



Characterization of phytonutrients of the pulp of three endemic Malagasy baobab and one African species according to the treatment method of conservation and harvest area

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Abstract

In order to provide extensive data on the nutritional value and antioxidant capacity of Baobab pulp extracts, 4 species were selected: *Adansonia grandidieri*, *A. rubrostipa*, *A. za*, *A. digitata*. A comparative analysis was carried out according to the species, the treatment method of conservation performed and the harvesting area identified.

The fruit pulps collected from different areas are submitted to 3 treatments: freezing at -20 °C, indirect sun drying and freeze-drying at -60 °C for 10 hours. The nutritional values are measured: by gravimetry at 103 °C for humidity, by the Kjeldhal method for proteins, by hexane extraction for fats, incineration at 550 °C for ash and by the enzymo gravimetric method for dietary fibers. The antioxidant capacity is assessed by the DPPH radical measurement.

The water content of the pulps is between 12 and 14%; it can reach less than 10% after freeze-drying or sun-drying. The proteins quantities vary from 2 to 5% and from 0.2 to 2% of dry matter for lipids. The crude ash contents, fluctuates from 5.8 to 11.7% of dry matter. Antioxidant capacity varies from 9 to 63 μmol TE/g of dry matter. The results highlight nutrient values that are function of species, processing and harvesting areas.

In conclusion i) Endemic species have better nutritional qualities while *digitata* has higher antioxidant activity ii) Freeze-drying better preserves nutritional values and antioxidant activities of the pulps.

Keywords: baobab pulp, freeze-drying, indirect solar drying, freezing, nutritional value, antioxidant activity, phytonutrients

Introduction

The genus *Adansonia* belongs to the Malvaceae family includes 8 species in the world. 7 are available in Madagascar and 6 among them are endemics. The genus *Adansonia* is native to Madagascar Island, to Africa and to Australia (Wickens, 1982) [28]. Tree grows in the wild and is nicknamed *the bottle tree* because of its ability to store water in the form of juice or the *upside-down tree* because of its branches reflecting roots. Three different taxonomic sections according to floral morphology exist (Baum, 1995) [5]: i) ADANSONIA section includes the African species (*digitata*), ii) BREVITUBAE section includes two endemic species from Madagascar (*suarezensis* and *grandidieri*) and iii) four other Malagasy species (*rubrostipa*, *za*, *perrieri*, *madagascariensis*) as well as the Australian species (*gregorii*) belong to the LONGITUBAE section.

The baobab is extremely exploited in Africa since it offers shelter, materials, water; it is also a food and a medicine. Indeed, it is traditionally used to treat various ailments such as fever, diarrhea, cough and dysentery (Razafimamonjy, 2017). The different parts of the African baobab (*digitata*) have been the subject of numerous scientific studies in order to identify bioactive compounds and have shown that baobab fruit pulp is very rich in vitamin C (up to 540 mg/100 g on fresh weight), the seeds contain high levels of polyphenols (epicatechin and procyanidin), provitamin A carotenoids, fatty acids (linoleic and oleic acids) and high antioxidant activity (Tembo *et al.*, 2017) [26]. It emerged that many interesting biological properties are attributed to this species due particularly to his high level of antioxidants. In

fact, it reduces the risk of chronic diseases associated with oxidative stress in human health and preserves also foods' quality by inhibiting enzymatic browning and lipid autoxidation in foods (Tembo *et al.*, 2017) [26]. However, data on the 6 endemic Malagasy species are not enough. Research work has already been carried out on the physico-chemistry of baobab oil (Nkafamiya *et al.*, 2007, Thomas, 1913) [13, 27], on its fatty acid composition (Gaydou *et al.*, 1983; Randriamarinarivo, 2012; Razafimamonjison *et al.*, 2017) [6, 17, 22], on its physiological effects (Bianchini *et al.*, 1983) [6, 8], on its fruit's transformation on derived products (Rakotonindrainy, 2008) [16]. The oil is an excellent source of essential fatty acids and has a significant antioxidant activity depending on the species and the extraction method used (Ratsimbazafy, 2015). The consumption of baobab leaves is not yet part of the local population's dietary habits. Being reputedly rich in calcium, the leaves and bark are used in decoction to treat dizziness, fatigue and fever. The tree has essentially an ecotouristic and symbolic value (Randrianantenaina, 2012; Razafindralambo, 2014) [18, 23]. Valorization of *Adansonia grandidieri* and *za* fruits was carried out for the first time by Rakotonindrainy *et al.* (Rakotonindrainy, 2008) [16]. Fruits-processed products are beginning to be available on local markets (jam, juice, pulp powder, oil, etc.). Despite these scientific and technological knowledges, the results reported on the nutritional compositions and the use of pulps remain to be expanded. Four species were selected for this study, three endemic to Madagascar (*grandidieri*, *rubrostipa*, *za*) and the African species *digitata*. The main objective is to identify

compounds in the plant or in its derived products (oil, powders,) that confer nutritional, therapeutic and medical properties. Knowledge of its properties should make it possible to point out the existing differences with other plants and to target the most interesting species. The specific objectives are to complete the macronutrient composition and to study the antioxidant activity of the pulps taking into account the inter-species variability, the method of conservation adopted and the geographical origin of the fruits.

Materials and methods

1. Fruit collection

Four species of baobab were selected for their genetic diversity (*Adansonia za*, *grandidieri*, *rubrostipa* compared to *digitata*) and their availability in different regions of Madagascar. At each area collection, 10 feet of trees of the same species and having at least 1 meter in diameter were identified. On each foot and this as far as possible, 20

apparently healthy and mature pods were picked. As soon as they were collected in the field, the fruits obtained from each tree were stored in an individual labeled bag. This method was retained for all collections for each species and at each site. In the laboratory, the pods were spread out in a solar dryer for 24 hours to reduce any traces of water on the fruits 'walls, then repackaged in their respective transport bags until preparation time. Packages are put in a dry place. Fresh fruits are collected from their natural habitat during the ripening season of each species, between October 2018 and October 2019.

2. Estimation of the edible pulp proportion

The fruit pulp, called "monkey bread", is usually whitish but can be yellow or pinkish (Rakotonindrainy, 2008) ^[16]. The determination of the edible part consisted in evaluating the mass of the "pulp" compared to the mass of the whole fruit. Each fruit was first weighed, then peeled and pitted to obtain the pulp which was weighed again.



Fig 1: Fruit and pulp of *Adansonia grandidieri*

3. Pulp treatments

Fruit pulp from the same plant was subjected to three different treatments: i) indirect solar drying for 10 hours ii) lyophilization at -60 °C for 10 hours. The pulps obtained from these methods are reduced to powder and stored in airtight jars at room temperature. iii) the pulp was ground into a powder and stored immediately in freezer bags and deep-frozen at -20 °C.

4. Nutritional value analysis

The samples humidity (H%) was determined by weight loss after oven drying at 103 °C±2 (Afnor, 1989) ^[1], protein content (P%) by using the factor 6.25 of conversion of total nitrogen into protein (P%), measured according to the KJELDAHL method (Afnor, 1993) ^[2]. The lipids (L%) were measured by direct Soxhlet extraction using hexane (NFV 03-908, 1998) ^[11], crude ash content (C%) after incineration

at 550 °C. for 5 hours. The total dietary fiber content (F%) was assayed by the AOAC 985.29 enzymo-gravimetric method (Prosky *et al.*, 1985) [14]. The content of digestible carbohydrates (G%) was deduced from the difference between the nutrients, and the energy value by multiplying the content of nutrients with their respective Atwater index (Greenfield and Southgate, 1992) [9].

5. Determination of antioxidant activity

The method adapted by Ranovona from direct measurement described by Serpen (Serpen *et al.*, 2007, Ranovona, 2012) [25, 21] was used. The antioxidant activity of fruit pulps was determined by the method of 2,2'-diphenyl-1-picrylhydrazyl or DPPH (oxidants). The optical density (OD) is read at 517 nm. The antioxidant activity was expressed in micromole Trolox equivalent per gram of dry matter (DM) (mole TE/g DM).

All the reagents used in various analyzes were purchased from Grosseron (France) except the kit used for total dietary fiber determination, from Libios (France).

6. Statistical analysis

The XLSTAT software was used to perform the statistical analyzes that is the analysis of variance test (ANOVA). Three levels of comparison were retained to interpret the differences observed according to i) the species, ii) the treatments iii) the geographical origin of the fruits.

Results and discussions

1. Collection areas

The harvest areas and the number of trees retained after sorting are presented in Table 1. The number of tree trunks corresponding to the criteria initially established was insufficient in some accessible localities.

Table 1: Collection sites and periods

Species	Region	Area	Harvest period	Number of trunk	Geographical indications
<i>Grandidieri</i>	Sud-ouest	Befandriana-sud	October 2018	9	22°6'9.2''S - 43°53'36.8''E
	Menabe	Andranomena	November 2018	10	20°10'27.1''S - 44°30'9.1''E
	Menabe	Ampataka	November 2018	7	20°7'26.8''S - 44°26'51.7''E
<i>Rubrostipa</i>	Menabe	Mangily	September 2019	9	20°52'22.9''S - 44°24'14.2''E
<i>Za</i>	Diana	Ambanja	June 2019	2	13°52'43.7''S - 48°32'02.9''E
	Menabe	Anivorano	October 2019	6	20°11'21.0''S - 44°26'12.7''E
	Sud-ouest	Ampanihy	June 2019	10	24°41'26.4''S - 44°44'22.3''E
<i>Digitata</i>	Boeny	Mangatsa	July 2019	9	15°37'30.6''S - 46°25'10.1''E

2. Proportion of edible pulp

Depending on the species, fruit weights vary significantly. Referring to the average fruit weights (Table 2), those of *digitata* are significantly 2 to 3 times heavier and bulkier than the others; *rubrostipa* has the smallest and lightest fruits ($p < 0.05$). Concerning the mass percentage in pulp, a similarity was observed between *grandidieri*, *za* and *digitata* despite the variability in the fruits' weight. In general, the pulp represents the 19.5 to 21.5% of the fruits, while it is only 15.5% for *rubrostipa*.

3. Nutritional composition of pulps

The variability of macronutrient contents in pulps according to species, preservation treatment and collection site are presented in Tables 3, 4 and 5 respectively.

3.1 Variability by species

As reported in Table 3, baobab have dry fruits because the water content of fresh pulp (measured before freezing) is 14% of the raw material (Fresh weight or FW) regardless of the species considered ($p > 0.05$). The water content of the freeze-dried pulps is between 8 and 13% FW, respectively for *grandidieri* and for the other three species. For the sun-dried pulps, the water contents are comparable for *grandidieri* and *rubrostipa*, ~10%; those of *digitata* and *za* are respectively 11 and 12% FW (Table 3). These variations could be due to temperature fluctuations inside the dryer during the day, which ranged from 23 to 40°C. In all cases, low water contents mean a richness of nutrients traduced by high level of DM, 86 to 92%, and this for all species and for all types of treatment. Previous studies on untreated pulp reported water contents of 11.7 to 13.5% for the different baobab species (Cisse, 2012) [7], around 20% for *grandidieri* and *za* (Rakotonindrainy, 2008) [16]. Such differences can be ascribed to the environmental conditions, the harvest period, the degree of maturity of the fruits. The pulps have low

protein content, with 1.66 to 4.94g % DM, with variability depending on the species ($p < 0.05$), because regardless of the treatment, *rubrostipa* is always the richest (between 4.50 and 4.94g % DM) and *za* the poorest (1.66 to 2.17g % DM). The results of Cisse (2012) [7] on untreated pulps also reported that *rubrostipa* has the highest protein content (6.3g% DM) against 2.5g% DM for *za*. The ash content is an indicator of its richness in minerals. Ash of the pulps varies significantly from 5.85 to 11.72g % DM, respectively for *grandidieri* and *rubrostipa* which is also the richest. Independantly of the drying method, *rubrostipa* always showed the highest ash content. On untreated pulps, ash contents ranging between 5.2 to 7.8g for different species have been reported (Cisse, 2012) [7]; Nivoarilanto (2018) [12] reported 9.21g for *rubrostipa* and 7.21g for *grandidieri*. The lipids contents in the pulps are low, ranging from 0.20 to 1.87 g% DM. In decreasing order, *grandidieri* has the highest content, followed by *za*, *rubrostipa* and *digitata* the least. The *grandidieri* value is comparable to Cisse's value (2012) [7] of the same species (1.69 g% DM). They are remarkably very rich in dietary fiber, depending on the species considered. Almost 2/3 of the dry weight of *digitata* and *za* are made up of these compounds, followed by *rubrostipa* and finally almost 40% for *grandidieri*. Baobabs can be said to be "rich" in dietary fiber (Afssa, 2002) [3]. The content of digestible carbohydrates, deduced by difference, is 21.68 to 50.04 g%. It is inversely proportional to that of total fibers and ash. The highest grade is attributed to *grandidieri*. Thus, the energy, essentially from carbohydrate, varies from 106.84 kcals to 228.34 kcals. It is noticed the genetic effect on the nutritional composition but this effect is variable according to the considered nutrient, *rubrostipa* always displays the highest contents in proteins and ashes, the *grandidieri* species in lipids and *digitata* and *za* in fibers.

3.2 Variability by treatment

The water contents of the lyophilized-dried pulps and those indirectly-dried in the sun are lower than that of the deep-frozen samples (Table 4), which corresponds to that of the fresh samples (around 14% FW). Content variations were observed for proteins, ashes and lipids. Levels are higher in deep-frozen samples than in lyophilized and sun-dried ones. Also, dietary fibers are one of the major factors of fruit texture, they also experience significant variations related to processing, but the latter has little impact on their total content.

The drying methods have led to sometimes significant variations in the quantities of nutrients, but the levels remain practically the same for each species regardless of the adopted method. Indeed, these different dryings did not cause any loss by nutrients' release. It should be noted, however, that deep-freezing has the added advantage of better preserving the nutrients because it does not destroy the structures of the molecules and inhibits the reactions that may be the cause of degradation. It allowed the fruits to keep their time zero fresh state and nutritional value, if it is carried out in the few times following the harvest. Since frozen samples are the richest in water, they have also the low energy value.

3.3 Variability according to collection areas

Variance analysis was carried out to observe the effect of geographical areas of collection on the pulps 'composition, *grandidieri* and *za* were selected since these have different harvesting areas. Deep-frozen pulps were taken into account since they are considered fresh since just after collection, they are immediately crushed and frozen at -20 °C. It appears that the water contents of the samples have variability between the sites for each species (Table 5). The protein contents appear similar between the different sites whether for *grandidieri* or for *za*. For *grandidieri*, the samples from Amalaka differ from those from the other sites by their high ash content and their low lipid content. In addition, the samples from Befandriana-south stand out for their richness in carbohydrates and their low fiber content compared to samples from other sites. Concerning *za*, the samples from Ambanja are low in ash and richer in lipids. For carbohydrate content, samples from Ampanihy have the highest content. In terms of fibers, the contents are

statistically identical for the three sites. The levels of nutrients present in a food vary more or less significantly, due to environmental conditions (temperature, radiation, rainfall, soil, etc.). However, these trends remain lower and largely dominated by the species effect (as reported in Table 3).

4. Antioxidant capacity

Tables 6, 7 and 8 present the variation levels of comparisons of the 4 species samples treated in the same conditions.

4.1 Antioxidant activity according to species

The antioxidant activity varies significantly depending on the species (Table 6), *digitata* has 3 to 7 times higher than the other three species regardless of the type of treatment. For all species, deep-freezing has a conservative effect on this antiradical capacity. The values (µmol TE/g MS) reported by other authors for these same species are given for comparison. Their samples, which have not submitted to any treatment, are comparable to our deep-frozen samples: 16.83 µmol for *grandidieri* (Nivoarilanto, 2018) [12], 11.04 µmol for *rubrostipa* (Nivoarilanto, 2018) [12], 28.60 µmol for *za* (Razafindralambo, 2014)

4.2 Antioxidant activity according to treatment

Sun-dried samples often show the lowest values but statistically at the same level as freeze-dried ones; frozen ones have significantly higher activity (Table 7). This significant loss of antioxidant capacity (ACO) of sun-dried samples could be attributed to the degradation of some molecules during drying (example: vitamin C, polyphenols, etc.).

4.3 Antioxidant activity according to sites

Considering the frozen samples, the OAC of *za* from the 3 sites shows no significant difference (Table 7). For *grandidieri*, the antioxidant capacity of the samples from Befandriana-south is particularly high compared to those from the other two sites. The probable arguments in favor of these dissimilarities between the samples are the presence of antioxidant molecules, different both in kind and in quantity associated with environmental conditions and maturity level of the fruits.

Table 2: Mass of fruits and pulps of *Adansonia* according to species

Species	Observation Number	Weight of fruit (gramme)			Weight of pulp (gramme)			Percentage of pulp (%)		
		Min	Max	Mea ±SD	Min	Max	Mean ±SD	Min	Max	Mean ±SD
<i>Grandidieri</i>	130	37,90	534,90	159,24 ± 77,02 ^c	7,60	110,50	31,10±17,06 ^c	20,05	20,66	19,53± 0,00 ^b
<i>Rubrostipa</i>	80	42,60	175,30	106,16 ± 37,30 ^d	5,40	38,40	16,60±9,75 ^d	4,41	38,00	15,50±6,67 ^a
<i>za</i>	80	120,00	437,00	197,93 ± 64,71 ^b	21,50	124,10	38,23±15,05 ^b	11,40	36,70	19,63±4,91 ^b
<i>digitata</i>	80	150,60	602,10	356,54 ± 24,88 ^a	29,90	198,00	77,32±46,44 ^a	10,00	39,00	21,45±8,59 ^b

Mean ± standard deviation of results

The values in the same column followed by different letters are significantly different (p <0.05)

Table 3: Macronutrient content of pulps according to species

Treatment	Species	Watercontent (g/100g FW)	Dry matter (g/100gDM)	Proteins (g/100gDM)	Ash(g/100g DM)	Fats(g/100g DM)	Totaldietary fiber(g/100g DM)	Edible carbohydrates (g/100g DM)	Energy value (kcal/100g DM)
Lyophilisation	<i>grandidieri</i>	7,94± 1,44 ^b	92,06± 1,44 ^a	3,61± 0,44 ^b	6,72± 1,20 ^b	1,53 ± 0,61 ^a	38,10± 3,77 ^d	50,04± 4,02 ^a	228,34± 16,58 ^a
	<i>rubrostipa</i>	11,96± 0,71 ^a	88,04± 0,71 ^b	4,94± 0,36 ^a	10,10± 0,17 ^a	0,36 ± 0,01 ^c	52,28 ± 0,61 ^c	31,98 ± 0,49 ^b	150,94± 2,38 ^b
	<i>Za</i>	12,31± 0,15 ^a	87,69± 0,15 ^b	1,67 ± 0,36 ^d	7,46 ± 2,43 ^b	0,62 ± 0,63 ^b	62,84 ± 3,59 ^b	27,34 ± 3,51 ^c	121,69± 9,62 ^c
	<i>Digitata</i>	13,15± 1,47 ^a	86,85± 1,47 ^b	2,28 ± 0,23 ^c	6,26 ± 1,38 ^b	0,21 ± 0,01 ^d	66,00 ± 1,06 ^a	25,21 ± 2,14 ^c	111,94± 7,66 ^d
indirect solar	<i>grandidieri</i>	10,25± 1,40 ^b	89,75± 1,40 ^a	3,51 ± 0,69 ^a	5,85 ± 1,08 ^b	1,87± 0,78 ^a	39,29± 3,05 ^c	49,48± 3,27 ^a	228,32± 14,12 ^a

drying	<i>rubrostipa</i>	10,53±0,75 ^b	89,47±0,75 ^a	4,50±0,23 ^a	10,32±0,25 ^a	0,30±0,02 ^c	54,07±0,46 ^b	30,78±0,46 ^b	143,90±2,05 ^b
	<i>Za</i>	12,25±0,33 ^a	87,75±0,33 ^b	1,66±0,07 ^c	7,11±1,93 ^b	0,80±0,79 ^b	65,05±2,54 ^a	25,48±2,38 ^c	115,83±5,97 ^c
	<i>Digitata</i>	11,53±1,56 ^{ab}	88,47±1,56 ^a	2,32±0,18 ^b	6,24±1,51 ^b	0,20±0,01 ^d	64,76±1,01 ^a	26,46±2,44 ^c	116,95±9,19 ^c
Deep-freezing	<i>grandidieri</i>	14,75±2,04 ^a	85,25±2,04 ^a	3,71±0,61 ^b	6,41±1,17 ^b	1,99±0,81 ^a	41,42±2,82 ^c	46,47±3,28 ^a	218,66±15,68 ^a
	<i>rubrostipa</i>	13,78±1,21 ^a	86,22±1,21 ^a	4,90±0,42 ^a	11,72±0,58 ^a	0,31±0,01 ^b	59,70±0,72 ^b	21,68±3,73 ^b	109,16±14,49 ^b
	<i>Za</i>	14,25±1,28 ^a	85,45±1,28 ^a	2,17±0,29 ^c	7,87±2,66 ^b	1,27±1,01 ^a	67,24±2,69 ^a	21,68±2,14 ^b	106,84±9,66 ^b
	<i>Digitata</i>	14,55±1,19 ^a	85,45±1,19 ^a	2,38±0,16 ^c	6,37±1,23 ^b	0,28±0,04 ^b	66,51±0,96 ^a	24,10±2,33 ^b	108,51±8,45 ^b

Mean ± standard deviation of results

For each **treatment**, the values in the same column followed by different letters are significantly different (p < 0.05)

Table 4: Pulp macronutrient content according to treatment

Species	Treatment	Water content (g/100g FW)	Dry matter (g/100g FW)	Proteins (g/100g DM)	Ash (g/100g DM)	Fats (g/100g DM)	Total dietary Fibers (g/100g DM)	Edible carbohydrates (g/100g DM)	Energy value (kcal/100g DM)
<i>grandidieri</i>	Lyophilisation	7,94 ± 1,44 ^c	92,06 ± 1,44 ^a	3,61 ± 0,44 ^a	6,72 ± 1,20 ^a	1,53 ± 0,61 ^c	38,10 ± 3,77 ^b	50,04 ± 4,02 ^a	228,34 ± 16,58 ^a
	Indirect solar drying	10,25 ± 1,40 ^b	89,75 ± 1,40 ^b	3,51 ± 0,69 ^a	5,85 ± 1,08 ^b	1,87 ± 0,78 ^b	39,29 ± 3,05 ^b	49,48 ± 3,27 ^a	228,32 ± 14,12 ^a
	Deep freezing	14,75 ± 2,04 ^a	85,25 ± 2,04 ^c	3,71 ± 0,61 ^a	6,41 ± 1,17 ^a	1,99 ± 0,81 ^a	41,42 ± 2,82 ^a	46,47 ± 3,28 ^b	218,66 ± 15,68 ^b
<i>rubrostipa</i>	Lyophilisation	11,96 ± 0,71 ^a	88,04 ± 0,71 ^b	4,94 ± 0,36 ^a	10,10 ± 0,17 ^b	0,36 ± 0,01 ^a	52,28 ± 0,61 ^c	31,98 ± 0,49 ^a	150,94 ± 2,38 ^a
	Indirect solar drying	10,53 ± 0,75 ^b	89,47 ± 0,75 ^a	4,50 ± 0,23 ^b	10,32 ± 0,25 ^b	0,30 ± 0,02 ^b	54,07 ± 0,46 ^b	30,78 ± 0,46 ^a	143,90 ± 2,05 ^a
	Deep freezing	13,78 ± 1,21 ^a	86,22 ± 1,21 ^c	4,90 ± 0,42 ^{ab}	11,72 ± 0,58 ^a	0,31 ± 0,01 ^b	59,70 ± 0,72 ^a	21,68 ± 3,73 ^b	109,16 ± 14,49 ^b
<i>za</i>	Lyophilisation	12,31 ± 0,15 ^b	87,69 ± 0,15 ^a	1,67 ± 0,36 ^b	7,87 ± 0,17 ^a	0,62 ± 0,01 ^b	62,84 ± 0,61 ^b	27,34 ± 0,49 ^a	121,69 ± 2,38 ^a
	Indirect solar drying	12,25 ± 0,33 ^b	87,75 ± 0,33 ^a	1,66 ± 0,07 ^b	7,11 ± 1,93 ^a	0,80 ± 1,79 ^b	65,05 ± 2,54 ^{ab}	25,48 ± 2,38 ^a	115,83 ± 5,97 ^{ab}
	Deep freezing	14,25 ± 1,28 ^a	85,75 ± 1,28 ^b	2,17 ± 0,29 ^a	7,87 ± 2,66 ^a	1,27 ± 1,01 ^a	67,24 ± 2,69 ^a	21,68 ± 2,14 ^b	106,84 ± 9,66 ^b
<i>Digitata</i>	Lyophilisation	13,15 ± 1,47 ^b	86,85 ± 1,47 ^b	2,28 ± 0,23 ^a	6,26 ± 1,38 ^a	0,21 ± 0,01 ^a	66,00 ± 1,06 ^{ab}	25,21 ± 2,14 ^a	111,94 ± 7,66 ^a
	Indirect solar drying	11,53 ± 1,56 ^c	88,47 ± 1,56 ^a	2,32 ± 0,18 ^a	6,24 ± 1,51 ^a	0,20 ± 0,01 ^a	64,76 ± 1,01 ^b	26,46 ± 2,44 ^a	116,95 ± 9,19 ^a
	Deep freezing	14,55 ± 1,19 ^a	85,45 ± 1,19 ^c	2,38 ± 0,16 ^a	6,37 ± 1,23 ^a	0,28 ± 0,04 ^a	66,51 ± 1,23 ^a	24,10 ± 2,33 ^a	108,51 ± 8,45 ^a

Mean ± standard deviation of results

For each **species**, the values in the same column followed by different letters are significantly different (p < 0.05)

Table 5: Pulp macronutrient content by site

Species	Area	Water content (g/100g FW)	Dry matter (g/100g FW)	Proteins (g/100g DM)	Ash (g/100g DM)	Fats (g/100g DM)	Total dietary fibers (g/100g DM)	Edible carbohydrates (g/100g DM)	Energy value (Kcal/100g DM)
<i>Grandidieri</i>	Befandriana sud	13,10±0,93 ^c	86,90±0,93 ^a	3,63±0,57 ^b	6,35 ± 0,69 ^b	2,50 ± 0,57 ^a	38,83 ± 3,77 ^b	48,70 ± 3,11 ^a	231,77 ± 11,82 ^a
	Andranomena	14,69 ± 1,70 ^b	85,31 ± 1,70 ^b	3,84 ± 0,80 ^a	5,58 ± 0,58 ^c	2,29 ± 0,54 ^a	42,50 ± 0,79 ^a	45,79 ± 1,71 ^b	219,12 ± 5,18 ^b
	Ampataka	16,97 ± 1,42 ^a	83,03 ± 1,42 ^c	3,65 ± 0,39 ^b	7,56 ± 1,25 ^{ab}	0,97 ± 0,30 ^b	43,35 ± 2,16 ^a	44,47 ± 3,65 ^b	201,21 ± 12,18 ^c
<i>Za</i>	Ampanihy	14,25 ± 1,28 ^a	85,60 ± 1,28 ^b	2,17 ± 0,29 ^a	9,69 ± 2,40 ^a	0,78 ± 0,39 ^b	64,51 ± 2,16 ^b	22,82 ± 1,87 ^a	109,40 ± 2,93 ^a
	Ambanja	12,47 ± 0,30 ^b	87,53 ± 0,30 ^a	2,02 ± 0,10 ^a	5,74 ± 0,02 ^b	2,44 ± 0,08 ^a	69,96 ± 0,67 ^a	19,82 ± 0,63 ^b	107,00 ± 9,68 ^a
	Anivorano	14,88 ± 0,68 ^a	85,12 ± 0,68 ^b	2,44 ± 0,43 ^a	10,10 ± 0,59 ^{ab}	0,41 ± 0,02 ^c	68,00 ± 3,68 ^a	19,03 ± 3,30 ^b	89,61 ± 13,94 ^b

Mean ± standard deviation of results

For each species, the values of the same column designated by different letters are statistically different (p < 0.05)

Table 6: Antioxidant capacity (µmol TE/g DM) of pulps according to species

Species	Lyophilisation	Indirect solar drying	Deep-freezing
<i>Grandidieri</i>	14,77 ± 3,21 ^c	13,64 ± 2,45 ^c	15,09 ± 3,99 ^c
<i>Rubrostipa</i>	4,70 ± 5,96 ^d	4,75 ± 2,39 ^d	12,86 ± 6,01 ^c
<i>Za</i>	27,44 ± 9,66 ^b	26,72 ± 10,08 ^b	29,21 ± 8,33 ^b
<i>Digitata</i>	36,00 ± 1,34 ^a	31,03 ± 4,50 ^a	60,87 ± 9,77 ^a

Mean ± standard deviation of results from all feet

The values of the same column designated by different letters are statistically different (p < 0.05)

Table 7: Antioxidant capacity (µmol TE/g DM) of pulps according to treatment and site

Parameter	Species	Considered factor	ACO (µmol TE/g DM)
Treatment	<i>Grandidieri</i>	Lyophilisation	14,77 ± 3,21 ^b
		Indirect solar drying	13,64 ± 2,45 ^b
		Deep-freezing	15,09 ± 3,99 ^a
	<i>Rubrostipa</i>	Lyophilisation	4,70 ± 5,96 ^b
		Indirect solar drying	4,75 ± 2,39 ^b
		Deep-freezing	12,86 ± 6,01 ^a
<i>Za</i>	Lyophilisation	27,44 ± 9,66 ^b	
	Indirect solar drying	26,72 ± 10,08 ^b	

	<i>Digitata</i>	Deep-freezing	29,21 ± 8,33 ^a
		Lyophilisation	36 ± 1,13 ^b
		Indirect solar drying	31,03 ± 4,50 ^c
Site	<i>Grandidieri</i>	Deep-freezing	60,87 ± 9,77 ^a
		Befandriana-sud	18,21 ± 3,76 ^a
		Andranomena	13,23 ± 2,86 ^b
	<i>Za</i>	Amataka	13,49 ± 3,34 ^b
		Ampanihy	25,54±3,17 ^a
		Ambanja	26,05 ± 16,06 ^a
		Anivorano	25,52±14,45 ^a

Mean ± standard deviation of results from all feet;

For each species or site, the values of the same column designated by different letters are statistically different ($p < 0.05$).

Conclusion

The pulps of *Adansonia* have an essentially energetic nutritional value provided by carbohydrates, and are also characterized by their richness in total dietary fibers and their low protein and lipid contents. The nutritional compositions of baobabs, like all fruits and vegetables, experience more or less significant variability, depending on climato-edaphic conditions, and methods of drying and preservation, but the preponderant factors are ascribed to genetics factors. Indeed, endemic species are richer in proteins and lipids. On the other hand, the greater antiradical activity for *digitata* could be related to the compositions of the phytonutrients naturally present in these fruits.

In view of these preliminary results, much work remains to be done on pulps with regard to the characterization and identification of molecules with antioxidant activity (phenols, vitamins A, E and C, etc.) and also to complete this information on organoleptic variability in order to propose nutritional recommendations based on the variability of baobab species. Seed studies are also underway.

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