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Morphological Characterization, Nutritional and Biochemical Properties of Baobab (*Adansonia digitata* L.) Fruit Pulp from Two Districts of Mozambique

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Abstract

Baobab (*Adansonia digitata* L.) is a large iconic tree species indigenous to Africa in several arid regions of Sub-Saharan Africa. In Mozambique, the nutritional value of the baobab fruit is unknown since there are very few studies describing this multi-purpose tree mostly appreciated for its nutritional and health values. This work was conducted with the aim of defining the nutritional quality and functional properties of baobab pulp harvested from two different districts. The present study aimed at characterizing morphologically and the nutritional quality and functional properties by analyzing for several nutrients and biochemical properties of the pulp of the baobab fruit. For the nutritional and biochemical composition of the baobab pulp from the two districts the samples were not significantly different ($P < 0.05$) and the levels ranged between 0.70% - 1.03% for lipids, 3.31% - 3.76% for crude protein, 5.95% - 6.38% for ash, 20.62% - 24.19% for crude fibre, 70.74% - 77.23% for carbohydrates, 308.33 - 312.16 kcal/100g for energy, 0.25 - 0.26% for calcium, 3.50 - 6.75 mg/100g for iron, 1948.49 - 1951.00 mg/100g for potassium, 1292.81 - 1898.52 mg/100g for sodium, 0.33 - 0.35 mg/100g for thiamine and 52.83 - 62.38 mg/100g for vitamin C. For both districts the values of phosphorus and riboflavin did not change much, being 0.26% and 0.00 mg/100g. The therapeutic value of baobab resides on its antioxidant activity in the pathway of oxidative stress and health impacts but naturally occurring antioxidant enzymes were not evaluated. The results showed that the morphological parameters of the baobab fruit from Nacarôa and Eráti districts of Nampula's Province did not differ. However, biological and/or biochemical evidences that confirm the effects and standardize the level of intake are hardly known. In this respect, a large area of research remains open.

Keywords: *Mozambican Baobab; Nutritional Value; Biochemical Composition*

Introduction

There are 9 species of the majestic Baobab tree of the genus *Adansonia*; 6 of them are endemic to Madagascar, 2 to North West Australia and 1, *Adansonia digitata* L is endogenous to arid and semi-arid areas of Africa [1]. Naturally the baobab occurs in Sahelian prairies, Sudano-sahelian savannas and grasslands of Sub-Saharan Africa [2,3], where rainfall is 200 - 800 mm annually [4]. In southern Africa baobab is found in Zambia, Zimbabwe, Malawi, Mozambique, South Africa and Angola [5-7]. In Mozambique the baobab tree is commonly founded in centre and northern region [6]. The average mature fruiting baobab produces around 200 kg of fruit per season and a potential yield of whole fruit that is just over 670,000 tonnes per year [8]. The different parts of baobab plant has different uses and importance for the local community and industries [6-9]. In Mozambique different parts of the baobab plant (leaves, seeds, shell, pulp) are used as ingredients in sauce, porridges and beverages. The baobab fruit is rich in several nutrients that the human body requires, such as prebiotics, vitamin C, potassium, calcium, carbohydrates, dietary fibre, protein, pectin, energy, iron, thiamine, magnesium, zinc, valine, tryptophan, phenylalanine and tyrosine [10,11]. It has a strong integral antioxidant capacity 10 times higher than orange pulp. Because of this high nutritional value, baobab has been called "super fruit" [12], "novel food" by European Commission [13] and as a "food ingredient" in United States of America [14]. The present study was conducted to analyze the nutritional and biochemical properties of the pulp of the baobab fruit in Mozambique expecting to assist in the ongoing investigation on such exotic and valuable product with long history of traditional use in Africa.

Materials and Methods

Area of study

The fruit samples of *Adansonia digitata* L. (baobab) were collected from natural populations of the Nacarôa and Eráti districts. The Nacarôa and Eráti districts are located in the northern part of Nampula Province, northern Mozambique. These two districts have almost similar characteristics and are thus dominated by semi-arid and dry sub-humid climates. The average annual rainfall varies from 800 to 1200 mm, while the potential evapotranspiration of reference is between 1300 and 1500 mm. Most soils have medium to heavy texture, being deep, well to moderately well drained. On the intermediate slopes of interfluvial soils, the soils vary in colour from brownish to yellowish brown, moderately well drained, clayey soils.

Collection and treatment of samples

For the present study, the natural population of baobab was defined as a group of baobab trees randomly and naturally distributed in the region in an area restricted to a radius of 5 Km. In September 2017, were harvested 218 fruits of 36 baobab trees of the districts of Eráti (16) and Nacarôa (20), on average of 4 to 16 fruits per tree. Mature fruit of baobab were collected and sent to Quality and Food Safety Laboratory, located in Lúrio University, Marerre, Nampula city. They were kept on room temperature and some selected to be used as a sample. After breaking the fruit the internal contents were pounded and sieved to separate the pulp from the seed and fibres. Then the pulp was packaged in sterilized plastic bag and wrapped in aluminum foil and stored in the refrigerator.

Analytical procedures

For the morphological characterization of the components of the baobab products an electronic balance was used to determine for each fruit the total fresh weight, pulp weight, seed weight, shell weight and fibre weight, and a ruler was used to measure the diameter and the length.

The pulp pH was determined using a pH meter (Precision pH/ORP Meter 920). The moisture content was determined by the gravimetric method at 104° [15]. Total nitrogen content was determined with the Kjeldahl method using 6.25 as the conversion factor of total nitrogen to crude protein [15]. Fat was extracted with Soxhlet and petroleum ether as solvent. The contents in ashes, carbohydrates, and dietary fibres were determined according to well established methods [15].

Pulp nutritive mineral contents (Ca, P, K, and Na) were determined by atomic adsorption spectrophotometry, whereas iron (Fe) was determined by flame photometry. Vitamins B1, B2 and C content were determined by spectrophotometric method [15].

Data and statistical analysis

T-test ($P < 0.05$) was used to verify the mean difference of the parameters measured. All analysis were carried out using SPSS 21.

Results

Morphological characterization of baobab fruit

The values obtained among parameters of the baobab fruit between the two districts (Nacarôa and Eráti) did not show much variation. Table 1 show the results obtained in the weight and measurement of the considered parameters. In fruits from Nacarôa and Eráti the mean of length and diameter were of 20.19 x 10.69 cm and 19.41 x 10.87 cm, respectively. Baobab fruits are bottle or cucumber shaped containing woody outer shell with 7.5 - 54 cm long x 7.5 - 20 cm wide [11], 20 to 30 cm long and up to 10 cm in diameter [16]. According to several authors [4-6], the baobab fruit capsule has one large egg-shaped form and can reach 12 cm or more. The baobab fruits composed of an outer shell (epicarp) (45%), fruit pulp (15%) and seeds (40%) [11]. Our present results show mean fruit shell and fibre (56%), fruit pulp (13%) and seeds (31%) in Nacarôa's district and mean fruit shell and fibre (51%), fruit pulp (12%) and seeds (37%) in Eráti.

Parameters	Whole fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Pulp weight (g)	Shell and fiber weight (g)	Seed weight (g)
N	377.40	20.19	10.69	45.07	204.13	112.46
E	389.15	19.41	10.87	45.35	189.95	137.65

Table 1: *Morphological characterization of baobab fruit from district of Nacarôa (N) and Eráti (E).*

Nutritional composition

The nutritional composition of baobab pulp from Nacarôa and Eráti is presented in table 2. The pH of the baobab fruit pulp was 2.86 for Nacarôa and 2.83 for Eráti. The pH value of the pulp is lower than that recorded in another study (3.3), indicating the acidic character of the baobab pulp [3]. As the baobab fruit is dry its pulp is also dry, the dryness being attributed to sunlight and wind exposure [17]. For moisture content values were 12.27% for Nacarôa and 12.49% for Eráti, similar to those presented by other authors [2], which obtained an average of 12.5%. This value of moisture content can influence negatively its shelf life because is considered slightly high [3].

	pH	Moisture (%)	Lipid (%)	Protein (%)	Total ash (%)	Crude fibre (%)	CHO (%)	Energy (Kcal/100g)
N	2.86 ± 0.03^a	12.27 ± 0.20^a	0.70 ± 0.22^a	3.76 ± 0.44^a	6.38 ± 0.52^a	20.62 ± 1.24^a	70.74 ± 0.49^a	308.33 ± 1.66^a
E	2.83 ± 0.04^a	12.49 ± 0.18^a	1.03 ± 0.28^a	3.31 ± 0.23^a	5.92 ± 0.39^a	24.19 ± 2.38^a	77.23 ± 0.32^a	312.16 ± 3.00^a

Table 2: *Macronutrients composition, pH, moisture and energy of baobab pulp from district of Nacarôa (N) and Eráti (E).*
All data represent the mean of three determinations.
Means with the same superscript in each column are not significantly different ($P < 0.05$).

The lipid content of baobab pulp in this study showed that the samples from Eráti had higher values (1.03%) while Nacarôa had lower values (0.70%). These results are within the ranges obtained by several researches, such as 0.5 to 2.1 g lipid/100g dry matter (DM) [2], 0.21 g/100g DM to 15.5 g/100g DM [3], 0.4 g/100g to 0.7 g/100g [10] and even closer 0.46% to 1.98 [18].

The values of crude protein in different reports also vary a lot, and the lowest value found was 2.04 - 2.5 g/100g DM [3,10] and the maximum was 17 - 19.1 g/100g DM [3]. Mean values of 3.53%, 3.23% and 3.52% were recorded [18]. The protein content of baobab fruit pulp found in this study was 3.76% for Nacarôa and 3.31% for Eráti, results similar to those reported above.

For total ash the highest value was found in Nacarôa with 6.38 ± 0.52% and the lowest value in Eráti with 5.92%. The reported ash content for different authors was 7.8 g/100g DM and 5.3 g/100g DM [2], 6.4 g/100g DM and 1.9 g/100g DM [3], 6.6 g/100g and 5.5 g/100g [10] and 5.21%, 4.87% and 4.75% [18].

The crude fibre content of baobab pulp in this study show that the sample from Eráti had higher values (24.19 ± 2.38%) compared to Nacarôa (20.62 ± 1.24), being similar to other recorded data [2], which varied from 17.2 to 27.9 g/100 g DM. But other values are also reported, such as 6.29%, 9.65% and 5.91% [17], 6.0 g/100 g DM to 45.1 g/100 g DM [3] and 45.8 g/100g to 53.90 g/100g [10].

As shown in table 2, carbohydrate content of baobab pulp collected in Eráti was 77.23 ± 0.32% a higher value than collected in Nacarôa with 70.74 ± 0.49%. In other work [3], the average carbohydrate (CHO) content was 79.9, although the values are in the range from 46.6 g/100g DM to 88 g/100g DM. Other carbohydrate values were recorded as 78.3 g/100g to 78.90 g/100g [10] and 80.49%, 83.58% and 85.19% [18]. In the baobab pulp total carbohydrate content was 35.6% of simple sugars, which gives the sweet taste to the pulp [3].

Energy content for baobab pulp was 308.33 kcal/100g for Nacarôa and 312.16 kcal/100g for Eráti. These result are slightly lower when compared with those obtained by other authors [3], which found values from 203 kcal/100g DM to 357 kcal/100g DM.

The concentration of minerals in the baobab pulp varied greatly in this study in relation to the values found in the other studies. The calcium content in the baobab pulp was 0.26% for Nacarôa and 0.25% for Eráti, these are the lowest values reported in studies on baobab pulp. The lowest value of calcium that had been reported was 3.0 mg/100g DM and the highest value was 700.9 mg/100g DM [3]. In another study this micronutrient content ranged from 257 to 370 mg/100g [10] and 1800 mg/kg to 4300 mg/kg [17]. The value of phosphorus content was 0.26% for Nacarôa and 0.26% for Eráti. Studies report phosphorus content ranging from 0.04 mg/100g DM to 425 mg/100g DM [3], and average content between 56.10 - 73.30 mg/100g [10], 570 mg/kg to 1100 g/kg [17].

As shown in table 3, baobab pulp collected from Nacarôa contains 3.50 mg/100g of iron and from Eráti contains 6.75 mg/100g of iron. These results are identical to others [10] with values between 3.95 and 9.13 mg/100g. And we can still find values in a range from 1.1 to 10.4 mg/100g DM [3] and 12.0 μg/g to 64.1 μg/g [17]. The potassium content in baobab pulp was 1951 mg/100g for Nacarôa and 1948 mg/100g for Eráti. In other studies, these values ranged from 726 to 3272 mg/100g DM [3], from 2010 to 2390 mg/100g [10] and from 1330 to 2530 mg/100g [17]. For Sodium, the content found in baobab pulp was 1898.52 and 1292.81 mg/100g. These values are very high in relation to the values reported in other studies such as 0.8 to 31.2 mg/100g DM [3], 7.00 to 31.10 mg/100g [10] and 200 mg/kg to 1000 mg/kg [17]. In general the mineral content showed no significant differences ($P < 0.05$) between samples from Nacarôa and Eráti.

Micronutrients	Iron (mg/100g)	Calcium (%)	Phosphorus (%)	Potassium (mg/100g)	Sodium (mg/100g)
N	3.50 ± 1.13^a	0.26 ± 0.01^a	0.26 ± 0.08^a	1951.00 ± 234.30^a	1898.52 ± 291.28^a
E	6.75 ± 2.50^a	0.25 ± 0.04^a	0.26 ± 0.06^a	1948.49 ± 288.47^a	1292.81 ± 687.63^a

Table 3: *Mineral content of baobab pulp from district of Nacarôa (N) and Eráti (E).*
All data represent the mean of three determinations.
Means with the same superscript in each column are not significantly different (P<0.05).

The table 4 shows the baobab pulp content values of thiamine, riboflavin and vitamin C of the samples from Nacaroa and Erati. For riboflavin, the contents were very low which approaching zero. For thiamine, the content was 0.35 mg/100g for Nacarôa and 0.33 mg/100g for Eráti. The Vitamin C contents were 62.38 mg/100g for Nacarôa and 52.83 mg/100g for Eráti. The highest value found of the nine determinations of vitamin C was 83 mg/100g for Nacarôa and 70 mg/100g for Eráti. In other studies the contents recorded were for thiamine 0.30 to 0.60 mg/100g, riboflavin 0.07 to 014 mg/100g and vitamin C 150 to 500 mg/100g [3] and also thiamine 0.01 to 0.09 mg/100g, riboflavin 0.01 to 0.03 and vitamin C 74.00 to 163.00 mg/100g [10]. Thiamine values found in this study was high. Statistically there were no significant differences ($P < 0.05$) between samples from Nacarôa and Eráti districts for thiamine, riboflavin and vitamin C.

Vitamins	Thiamine (mg/100g)	Riboflavin (mg/100g)	Vitamin C (mg/100g)
N	0.35 ± 0.03[a]	0.00 ± 0.00[a]	62.38 ± 4.21[a]
E	0.33 ± 0.04[a]	0.00 ± 0.00[a]	52.83 ± 7.37[a]

***Table 4:** Vitamins contents of baobab fruit pulp from district of Nacarôa (N) and Eráti (E).*
All data represent the mean of nine determinations.
Means with the same subscript in each column are not significantly different (P < 0.05).

Discussion

The staple diets in sub-Sahara Africa, which consist largely of maize, roots, tubers such as cassava, are low in calcium and at the same time high in phytic acid, oxalic acid and tannic acids that can hinder the bioavailability of calcium.

The nutrient composition (mean and range) of baobab leaves, pulps and seeds in dry matter basis and a comparison of some common foodstuffs with baobab has been reported by many authors [19], but the problems of standardization in sample collection, preservation, preparation and analysis, renders difficult to compare data from different sources although there strong evidence of the nutritional and therapeutic value of baobab.

Although between the Nacarôa and Eráti samples were not statistically different ($P < 0.05$), they differ with some results revealed by other authors. Nacarôa and Eráti are located in the same geographic region, soil characteristics and have identical species/varieties because of this the content in terms of nutrients do not change significantly [2,10,18]. Similar results from our two studied districts differ from results from other sources due to different geographic region, soil characteristics, chemical composition, species/varieties, storage conditions and analytical method used [2].

In this research with baobab pulp it was recorded the lowest value of calcium, some 0.26% for both districts, although it is known that baobab leaves contain 10 - 18 times more calcium than the common foodstuffs known as calcium-rich (e.g. milk, green-leafy-vegetables and pulses). Furthermore, baobab pulp has an unequalled content of vitamin C. The low values obtained in the calcium content in the baobab pulp in our study can be explained with the excess or greater sodium content. The high content of Na^+ interferes in plant growth and production because it reduces the Ca^{2+} availability, translocation and mobilization [20], causing calcium deficiency in the plant [21]. Potassium, phosphorus and sodium values found in the baobab pulp could be attributed to soil properties other than the climatic conditions [17].

The iron content of baobab leaves, some five times more than legumes and fifteen times more than meat, have the potential of rectifying the problems of anaemia, health problem affecting about 2 billion people in the world. Iron levels in baobab pulp is more moderate.

The sweetness and acidity of the pulp is due to the amount of carbohydrates and the low pH level. However, the present work, did not perform organoleptic tests neither determined important elements such as ß-carotene, magnesium and phenolic antioxidants, and further work is necessary to overcome these gaps so it will be possible to demonstrate the high potential of neutralizing the reactive oxygen species that in baobab exceed natural antioxidants.

ß-carotene provides about 66% of vitamin A in African diets and most requirements are covered by red palm oil and yellow maize. African green leafy vegetables are vital contributors to the food supply, which in itself is a component of food security in Africa, but cooking affects their phenolic composition and resultant health promoting properties.

Although magnesium is essential for a wide range of metabolic reactions because of its activities as the co-factor of at least 300 enzymes that are involved in energy, protein and DNAs metabolisms and its involvement in bone formation and function, some of the causes of the decline in the supply and intake of magnesium include factors not so common in Africa such as the depletion of soil magnesium due to intensive monoculture agricultural, and the processing and refining of foodstuffs, as well as softening of drinking water to increase its household cleaning quality.

Conclusions

It is well known the wide range of variability of nutrient content even within similar botanical parts of any plant including baobab. The standardization of samples according to botanical characteristics, site of growth, soil characteristics, climate, harvesting procedures, season, dehydration, collection, transport and storage, laboratory analysis, are some of the factors that affect data, making comparison of results difficult and unreliable.

In terms of morphological characterization, biochemical and nutritional properties of baobab fruit pulp from the Nacarôa and Erati districts, most of the results are in agreement with the ranges shown by other studies. Major differences comparing with previous reported data relate to the higher values of sodium and thiamine.

Future work will also involve the determination of the nutritional value and the ethno medical value of baobab leaves as part of a staple diet therefore the mechanisms by which it can counter balance nutrient deficiency, hinder oxidative stress and maintain health in smallholder famers. Present data just add knowledge to the "food composition data" available for Mozambique.

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Bibliography

1. Zahra'u B., *et al*. "Baobab Tree (Adansonia digitata L) Parts: Nutrition, Applications in Food and Uses in Ethno-medicine - A Review". *Annals of Nutritional Disorders and Therapy* 1.3 (2014): 1011.

2. Ibrahima C., *et al*. "Biochemical and nutritional properties of baobab pulp from endemic species of Madagascar and the African mainland". *African Journal of Agricultural Research* 8.47 (2013): 6046-6054.

3. Chadare FJ., *et al*. "Baobab Food Products: A Review on their Composition and Nutritional Value". *Food Science and Nutrition* 49.3 (2008): 254-274.

4. Venter SM and Witkowski ETF. "Baobab (Adansonia digitata L.) density, size-class distribution and population trends between four land-use types in northern Venda, South Africa". *Forest Ecology and Management* 259.3 (2010): 294-300.

5. Kamatou GPP., *et al*. "An updated review of Adansonia digitata: A commercially important African tree". *South African Journal of Botany* 77.4 (2011): 908-919.

6. Vermaak I., *et al*. "African seed oils of commercial importance - Cosmetic applications". *South African Journal of Botany* 77.4 (2011): 920-933.

7. Komane BM., *et al*. "Beauty in Baobab: a pilot study of the safety and efficacy of Adansonia digitata seed oil". *Brazilian Journal of Pharmacognosy* 27.1 (2017): 1-8.

8. Kabbashi NA., *et al*. "Characterization of the Baobab fruit shells as adsorption material". *International Food Research Journal* 24 (2017): 472-474.

9. Aisha ZM., *et al*. "Microbiological Analysis of Baobab Yoghurt Produced Using Lactobacillus bulgaricus". *International Journal of Microbiology and Biotechnology* 2.2 (2017): 93-101.

10. PhytoTrade Africa. Summary Report: Nutritional Evaluation of Baobab Dried Fruit Pulp and its Potential Health Benefits. Leatherhead Food Research (2009).

11. Namratha V and Sahithi P. "Baobab: A Review about "The Tree of Life"". *International Journal of Advanced Herbal Science and Technology* 1.1 (2015): 20-26.

12. Rahul J., *et al*. "Adansonia digitata L. (baobab): a review of traditional information and taxonomic description". *Asian Pacific Journal of Tropical Biomedicine* 5.1 (2015): 79-84.

13. Buchmann C., *et al*. "The importance of baobab (Adansonia digitata L.) in rural West African subsistence-suggestion of a cautionary approach to international market export of baobab fruits". *Ecology of Food and Nutrition* 49.3 (2010): 145-172.

14. Addy R. "Baobab Fruit Approved as Food Ingredient in US" (2009).

15. Zenebon O., *et al*. "Métodos físico-químicos para análise de alimentos". São Paulo. Brazil. Instituto Adolfo Lutz (2008): 1020.

16. Kaboré D., *et al*. "A review of baobab (Adansonia digitata) products: Effect of processing techniques, medicinal properties and uses". *African Journal of Food Science* 16.5 (2011): 833-844.

17. Kinuthia UM., *et al*. "Nutritional variation in baobab (Adansonia digitata L.) fruit pulp and seeds based on Africa geographical regions". *Food Science and Nutrition* 5.6 (2017): 1116-1129.

18. Aluko A., *et al*. "Nutritional Quality and Functional Properties of Baobab (Adansonia digitata) Pulp from Tanzania". *Journal of Food Research* 5.5 (2016): 23-21.

19. Habte TY and Krawinkel MB. "Metaphysical Analysis of the Nutritional and Therapeutic Value of Baobab (Adansonia Digitata L.)". *Journal of Nutrition and Health Sciences* 5.1 (2017): 101.

20. Da Silva Júnior EG., *et al*. "Vegetative development and content of calcium, potassium, and sodium in watermelon under salinity stress on organic substrates". *Pesquisa Agropecuária Brasileira* 52.12 (2017): 1149-1157.

21. Zaman B., *et al*. "Response of wheat plants to sodium and calcium ion interaction under saline environment". *International Journal of Environmental Science and Technology* 2.1 (2005): 7-12.

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