.00
Non-reducing sugar (%)	8.05
Reducing sugar (%)	6.08
Length of fruit (cm)	1.13
Length of shaft (cm)	0.78
Diameter of fruit (cm)	0.61
Ashes (%)	0.23
pH	0.16
Protein (%)	0.15
Pulp thickness (cm)	0.13
Shaft diameter (cm)	0.12
Fruit weight (kg)	0.02
Pulp weight (kg)	0.02
Shaft weight (kg)	0.00
Peel weight (kg)	0.00
Titratable acidity (g 100g^{-1} ascorbic acid) (%)	0.00

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