Adansonia digitata L. – A review of traditional uses, phytochemistry and pharmacology

Emmy De Caluwé (1), Kateřina Halamová (2), Patrick Van Damme (1)

(1) Department of Plant Production, Ghent University, Belgium
(2) Department of Crop Sciences and Agroforestry in Tropics and Subtropics, Czech University of Life Sciences Prague, Praha, Czech Republic

Baobab (*Adansonia digitata* L., Malvaceae) is a multi-purpose tree species native to Africa. Its fruit pulp has very high vitamin C content (ffi ten times that of orange), and can be used in seasoning, as an appetizer and to make juices. Seeds contain appreciable quantities of crude protein, digestible carbohydrates and oil, whereas they have high levels of lysine, thiamine, Ca and Fe. They can be eaten fresh or dried, ground into flour and thus added to soups and stews. Processing eliminates a number of anti-nutritional factors present in the seed. Baobab leaves are superior in nutritional quality to fruit pulp, and contain significant levels of vitamin A. The leaves are a staple for many populations in Africa, and are eaten fresh or dried. Several plant parts have interesting anti-oxidant and anti-inflammatory properties, and baobab has been used extensively since ancient times in traditional medicine.

Key words: Baobab, Adansonia digitata L., traditional use, phytochemistry, pharmacology, amino acids, fatty acids, minerals, vitamins, anti-nutritional factors

Introduction

Baobab or *Adansonia digitata* L. belongs to the Malvaceae family (Bremer *et al.*, 2003) and is a deciduous tree native to arid Central Africa (Yazzie *et al.*, 1994). Its distribution area is large and this species can be found in most of Sub-Sahara Africa's semi-arid and sub-humid regions as well as in western Madagascar (Diop *et al.*, 2005). It has been introduced to areas outside Africa and grown successfully (Sidibe & Williams, 2002). Baobab is a very long-lived tree with multipurpose uses. The different plant parts are widely used as foods, medicines and the bark fibres are also used (Sidibe & Williams, 2002). The tree provides food, shelter, clothing and medicine as well as material for hunting and fishing (Venter & Venter (1996) cited in Gebauer *et al.*, 2002). Every part of the baobab tree is reported to be useful (Owen (1970) cited in Igboeli *et al.*, 1997 and Gebauer *et al.*, 2002).

Objectives and Methodology

Many authors have published about the multipurpose baobab tree. Nevertheless, only a few of these authors have presented a (general) literature review, and none of these dealt simply and solely with the nutritional and medicinal value of baobab products. For that reason, we decided to collect, document and compare detailed data on traditional uses, phytochemistry and pharmacology for fruit pulp, seeds, leaves and flowers, and bark of the baobab tree.

The literature search was done by using the following search terms: 'baobab' and '*Adansonia digitata*'. The authors included, without time limitation, all available information as proposed on Web of Science, consisting of different databases containing information gathered from thousands of scholarly journals, books, book series, reports and conferences. As is conventional in ethnobotanical reviews, authors respected original definitions, descriptions and/or naming of diseases and afflictions. However, we are fully aware that this leaves sometimes doubt on the exact nature (i.e. disease names as known in formal western medicine) but consider the latter equations to be outside of the scope of this article.

During our literature review, a large variation in information and data was encountered and the reported values were, as much as possible, converted into the same unit. Authors are thus aware that there might be discrepancies in analytical data presented in some tables (e.g. Table V and Table X). It should be understood however, that each laboratory or research group uses specific analytical tools and that it is impossible to streamline results in such a way that they could be compared using the same standard. The reader is referred to the original articles for details about analytical methods and correct interpretation of the results obtained.

Food Uses

Fruits

The baobab fruit pulp is probably the most important foodstuff. It can be dissolved in water or milk. The liquid is then used as a drink, a sauce for food, a fermenting agent in local brewing, or as a substitute for cream of tartar in baking (Sidibe & Williams, 2002) (Figure 1).

Figure 1. Preparation of baobab fruit pulp porridge: (1-2-3) pulp, seeds and fibres are diluted in water; (4) seeds and fibres are removed (4a) and dissolved pulp remains (4b); (5-6-7) at the same time, water is added to e.g. maize flour, boiled and thickened to a porridge which is mixed with the dissolved baobab pulp (Source: Emmy De Caluwé, Benin, 2004).

The pulp has recently become a popular ingredient in ice products in urban areas (Scheuring *et al.*, 1999; Sidibe *et al.* (1998b) cited in Gebauer *et al.*, 2002), in different kinds of juices and jams (Figure 2). The pulp is never cooked as the hot drinks are being prepared, rather it is added at the end of the preparation process after the drinks are allowed to cool (Sidibe *et al.*, 1996). Fruit pulp is important in local diets as a seasoning component and appetizer (Burkill (1985) cited in Ajayi *et al.*, 2003). When the pulp is soaked in water, it produces a milky solution, which can be consumed as a milk substitute (Burkill (1985) cited in Ajayi *et al.*, 2003). The baobab fruit pods are also good for burning and a potash-rich vegetable salt may be obtained from this ash for making soap (Burkill (1985) cited in Ajayi *et al.*, 2003).

Figure 2. From left to right: baobab nectar, two different kinds of baobab syrup and two different kinds of baobab jam (Source: Emmy De Caluwé).

Seeds

Baobab seeds can be eaten fresh, or they may be dried and ground into a flour which can either be added to soups and stews as a thickener, or roasted and ground into a paste, or boiled for a long time, fermented and then dried for use (Sidibe & Williams, 2002; FAO (1988) cited in Nnam & Obiakor, 2003) (Figure 3).

Figure 3. Left: after boiling the seeds, the latter can be shelled more easily and prepared into sauces baobab seeds (Source: Emmy De Caluwé, Benin, 2004); Right: (1) crushed baobab seeds are (2) fermented in the sun and (3) prepared into a sauce (Source: Emmy De Caluwé, Benin, 2004).

Leaves

The leaves of the baobab tree are a staple for many populations in Africa, especially the central region of the continent (Yazzie *et al.*, 1994; Gebauer *et al.*, 2002). During the rainy season when the baobab leaves are tender, people harvest the leaves fresh. During the last month of the rainy season, leaves are harvested in great abundance and are dried for domestic use and for marketing during the dry season. The leaves are typically sun-dried and either stored as whole leaved or pounded and sieved into a fine powder (Sidibe *et al.* (1998b) cited in Gebauer *et al.*, 2002) (Figure 4). Young leaves are widely used, cooked as spinach, and frequently dried, often powdered and used for sauces over porridges, thick gruels of grains, or boiled rice (Sidibe & Williams, 2002).

  

Figure 4. Left: baobab leaves drying in the sun (Source: Camille De Moor, Mali, 2007); Middle: woman selling baobab leaf powder at market (Source: Camille De Moor, Mali, 2007); Right: woman selling fresh baobab leaves at market (Source: Emmy De Caluwé, Mali, 2007).

Phytochemistry

In general and regardless the variation in reported data, one can conclude that baobab pulp is rich in vitamin C, the leaves are rich in good quality proteins – most essential amino acids are present in the leaves – and minerals, and the seeds in fat. Moreover, pulp and leaves exhibit antioxidant activity (Chadare *et al.*, 2009). A variety of chemicals have been isolated and characterised from A. digitata. They belong to the classes of terpenoids, flavonoids, steroids, vitamins, amino acids, carbohydrates and lipids (Shukla *et al.*, 2001). Literature review revealed a great variation in reported values of nutrient contents of baobab part. According to Chadare *et al.* (2009), the causes of these variations are not well known, however they made several assumptions. The variation may be due to the quality of the sample, the provenance of the sample, the age of the sample, the treatment before analysis, the storage conditions, the processing methods, a probable genetic variation, and the soil structure and its chemical composition. Apart from the variability in the material, the analytical methods and inherent variability may also be a cause of variability. Moreover, some of the micronutrients, such as vitamins and minerals, are biologically active. They can interact with other nutrients and change in their bioavailability. Chadare *et al.* (2009) give a critical evaluation of similarities and divergences of the values in relation to the research methods used. Based on this variation, Chadare *et al.* (2009) made three recommendations for future research: (1) more attention should be given to accuracy and precision of analytical methods; (2) research about digestibility and bioavailability of baobab products is needed; and (3) the effect of storage and processing on the nutritional value of baobab products needs to be assessed.

Fruits

The baobab fruit is composed of an outer shell (epicarp) (45%), fruit pulp (15%) and seeds (40%) (Shukla *et al.*, 2001). The woody epicarp or pod contains the internal fruit pulp (endocarp) which is split in small floury, dehydrated and powdery slides that enclose multiple seeds and filaments, the red fibres, that subdivide the pulp in segments (Nour *et al.* (1980) cited in Besco *et al.*, 2007) (Figure 5).

Figure 5. Baobab fruit (Source: Emmy De Caluwé, Benin, 2004).

Fruit Pulp

The dry baobab fruit pulp has a slightly tart, refreshing taste and is very nutritious, with particularly high values for carbohydrates, energy, calcium, potassium (very high), thiamine, nicotinic acid and vitamin C (very high) (Arnold *et al.*, 1985). The baobab fruit pulp is dry, acidulous and mealy, and rich in mucilage, pectins, tartarate and free tartaric acids. The presence of the tartarate gives rise to the name 'cream of tartar tree' (Sidibe & Williams, 2002; Wickens (1982) cited in Ajayi *et al.*, 2003). Pulp sweetness is provided by fructose, saccharose and glucose contents. Fruit pulp is also acidic and this is due to the presence of organic acids including citric, tartaric, malic, succinic as well as ascorbic acid (Airan & Desai (1954) cited in Sidibe & Williams, 2002). When eaten raw, the pulp is a rich *source* of calcium and vitamins B and C (Burkill (1985) cited in Ajayi *et al.*, 2003). It contains sugars but no starch, and is rich in pectins. The fruit pulp has a very high vitamin C content, almost ten times that of oranges. However, the vitamin C content of the bulk fruit pulp reportedly varies from 1623 mg/kg in one tree to 4991 mg/kg in another (Sidibe *et al.*, 1996; Sidibe *et al.* (1998a) cited in Gebauer *et al.*, 2002).

Chemical Composition

The pulp is acidic, due to the presence of the organic acids citric, tartaric, malic, succinic and ascorbic, with pH 3.3 (Nour *et al.*, 1980). The latter *source* also shows that the pulp is rich in pectin (average 56.2%). The pectin is mainly water soluble and has a low degree of esterification and a low intrinsic viscosity. This suggests that it will probably not yield a high quality jelly of high solids content, because it tends to precipitate rapidly in acid media to form irregular gels. It is of lower quality than commercial apple pectin and citrus waste pectin (Mubarak *et al.* (1977) cited in Nour *et al.*, 1980).

The fruit pulp contains a high amount of carbohydrate, low protein, and extremely low fat (Osman, 2004). According to Murray *et al.* (2001), simple sugars in baobab pulp account for about 35.6% of the total carbohydrate content. This explains the noticeable sweet taste of the pulp. However, the sweetness may vary for different types of pulp (Chadare *et al.*, 2009). The low water content, strong acidity and high sugar content was confirmed by Cisse *et al.* (2009). Proximate composition of the fruit pulp of baobab differs according to different literature *source*s (Nour *et al.*, 1980; Becker, 1983; Arnold *et al.*, 1985; Obizoba & Amaechi, 1993; Saka & Msonthi, 1994; Odetokun, 1996; Lockett *et al.*, 2000; Murray *et al.*, 2001; Shukla *et al.*, 2001; Osman, 2004) (Table I). Green (1932, cited in Nour *et al.*, 1980) reported the absence of starch in the pulp, which was confirmed by Nour *et al.* (1980).

Chadare *et al.* (2009) estimated the contribution of baobab pulp to the recommended daily intake (RDI) for energy, carbohydrates and protein for children and pregnant women. The reported lowest and highest carbohydrate content of the pulp allows coverage of 21.5% and 40.6% of the RDI when 60 g is consumed by a child. A consumption of 100 g pulp will cover 26 to 50% of the carbohydrate RDI for pregnant women. On the other hand, the energy content of the pulp is rather low when compared with the RDI for children and pregnant women.

Constituent	A	B	C	D	E	F	G	H	I	J
Moisture (%)	-	8.70	4.70	25.85	6.70	19.90	-	6.21	-	10.40
Dry matter (%)	85.50	-	-	-	-	-	86.80	-	89.45	-
Protein	2.50	2.70	2.50	1.80	2.60a	15.30	3.10	10.90	2.19	3.20
Fat	0.80	0.20	0.70	0.38	0.20	4.10	4.30	4.28	0.37	0.30
Ash	-	5.80	5.10	3.31	5.30	1.90	5.00	1.98	5.71	4.50
Crude fibre	11.40	8.90	45.10	-	5.70	-	8.30	6.21	11.15	5.40
Carbohydrate	81.30	73.70	35.60b	-	23.20c	58.80	79.40	45.21	70.03	76.20
Metabolizable energy (kJ/100g)	846.00	1292.00	849.00	-	-	-	1480.00	820.47	-	1341.03

Table I. Proximate Composition of Baobab Fruit Pulp. Note: A-D: units are g/100 g dw; E-J: units are percent (%);a:%N x 6.25; b: simple sugars; c: sugars; -: not mentioned in the original paper. Source: A: Becker (1983); B: Arnold et al. (1985); C: Murray et al. (2001); D: Shukla et al. (2001); E: Nour et al. (1980); F: Obizoba & Amaechi (1993); G: Saka & Msonthi (1994); H: Odetokun (1996); I: Lockett et al. (2000); J: Osman (2004).

Amino Acid Profile

Protein accounts for about one-fifth of dry matter in baobab fruit pulp (17%) (Sena *et al.*, 1998), thus can be considered a rich *source* of amino acids (Table II) compared to the WHO 'ideal' standards (Sena *et al.*, 1998) (Table III). The baobab fruit pulp is particularly high in valine, tryptophan and phenylalanine + tyrosine. Comparing to baobab leaves, baobab fruit pulp is inferior in terms of overall protein quality (Sena *et al.*, 1998). There is a large variability in the reported amino acid contents of baobab fruit pulp, despite the fact that the authors uses similar methods for determination (Chadare *et al.*, 2009).

Fatty Acid Profile

Most fatty acids in the pulp do not reach detectable levels. Similarly to the amino acids, the variability in the reported values in high, even though the use of identical methods by the researchers (Chadare *et al.*, 2009). Glew *et al.* (1997) recorded total lipid content of 155 mg/g dry weight, and stated that significant linoleic acid is present. Sena *et al.* (1998) also points baobab fruit out as a rich *source* of linoleic acid, 27 mg/g dry weight, whereas it contains a very low amount of α-linolenic acid (<1 mg/g) (Table IV). The two fatty acids which are essential for human nutrition are linoleic acid (18:2n-6) and α-linolenic acid (18:3n-3) (Sena *et al.*, 1998).

Mineral Composition

Several reports have studied the mineral composition of baobab fruit pulp (Nour *et al.*, 1980; Becker, 1983; Arnold *et al.*, 1985; Obizoba & Amaechi, 1993; Prentice *et al.*, 1993; Saka & Msonthi, 1994; Smith *et al.*, 1996; Glew *et al.*, 1997; Sena *et al.*, 1998; Lockett *et al.*, 2000; Osman, 2004) (Table V). However, the reported mineral contents of baobab pulp show a great variability between authors which can be due to different methods used (Chadare *et al.*, 2009). Baobab fruit pulp contains very little iron and is a relatively poor *source* of manganese, but contains exceptionally high calcium content (Sena *et al.*, 1998; Osman, 2004). The high calcium contents of the fruit pulp make baobab fruits attractive as a natural *source* of calcium supplementation for pregnant and lactating women, as well as for children and the elderly (Osman, 2004; Prentice *et al.*, 1993).

Chadare *et al.* (2009) estimated the contribution of baobab pulp to the recommended daily intake (RDI) for iron, zinc and calcium for children and pregnant women. The coverage of those minerals is possible only when the highest reported values are considered for the pulp. Thus, considering the highest reported values, the consumption of 40 g of baobab pulp for children is enough to cover 41.5% of the DRI for iron, 25.4% of the RDI for zinc, and 35% for the RDI for calcium. For pregnant women, the consumption of 60 g and 100 g would cover 23.1% and 38.4% of the DRI for iron, 17.3% and 28.7% for the RDI for zinc, and 42.1% and 70.1% for the RDI for calcium, respectively.

Amino Acid		A	B	C	D
Crude protein (Total protein)		27.00	170.00	-	-
Aspartic acid	ASP	2.96	15.90	-	6.40
Glutamic acid	GLU	3.94	38.80	4.02	6.50
Serine	SER	1.18	8.80	-	3.20
Glycine	GLY	1.21	7.00	-	2.90
Histidine	HIS	0.42	3.80	2.71	1.20
Arginine	ARG	2.28	19.30	6.04	7.60
Threonine	THR	0.65	5.70	2.96	2.80
Alanine	ALA	2.21	7.20	-	3.30
Proline	PRO	2.35	7.50	0.92	2.20
Tyrosine	TYR	1.06	4.70	4.21	20.60
Valine	VAL	1.62	9.10	0.43	4.80
Methionine	MET	0.14	1.60	4.92	0.20
Isoleucine	ILE	1.37	6.50	10.73	2.20
Leucine	LEU	2.06	10.90	8.41	4.30
Phenylalanine	PHE	1.09	8.40	4.11	4.40
Lysine	LYS	1.63	8.70	14.62	1.70
Cysteine	CYS	1.37	3.60	11.23	1.00
Tryptophan	TRP	0.18	2.80	1.49	-

Table II. Amino Acid Composition of Baobab Fruit Pulp. Note: A-B: units are mg/g dw; C-D: units are mg/100 mg; -: not mentioned in the original paper. Source: A: Glew et al. (1997); B: Sena et al. (1998); C: Odetokun (1996); D: Osman (2004).

Amino Acid	*Baobab Fruit/Ideal x 100%*
Threonine	83
Valine	106
Methionine + cystine	86
Isoleucine	95
Leucine	91
Phenylalanine + tyrosine	128
Lysine	93
Tryptophan	170

Table III. Essential Amino Acid Content of Baobab Fruit Pulp Compared to WHO 'Ideal' Standards. Source: Sena et al. (1998).

Fatty Acid	*mg/g dw*
Total fatty acid content	84.10
C14:0 Myristic	0.18
C16:0 Palmitic	27.00
C18:0 Stearic	3.30
C18:1n-9 Oleic	25.00
C18:2n-6 Linoleic	27.00
C18:3n-3 α-Linolenic	0.86
C20:0 Arachidic	0.69
C20:1 Gadoleic	0.04
Total lipid content	127.00

Table IV. Fatty Acid Content of Baobab Fruit. Source: A: Sena et al. (1998.).

Minerals		A	B	C	D	E	F	G	H	I	J	K
Ca	Calcium	655.00	530.00	335.00	2.40	390.00	115.60	-	341.00	216.00	211.00	295.00
Cu	Copper	-	-	0.37	0.14	-	-	0.43	ND	1.15	0.55	1.60
Fe	Iron	8.60	2.52	2.65	0.86	-	5.80	1.20	1.70	2.92	4.23	9.30
K	Potassium	-	-	2409.00	-	-	2836.40	-	-	726.00	-	1240.00
Mg	Magnesium	-	-	167.00	-	-	209.00	78.10	209.00	300.00	123.00	90.00
Mn	Manganese	-	-	-	-	-	-	0.59	ND	0.98	0.39	-
Na	Sodium	-	-	11.20	-	-	18.80	-	5.46	0.79	-	27.90
P	Phosphorus	50.80	1330.00	76.20	0.03	35.00	45.00	-	73.30	452.00	49.79	-
Zn	Zinc	-	-	1.00	1.83	-	-	0.47	1.04	3.18	0.47	1.80

Table V. Mineral Content of Baobab Fruit Pulp. Note: units are mg/100 g dw; -: not mentioned in original paper.
Source: A: Nour et al. (1980); B: Becker (1983); C: Arnold et al. (1985); D: Obizoba & Amaechi (1993); E: Prentice et al. (1993); F: Saka & Msonthi (1994); G: Smith et al. (1996); H: Glew et al. (1997); I: Sena et al. (1998); J: Lockett et al. (2000); K: Osman (2004).

Vitamins

Authors have investigated mainly vitamin C (Chadare *et al.*, 2009). Baobab fruit pulp has among the highest vitamin C or ascorbic acid content found in any fruit (Carr, 1955; Nicol, 1957). Umoh (1988, cited in Nnam & Obiakor, 2003) reports 373 mg/100 g wet weight, which is more than six times the level of vitamin C in citrus fruits (30-50 mg/100 g wet weight) and the highest known in natural fruits. Besco *et al.* (2007) documented an ascorbic acid content in baobab fruit ranging from 150-499 mg/100 g of product. Scheuring *et al.* (1999) revealed a remarkable baobab tree-to-tree variability for vitamin C content in the fruit pulp, ranging from 1500-5000 mg/kg and reported that it was quite stable from one year to the next. The exact vitamin C content depends on the individual tree (Sidibe *et al.*, 1996). With baobab fruit powder, a drink with a vitamin C content equal to that of orange juice is easily obtained. However, to retain vitamin C in soft drinks it is important not to boil the pulp but rather to add the powder to previously boiled water (Sidibe *et al.*, 1996). Chadare *et al.* (2009) estimated the contribution of baobab pulp to the recommended daily intake (RDI) for vitamin C for children and pregnant women. The consumption of 13.9 g of pulp with the lowest reported vitamin C content and 8.3 g of pulp with the highest reported vitamin C content is enough to cover the RDI for a child. The consumption of 40 g of pulp by a pregnant women will cover 84 to 141% of her RDI of vitamin C, considering the lowest and the highest vitamin C content of the pulp reported by authors.

Baobab fruit contains detectable levels of α-carotene (0.17 µg/g dry weight) and lutein (1.53 µg/g dry weight) (Sena *et al.*, 1998). Toury *et al.* (1957) and Oliviera (1974) (both cited in Nour *et al.*, 1980), point out baobab pulp as a valuable *source* of thiamine. Becker (1983) reported thiamine, riboflavin, and niacin content of 0.04, 0.07 and 2.16 mg/100g dw, respectively. The methods used to determine each vitamin are seldomly described according to Chadare *et al.* (2009), which makes it hard to evaluate these figures critically.

Baobab Milk

In some areas the use of baobab milk is very common. The dried pulp is scraped from baobab fruits and made into a solution (Figure 6).

Figure 6. Pulp and seeds of baobab are crushed (1) and diluted with water or fresh milk (2) as a beverage. (Source: Emmy De Caluwé, Benin, 2004).

The milk is a highly nutritious drink (Obizoba & Anyika (1994) cited in Gebauer *et al.*, 2002). Baobab milk can be made from a mixture of baobab and acha flour, or from baobab pulp alone. Acha (*Digitaria exilis*) and baobab (*Adansonia digitata*) grains are cleaned, fermented for 24 to 120 hours, dried and hammer-milled into fine flours. The mixtures were composed of 70% acha and 30% baobab flours (70:30 protein basis) (Obizoba & Anyika, 1994). Baobab milk contains more protein (1.5%) and minerals (Fe : 17.8 mg; Ca: 134.2 mg) than human milk (protein: 1.3%; Fe: 0.2 mg; Ca: 30 mg) or cow milk (Fe: 0.1 mg; Ca: 1.20 mg) and most leading national commercial infant milk powder formulas e.g. Cerelac (Fe: 10.0 mg). The composite flours contain more nutrients than the baobab or the acha flour alone (Obizoba & Anyika, 1994).

Seeds

The vernacular name for Adansonia digitata, baobab, means 'fruit with many seeds' (Ajayi *et al.*, 2003) (Figure 7).

Figure 7. Baobab seeds (Source: Emmy De Caluwé, Benin, 2004).

The seeds are eaten raw or are roasted and have a pleasant nutty flavour (Wehmeyer (1971) cited in Arnold *et al.*, 1985). Murray *et al.* (2001) reported that baobab seed flour is an important *source* of energy and protein. The nutritious seeds have high values for proteins, fats (oils), fibre and most minerals (Arnold *et al.*, 1985). The baobab seed contains appreciable quantities of oil (29.7%, expressed on a dry weight basis) (Addy & Eka (1984) cited in Nnam & Obiakor, 2003) (Figure 8). Besides, baobab seeds have high levels of lysine, thiamine, calcium, and iron (FAO (1988) cited in Nnam & Obiakor, 2003). Baobab seed can be classified as both protein- and oil-rich. It is also a very rich *source* of energy and has a relatively low fat value (Igboeli *et al.*, 1997).

Figure 8. Two different kinds of baobab seed oil (Source: Emmy De Caluwé).

Fermentation of baobab seeds decreases protein and carbohydrate but increases fat levels. Fermentation has varied effects on the mineral concentrations of the baobab seeds (Nnam & Obiakor, 2003).

Chemical Composition

According to Osman (2004), the seed contains relatively high amounts of protein, crude fat, and crude fibre, and low levels of carbohydrates. The baobab seeds have been subjected to extensive research, a the proximate analysis of the seeds are provided (Table VI).

According to estimations made by Chadare *et al.* (2009), consumption of 20 g can cover 15 to 34% of the protein recommended daily intake (RDI) for children; while for pregnant women 60 g can cover 27% of the RDI based on the highest reported content. Moreover, consumption of 100 g can cover 22% of the energy RDI for pregnant women and 29.4% of energy RDI for children.

Constituent	A	B	C	D	E	F	G	H	I	J	K	L	M
Moisture	8.10	6.11	4.80	7.40	4.71	8.10	6.12	6.38	7.80	-	5.02	-	4.30
Dry matter	-	-	-	-	-	-	-	-	-	8.19	-	-	-
Protein	33.70	14.40	36.60	35.10	21.75	32.70	21.42	26.70	30.00	15.12	13.30	25.45	18.40
Fat	30.60	16.14	29.30	29.10	12.72	34.10	17.51	23.50	29.60	11.56	33.00	18.87	12.20
Ash	5.90	4.95	9.10	8.40	5.01	5.00	2.15	5.50	7.90	5.76	7.50	7.61	3.80
Crude fibre	16.90	-	14.10	-	6.71	-	7.15	-	-	49.72	20.14	-	16.20
Carbohydrate	4.80	56.75	11.20a	-	52.53	30.00	37.16	37.92	24.92	17.84	20.98	48.07	45.10
Metabolizable energy (kcal/100 g)	430.64	462.17	454.00	-	446.50	-	181.62	469.98	452.00	-	-	-	363.80

Table VI. Proximate Composition of Baobab Seeds.

Note: A-E: units are g/100 g dw; F-M: units are percent (%); a: simple sugars; -: not mentioned in the original paper.

Source: A: Arnold et al. (1985); B: Proll et al. (1998); C: Murray et al. (2001); D: Shukla et al. (2001); E: Nkafamiya et al. (2007); F: Obizoba & Amaechi (1993); G: Odetokun (1996); H: Igboeli et al. (1997); I: FAO analysis (1968, cited in Igboeli et al., 1997); J: Lockett et al. (2000); K: Ajayi et al. (2003); L: Nnam & Obiakor (2003); M: Osman (2004).

Amino Acid Profile

The seed contains a relatively high amount of essential amino acids (Odetokun, 1996; Glew *et al.*, 1997; Proll *et al.*, 1998; Osman, 2004). Table VII shows the amino acid composition of baobab seeds. Because Proll *et al.* (1998) showed results in units (mg/g N) that differ from those found by other researchers (Odetokun, 1996; Glew *et al.*, 1997; Osman, 2004) (mg/g dry weight), these data are not compared to each other in the table.

Amino Acid		A	B	C
Crude protein (Total protein)		196.00	-	-
Aspartic acid	ASP	21.10	-	10.30
Glutamic acid	GLU	48.90	2.10	23.70
Serine	SER	11.40	-	6.10
Glycine	GLY	10.40	-	8.60
Histidine	HIS	5.05	1.43	2.20
Arginine	ARG	2.21	8.62	8.00
Threonine	THR	6.98	1.64	3.80
Alanine	ALA	10.60	-	7.10
Proline	PRO	9.55	0.62	6.90
Tyrosine	TYR	5.59	3.62	1.50
Valine	VAL	11.60	0.76	5.90
Methionine	MET	2.29	5.94	1.00
Isoleucine	ILE	8.27	7.10	3.60
Leucine	LEU	14.00	7.48	7.00
Phenylalanine	PHE	10.30	5.18	4.00
Lysine	LYS	11.20	17.36	5.00
Cysteine	CYS	3.60	12.63	1.50
Tryptophan	TRP	2.81	2.64	-

Table VII. Amino Acid Composition of Baobab Seeds. Note: A: units are mg/g dw; B-C: units are mg/100 mg; -; not mentioned in the original paper. Source: A: Glew et al. (1997); B: Odetokun (1996); C: Osman (2004).

In contrast to other plant seed protein profiles, baobab seed protein contains a high amount of lysine. Because lysine is limited in most cereal plants, it may be possible to use baobab seed protein to improve cereal protein quality (Osman, 2004). The high protein solubility at acidic and alkaline pH suggests that the baobab seed protein could be an adequate food ingredient (Osman, 2004).

Table VIII provides a list of the essential amino acid content of baobab fruit pulp compared to WHO's 'ideal' standards (Glew *et al.*, 1997; Addy & Eteshola (1984) cited in Sidibe & Williams, 2002). Baobab seeds are rated "good" in that they scored as well or better than the WHO standard protein in 5 of 8 categories.

Amino Acid	A	B
Threonine	90.00	102.50
Valine	118.00	120.00
Methionine + cystine	85.71	51.43
Isoleucine	105.00	92.50
Leucine	101.43	108.57
Phenylalanine + tyrosine	135.00	23.33
Lysine	103.64	120.00
Tryptophan	35.00	35.00

Table VIII. Essential Amino Acid Content of Baobab Seeds Compared to WHO's 'Ideal' Standards. Note: units are baobab seeds/ideal x 100%. Source: A: Glew et al. (1997); B: Addy & Eteshola (1984, cited in Sidibe & Williams, 2002).

Fatty Acid Profile

The oil of baobab seeds contained high proportions of linoleic and oleic acid as well as palmitic and α-linolenic acid (Glew *et al.*, 1997; Ezeagu *et al.*, 1998) (Table IX). According to Osman (2004), baobab seed oil is an excellent *source* of mono-and polyunsaturated fatty acids. The principal fatty acids in baobab oil are linoleic and oleic acid, 39.42% and 26.07% respectively. Of the total fatty acids 73.11% is unsaturated while 26.89% is saturated (Ajayi *et al.*, 2003). Polyunsaturated fatty acids play an important role in modulating human metabolism, therefore, the high linoleic acid content is of nutritive significance. The ability of some unsaturated vegetable oils to reduce serum cholesterol level may focus attention on the seed oil of baobab (Ajayi *et al.*, 2003). This high content of mono- and polyunsaturated fatty acids suggests that baobab seed oil would be useful as a food oil (Osman, 2004). The saponification value is high, suggesting that baobab oil may be suitable for soap making (Nkafamiya *et al.*, 2007).

Fatty Acid	A	B	C	D	E	F
Total fatty acid content	-	67.79	-	-	-	-
C12:0 Lauric	-	-	0.34	0.15	-	-
C14:0 Myristic	Tr	1.90	1.46	0.90	-	0.20
C16:0 Palmitic	1.43	155.00	2.22	35.5	4.43	24.20
C16:1n-7 Palmitoleic	0.02	2.00	1.65	1.00	-	-
C18:0 Stearic	0.16	31.20	-	0.40	3.98	4.60
C18:1n-9 Oleic	2.14	246.90	58.71	40.00	26.07	35.80
C18:2n-6 Linoleic	1.38	191.10	23.25	20.50	39.42	30.70
C18:3n-3 α-Linolenic	1.02	15.80	8.17	4.00	-	1.00
C20:0 Arachidic	Tr	7.40	-	0.75	2.26	1.30
C20:1 Gadoleic	-	1.90	3.64	1.80	4.01	0.90
Total lipid content	90.00	-	-	-	-	-

Table IX. Fatty Acid Content of Baobab Seeds (Seed Oil). Note: A: units are mg/g dw; B: units are g fatty acid/100 g oil; C-F: units are percent (%); Tr: trace; -: not mentioned in the original paper. Source: A: Glew et al. (1997); B: Ezeagu et al. (1998); C: Odetokun (1996); D: Baobab Fruit Company (2002, cited in Sidibe & Williams, 2002); E: Ajayi et al. (2003); F: Osman (2004).

Mineral Composition

The most important minerals in baobab seeds are calcium and magnesium (Table X). Nkafamiya *et al.* (2007) reported phosphorous, calcium and potassium as the major mineral elements present in the seeds. At the same time, the seeds are a poor source of iron, zinc and copper (Glew *et al.*, 1997; Lockett *et al.*, 2000; Osman, 2004). The huge differences found may be due to the use of different methods, but may also have other causes (Chadare *et al.*, 2009).

Minerals		A	B	C	D	E	F	G	H
Ca	Calcium	273.00	2.00	395.00	264.00	0.50	410.00	58.90	4.34
Cu	Copper	2.78	0.41	ND	1.19	0.02	2.60	-	0.27
Fe	Iron	6.55	1.27	1.83	4.35	0.63	6.40	6.36	6.70
K	Potassium	1275.00	-	-	-	0.60	910.00	280.00	173.64
Mg	Magnesium	640.00	-	352.00	278.00	-	270.00	-	11.04
Mn	Manganese	-	-	1.06	1.01	-	-	-	1.52
Na	Sodium	2.48	-	1.94	-	-	28.30	6.07	1.71
P	Phosphorus	5.12	0.20	614.00	678.00	326.33	-	6.00	-
Zn	Zinc	6.68	1.90	2.57	4.29	1.29	5.20	3.60	1.03

Table X. Mineral Content of Baobab Seeds. Note: A-G: units are mg/100 g dw; H: unit is ppm; ND: not detected; -:not mentioned in the original paper. Source: A: Arnold et al. (1985); B: Obizoba & Amaechi (1993); C: Glew et al. (1997). D: Lockett et al. (2000); E Nnam & Obiakor (2003); F: Osman (2004); G: Nkafamiya et al. (2007); H: Ajayi et al. (2003).

Anti-nutritional Factors

The acceptability and optimal utilization of baobab seed as a protein *source* is limited by the presence of anti-nutritional factors such as trypsin inhibitors, protease inhibitors, tannins, phytic acid, oxalate, alkaloids, phytate and amylase inhibitors (Proll *et al.*, 1998; Osman, 2004). Osman (2004) investigated the anti-nutritional factors in baobab seeds and found that they contain a Trypsin Inhibitor Activity of 5.7 TIU/mg sample, 73 mg/100 g of phytic acid and 23% catechin equivalent of tannin. While processing techniques may 'rob' a food item of some nutrients, processing systems may also enhance food nutritional quality by reducing or destroying the anti-nutrients present. Some of the commonly used processing techniques include soaking in water, boiling in alkaline or acidic solutions. A decrease in tannin contents of baobab seeds was observed after a cold-water, hot-water and hot-alkali treatment. This can be explained by several possibilities: tannins are water soluble, tannin molecules are degraded when heated, heating may cause the formation of water-soluble complexes with other macromolecules of the seeds or reaction between tannic acid and the base. Dehulling and cold-water treatment of seeds greatly reduced the activity of amylase inhibitors (Igboeli *et al.*, 1997).

Sun drying, roasting and fermentation are traditional processing techniques that were tested by Obizoba & Amaechi (1993) to improve the chemical composition of both baobab pulp and seed. They showed that fermentation of the seeds for 6 days offered much advantages over roasting as shown by crude protein, moisture and minerals contents. A 6-day fermentation appeared to be the most promising method for producing nutritious food from baobab seed (Obizoba & Amaechi, 1993).

Nnam & Obiakor (2003) reported that fermentation decreased the tannin levels in baobab seed. Tannins are known to reduce the availability of proteins, carbohydrates, and minerals by forming indigestible complexes with nutrients. The reduced tannin level due to fermentation could improve the availability of nutrients in the seed.

When comparing the different processing methods such as boiling in water, acid or alkali or fermentation, the alkali treatment exhibited the best results (Addy *et al.*, 1995). Alkali treatment appeared to be the most effective method for reducing trypsin inhibitor and tannin contents, and had the additional advantage of improving protein digestibility. However, such alkali treatments may also cause the production of harmful compounds, such as lysinoalanine wich is nephrotoxic to rats (De Groot & Slump (1969) cited in Addy *et al.*, 1995).

Leaves

Depending on the season, families use either fresh and/or dried leaves, which can serve as a significant protein and mineral *source* for those populations for whom it is a staple food (Sidibe & Williams, 2002) (Figure 9). In general, baobab leaves are nutritionally superior to the fruit of the tree (Sena *et al.*, 1998). Relative to fruits, leaves contain more essential amino acids, minerals and vitamin A which make them more interesting as a food *source* because they cover a broader range of nutritional factors.

Figure 9. Baobab leaves (Source: Emmy De Caluwé, Benin, 2004).

Chemical Composition

According to Sidibe & Williams (2002), based on the data of Becker (1983), Yazzie *et al.* (1994) and Nordeide *et al.* (1996), the leaves contain (expressed on dry weight basis): 13–15% protein, 60–70% carbohydrate, 4–10% fat and around 11% fibre and 16% ash (see also Table XI). Energy value varies between 1180-1900 kJ/100g of which 80% is metabolizable energy (Sidibe & Williams, 2002). Chadare *et al.* (2009) calculated that, without considering the conversion factor or the effect of processing, the consumption of 20 g of dry leaf material would cover 10 to 16% of the protein recommended daily intake for children.

Chadare *et al.* (2009) concluded that the variability in the reported values for baobab leaves is lower than for the macronutrient composition of the pulp, despite the use of different measurement methods by the authors. This can be due to the rather low number of authors who investigated the macronutrient composition of the leaves.

Constituent	A	B	C
Dry matter	-	93.60	8.23
Protein	13.40	14.00	10.14
Fat	4.00	4.30	6.25
Ash	-	10.80	15.90
Crude fibre	11.00	-	27.49
Carbohydrate	60.00	64.60	40.21
Metabolizable energy (kJ/100 g)	1180.00	1480.00	-

Table XI. Proximate Composition of Baobab Leaves. Note: units are g/100 g dw; -: not mentioned in the original paper. Source: A: Becker (1983); B: Nordeide et al. (1996); C: Lockett et al. (2000).

The leaves also contain an important amount of mucilage (Gaiwe *et al.* (1989) cited in Sidibe & Williams, 2002). Ten percent of the dry matter of leaves consists of mucilage (Diop *et al.*, 2005). Woolfe *et al.* (1997, cited in Shukla *et al.* 2001), found that the mucilage is an acidic polysaccharide with associated proteins and minerals.

Amino Acid Profile

On a qualitative and quantitative basis, baobab leaf appears to be a good *source* of protein for those populations for whom this plant material is a staple (Yazzie *et al.*, 1994). The amino acid profile has been previously reviewed (Yazzie *et al.*, 1994; Nordeide *et al.*, 1996; Glew *et al.*, 1997; Sena *et al.*, 1998). Because Nordeide *et al.* (1996) showed results in units (mg of amino acid/g N) that differ from those found by other researchers (Yazzie *et al.*, 1994; Glew *et al.*, 1997) (mg of amino acid/g dry weight), these data are not compared to each other in this review. Nordeide *et al.* (1996) concluded that baobab leaves are potentially protein *source*s to be used to complement the amino acid profile to improve the overall protein quality of the local diet. Baobab leaf contains 10.6% protein on a dry weight basis and significant amounts of all the common amino acids (Table XII) (Yazzie *et al.*, 1994).

Amino Acid		A	B	C
Crude protein (Total protein)		106.30	103.00	112.00
Aspartic acid	ASP	10.30	12.90	12.40
Glutamic acid	GLU	13.40	11.40	14.40
Serine	SER	4.70	4.55	4.50
Glycine	GLY	6.00	5.57	5.40
Histidine	HIS	2.10	2.18	2.40
Arginine	ARG	8.50	7.07	8.30
Threonine	THR	4.10	3.65	4.30
Alanine	ALA	6.90	6.58	6.80
Proline	PRO	5.60	6.76	6.40
Tyrosine	TYR	4.50	4.15	4.30
Valine	VAL	6.30	6.55	7.00
Methionine	MET	2.40	1.04	1.50
Isoleucine	ILE	6.70	5.46	6.10
Leucine	LEU	8.70	8.75	9.80
Phenylalanine	PHE	5.70	6.02	6.70
Lysine	LYS	6.10	6.11	6.40
Cysteine	CYS	2.70	2.11	2.40
Tryptophan	TRP	1.60	2.05	3.40

Table XII. Amino Acid Composition of Baobab Leaves. Note: units are mg/g dw. Source: A: Yazzie et al. (1994); B: Glew et al. (1997); C: Sena et al. (1998).

To provide a reference point, Yazzie and collaborators (1994) compared the amino acid composition of baobab leaf to the 'ideal' protein as defined by the World Health Organization which is based on the amino acid needs of a preschool child. Baobab leaves contain the same amount or more of the following essential amino acids as contained in the 'ideal' protein: lysine (5.7%), arginine (8.0%), threonine (3.9%), valine (5.9%), tyrosine + phenylalanine (9.6%), tryptophan (1.5%) and methionine + cysteine (4.8%) (Yazzie *et al.*, 1994). A calculation of the 'chemical' score of protein quality using tryptophan, the most limiting of the essential amino acids, shows that the leaves contain significant amounts of all the essential amino acids (Yazzie *et al.*, 1994). In terms of protein content and WHO standards, leaves of baobab can be rated "good" in that they score well for 5 of the 8 essential amino acids (Table XIII). For each of the eight essential amino acid categories baobab leaves score close to or above the 100% mark.

Amino Acid	A	B	C
Threonine	93.00	87.50	95.00
Valine	124.00	128.00	124.00
Methionine + cystine	139.00	85.71	100.00
Isoleucine	130.00	132.50	138.00
Leucine	136.00	121.43	124.00
Phenylalanine + tyrosine	162.00	165.00	163.00
Lysine	105.00	107.27	104.00
Tryptophan	77.50	50.00	75.00

Table XIII. Essential Amino Acid Content of Baobab Leaves Compared to the WHO 'Ideal' Standards.
Note: units are baobab leaves/ideal x 100%. Source: A: Yazzie et al. (1994); B: Glew et al. (1997); C: Sena et al. (1998).

The fact that the leaves contain significant amounts of tryptophan has at least two implications. First, for those people for whom baobab leaves are a staple, this food *source* may provide significant amounts of tryptophan. Second, since a part of the niacin requirement in humans can be satisfied by the conversion of tryptophan to niacin (Satyanaryana & Rao (1983) cited in Yazzie *et al.*, 1994), baobab leaf may also serve as a niacin *source*.

Fatty Acid Profile

Few authors investigated the fatty acid content of baobab leaves, and the reported data by Glew *et al.* (1997) and Sena *et al.* (1998) show many differences (Chadare *et al.*, 2009). Total lipid content of baobab leaves was reported to be 55 mg/g of dry weight, though the fatty acid composition revealed that the leaves did not provide significant *sources* of linoleic acid (Glew *et al.*, 1997) (Table XIV). This observation was also confirmed by Sena *et al.* (1998).

Fatty Acid	A	B
Total fatty acid content	-	9.90
C8:0	-	0.01
C12:0	-	0.09
C14:0 Myristic	Tr	0.37
C16:0 Palmitic	0.24	3.20
C16:1 Palmitoleic	0.01	0.21
C18:0 Stearic	0.04	0.35
C18:1 Oleic	0.06	0.39
C18:2 Linoleic	0.10	1.00
C18:3 Linolenic	0.08	4.10
C20:0 Arachidic	Tr	0.15
Total lipid content	55.00	153.00

Table XIV. Fatty Acid Content of Baobab Leaves. Note: units are mg/g dw; ND: not detected; Tr: trace; -: not mentioned in the original paper. Source: A: Glew et al. (1997); B: Sena et al. (1998).

Mineral Composition

Baobab leaves are also significant *sources* of minerals (Becker, 1983; Prentice *et al.*, 1993; Yazzie *et al.*, 1994; Nordeide *et al.*, 1996; Smith *et al.*, 1996; Glew *et al.*, 1997; Sena *et al.*, 1998; Lockett *et al.*, 2000; Boukari *et al.*, 2001; Barminas *et al.*, 2007) as shown in Table XV. Some studies (Glew *et al.*, 1997; Lockett *et al.*, 2000; Barminas *et al.*, 2007) reported that baobab leaves have a higher content of iron compared to numerous other wild-gathered foods, and are a rich *source* of calcium. Yazzie *et al.* (1994) highlight baobab leaves as a substantial *source* of calcium, iron, potassium, magnesium, manganese, molybdenum, phosphorus, and zinc. Since iron-deficiency anaemia is common in regions of Africa were baobabs grow, the leaves may represent an important *source* of iron (Yazzie *et al.*, 1994; Sidibe & Williams, 2002). Barminas *et al.* (1998) showed that baobab leaves can be a valuable and important contributor in the diets of rural and urban people. A serving portion (300 g fresh leaves or 30 g dry weight leaves) contributes 46.2% to the recommended dietary allowance (RDA) of phosphorus, 57.1% to the RDA of magnesium, 74.2% to the RDA of calcium, 84.4% to the RDA of iron, 106.0% to the RDA of manganese, 45.0% to the DRA of copper, and 62.7% to the RDA of zinc (Barminas *et al.*, 2007). According to Chadare *et al.* (2009) and considering the highest reported values, 20 g would cover 89% of the zinc recommended daily intake (RDI) and 66% of the calcium RDI for children. Similarly, consumption of 20 g will cover 53% of the calcium RDI and 41% of the zinc RDI for pregnant women.

Comparisons between published data on the minerals iron, calcium, zinc and phosphorous show wide variations in content (Sidibe & Williams, 2002). The plant state of maturation, genetic variances, and environmental factors are all possible explanations for the reported discrepancies (Nordeide *et al.* (1996) cited in Boukari *et al.*, 2001). Moreover, mineral composition in food may vary greatly depending on where the food was grown (Boukari *et al.*, 2001), on seasonal variations (Yazzie *et al.*, 1994), and on the used analytical method (Boukari *et al.*, 2001). The latter was also discussed by Chadare *et al.* (2009). In addition, the bioavailability of these minerals has not yet been investigated. Although, this is necessary to determine to which extend baobab leaves can be used to combat certain micronutrient deficiency problems (Chadare *et al.*, 2009).

Minerals		A	B	C	D	E	F	G	H	I	J
Ca	Calcium	2600.00	1750.00	1087.33	1810.00	-	2000.00	1470.00	2526.00	2240.00	1824.60
Cu	Copper	-	-	-	-	0.53[a] 0.29[b] 0.49[c]	1.16	<0.50	1.02	-	1.60
Fe	Iron	24.00	-	128.70	41.00	27.80[a] 21.20[b] 11.70[c]	15.50	98.60	93.10	-	30.60
K	Potassium	-	-	1541.00	-	-	-	583.00	-	-	-
Mg	Magnesium	-	-	427.67	-	93.60[a] 121.70[b] 274.20[c]	549.00	423.00	246.00	-	400.60
Mn	Manganese	-	-	7.09	-	9.84[a] 1.85[b] 2.01[c]	3.10	8.76	6.82	-	6.60
P	Phosphorous	250.00	193.00	185.33	-	-	302.00	153.00	115.00	-	875.60
Na	Sodium	-	-	-	-	-	163.00	3.82	-	-	-
Zn	Zinc	-	-	3.69	2.50	1.97[a] 0.74[b] 1.21[c]	1.87	1.75	1.24	-	22.40

Table XV. Mineral Content of Baobab Leaves Note: units are mg/100 g dw; a: dark leaf; b: fine light leaf; c: rough light leaf; -: not mentioned in the original paper.
Source: A: Becker (1983); B: Prentice et al. (1993); C: Yazzie et al. (1994); D: Nordeide et al. (1996); E: Smith et al. (1996); F: Glew et al. (1997); G: Sena et al. (1998); H: Lockett et al. (2000); I: Boukari et al. (2001); J: Barminas et al. (2007).

Vitamins

Only a few authors have investigated the vitamin A content of baobab leaves (Chadare *et al.*, 2009). However, baobab leaves contain an interesting level of vitamin A (Nordeide *et al.*, 1996; Sidibe *et al.*, 1996). Vitamin A in the human diet is usually estimated in terms of Retinol Equivalent: 1µg RE = 6 µg ß-carotene or 12 µg α-carotene (Scheuring *et al.*, 1999). The amount of carotenoids in baobab leaves depends on the tree and the method of leaf drying. The simple practice of drying leaves in the shade doubles the provitamin A content of the leaf powder (Scheuring *et al.*, 1999). The choice of small leaves, which is tree-specific, further increased provitamin A by 20% (Sidibe *et al.*, 1996; Scheuring *et al.*, 1999). The use of leaves harvested from old or young trees does not seem to have any effect on the level of pro-vitamin A. The combination of small leaves and shade drying enabled the retention of the provitamin A content up to 27 µg retinol equivalent per gram of dried leaf powder (Scheuring *et al.*, 1999). To maintain the highest vitamin content, storage of baobab leaves as whole leaves rather than ground leaf powder has been recommended (Sidibe & Williams, 2002). Sena *et al.* (1998) shows also high content of lutein (50.9 µg/g dry weight). Becker (1983) reported vitamin A, thiamine, riboflavin and niacin content of 1618 µg RE, 0.13, 0.82 and 8.06 mg/100 g dw, respectively.

Bark

Baobab bark is mainly used for medicinal properties. Secondly, the bark is well-known for its fibers used to make ropes, sacks, clothes, baskets and mats (Sidibe & Williams, 2002) (Figure 10). The bark from the lower part of the stem can be removed to produce a valuable fibre. If managed properly the trees are not seriously damaged, and even after repeated use the bark regenerates and can be stripped again some years later (ICRAF, 2007). Modibbo *et al.* (2009) found that baobab appears to have high percentage extension at break compared to other fibres. The relative proportions of amorphous, which is relatively high in baobab bast fibres, to crystalline regions are presumed to be the major determinant.

Figure 10. Left: bark fibres of baobab twisted into ropes. (Source: Emmy De Caluwé, Benin, 2004); Right: baobab bark as ropes used for a well (Source: Camille De Moor, Mali, 2007).

The alkaloid 'adansonin' in the bark is thought to be the active principle for treatment of malaria and other fevers (Sidibe & Williams, 2002). Baobab bark which is often given to infants to promote weight gain (Lockett & Grivetti, 2000) was found to be high in fat, calcium, copper, iron, and zinc (Lockett *et al.*, 2000).

Friedelin, lupeol and baurenol (all three terpenoids) were identified in the leaf bark of baobab. In addition, betulinic acid was isolated from the bark whereas the leaf exclusively yielded taraxerone and acetate of lupeol and baurenol (Odetokur (1996) cited in Shukla *et al.*, 2001).

Biological Activity

Anti-oxidant Activity

Dietary antioxidants, including polyphenolic compounds, vitamins E and C, and carotenoids, are believed to be effective nutrients in the prevention of oxidative stress related diseases (Kaur & Kapoor 2001) cited in Besco *et al.*, 2007), such as inflammation, cardiovascular disease, cancer and aging related disorders (Willet (2001) cited in Besco *et al.*, 2007). The high antioxidant capacity of products deriving from *Adansonia digitata* show their therapeutical, nutraceutical and cosmoceutical potential. Moreover, in view of the very high antioxidant capacity, some authors (Vertuani *et al.*, 2002; Besco *et al.*, 2007) have proposed the red fiber as a new value-added ingredient for food preparation and/or nutraceutical application in the promotion of health. Research studies have (Vertuani *et al.*, 2002; Besco *et al.*, 2007) compared the overall antioxidant capacity (IAC), corresponding to the sum of the corresponding water- and lipid-soluble antioxidants capacity, of baobab plant products with those of orange and kiwi. The IAC value for the examined products resulted as follows: baobab red fibre (1617.3) >>> baobab fruit pulp (240.5) >> baobab fresh leaves (89.0) >> baobab seeds (51.4) > orange fresh fruit pulp (24.3) > kiwi fruit pulp (2.4).

Vitamin C Healing Effect

Vitamin C is a powerful antioxidant and extremely important in human nutrition. Vitamin C has been shown to be related to low blood pressure, enhanced immunity against many tropical maladies, lower incidence of cataract development and lower incidence of coronary disease. The daily recommended intake for healthy, non-smoking adults is 65 mg; smokers need more vitamin C than non-smokers. While 65 mg/day is the minimum recommended intake, a full saturation of the total pool of vitamin C in the body is about 140 mg/day. Convalescents recovering from infectious diseases or nursing mothers benefit significantly from daily intakes exceeding 250 mg. Using the average vitamin C content of baobab fruit, 2800 mg/kg, the recommendations can be converted into amounts of baobab powder. The daily recommended dose of vitamin C can be obtained from 23 g of baobab powder. The daily saturation of the vitamin C pool in the body requires 50 g of baobab powder; the special dosage for convalescents is 90 g (Sidibe *et al.*, 1996).

Anti-viral Activity

Adansonia digitata root-bark and leaf methanol extracts have shown high antiviral activity against Herpes simplex, Sindbis and Polio (Anani *et al.*, 2000), together with viricidal (direct inactivation of virus particles) and also intracellular antiviral activity, which could indicate the presence of multiple antiviral compounds, or a single compound with multiple actions (Hudson *et al.*, 2000). Whether such studies will show as effective results in humans is unknown but these couple of preliminary reports may provide rationale behind some of the medicinal uses of this plant.

Anti-inflammatory and Anti-pyretic Activity

According to Ramadan and co-workers (1993), aqueous extract of the baobab fruit pulp produced a marked anti-inflammation activity. This effect could be due to the presence of sterols, saponins and triterpenes in the fruit pulp. The extract also shows a marked antipyretic activity (Ramadan *et al.*, 1993). The antipyretic activity of the extract resembles that normally induced by standard dose of administered acetylsalicylic acid (ASA) in hyperthermic rats (Ramadan *et al.*, 1993). Analgesic and antipyretic activities were also mentioned by UN (2005, cited in Masola *et al.*, 2009), probably due to the presence of sterols, saponins and triterpenes in the fruit pulp. Leaves are applied locally for a variety of inflammatory conditions, insect bites and guinea worm sores (Shukla *et al.*, 2001).

Anti-microbial Activity

An acid medium, as created by the addition of baobab pulp powder to tempe fermentation could prevent the growth of pathogenic bacteria such as *Salmonella* sp., *Bacillus* sp. and *Streptococcus* sp. (Afolabi *et al.*, 2005). Moreover, increasing concentrations of baobab pulp powder led to an increase in the population of lactic acid bacteria. This is beneficial to consumers since most of the lactic acid bacteria species are nontoxic and have been reported to produce an enzyme that breaks the oligosaccharides in soybean (main component of tempe) down to their mono- and disaccharide constituents. The presence of lactic acid bacteria in tempe prepared as it is being done locally in Nigeria will not only improve the digestibility of tempe, but will also extend the shelf life of the product because of the preservative attributes of lactic acid bacteria (Afolabi *et al.*, 2005).

There was some antibacterial activity against *Staphylococcus aureus*, *Streptococcus faecalis*, *Bacillus subtilis*, *Escherichia coli* and *Mycobacterium phlei* (Anani *et al.* (2000) cited in Masola *et al.*, 2009). Stem and root barks of baobab contain bioactive constituents which are responsible for antimicrobial activity of the crude aqueous and ethanolic extracts. This explains the scientific basis for the use of crude stem and or root bark extracts in traditional medicine e.g. for treatment of fever caused by malaria (Masola *et al.*, 2009).

Anti-trypanosoma Activity

Extracts of baobab roots eliminate the motility in *Trypanosoma congolense* within 60 minutes and drastically reduce motility in *T. brucei brucei*. *T. brucei brucei* and *T. congolense* are unicellular parasites transmitted by the bites of tsetse fly and is the causative agent of sleeping sickness in humans and related diseases in animals (Atawodi *et al.*, 2003).

Uses in Traditional Medicine

Baobab leaves, bark, pulp and seeds are used as food and for multiple medicinal purposes in many parts of Africa (Etkin & Foss (1982) cited in Yazzie *et al.*, 1994; Diop *et al.*, 2005). Ethnomedicine has been an intensive area of research, with several authors discussing the main ethnomedicinal uses of baobab products (Table XVI).

Fruit

Baobab is used in folk medicine as an antipyretic or febrifuge to overcome fevers. Both leaves and fruit pulp are used for this purpose. Fruit pulp and powdered seeds are used in cases of dysentery and to promote perspiration (i.e. a diaphoretic) (Sidibe & Williams, 2002). Baobab fruit pulp has traditionally been used as an immunostimulant (El-Rawy *et al.* (1997) cited in Al-Qarawi *et al.*, 2003), anti-inflammatory, analgesic (Ramadan *et al.* (1993) cited in Al-Qarawi *et al.*, 2003), pesticide (Tuani *et al.* (1994) cited in Al-Qarawi *et al.*, 2003), antipyretic, febrifuge, and astringent in the treatment of diarrhoea and dysentery (Ramadan *et al.* (1993) cited in Al-Qarawi *et al.*, 2003). The fruit pulp has been evaluated as a substitute for improved western drugs (le Grand (1985) cited in Al-Qarawi *et al.*, 2003). The aqueous extract of baobab fruit pulp exhibited significant hepatoprotective activity and, as a consequence, consumption of the pulp may play an important part in human resistance to liver damage in areas where baobab is consumed (Al-Qarawi *et al.*, 2003). Medicinally, baobab fruit pulp is used as a febrifuge and as an anti-dysenteric, and in the treatment of smallpox and measles as an eye instillation (Burkill (ined.) cited in Wickens, 1979). In Indian medicine, baobab pulp is used internally with buttermilk in cases of diarrhoea and dysentery. Externally, use is made of young baobab leaves, crushed into a poultice, for painful swellings (Sidibe & Williams, 2002).

Seeds

Seeds are used in cases of diarrhoea, and hiccough. Oil extracted from seeds is used for inflamed gums and to ease diseased teeth (Sidibe & Williams, 2002). Since seed oil is used to also treat skin complaints, it can be considered to have cosmetic applications as well (Sidibe & Williams, 2002).

Leaves

Powdered leaves are used as an anti-asthmatic and known to have antihistamine and anti-tension properties. The leaves are also used to treat a wide variety of conditions including fatigue, as a tonic and for insect bites, Guinea worm and internal pains, and dysentery (Sidibe & Williams, 2002); and diseases of the urinary tract, opthalmia and otitis (Sidibe & Williams, 2002). In Indian medicine, powdered leaves are similarly used to check excessive perspiration (Sidibe & Williams, 2002). Baobab leaves are used medicinally as a diaphoretic, an expectorant, and as a prophylactic against fever, to check excessive perspiration, and as an astringent (Watt & Breyer-Brandwijk (1962), Woodruff (1969) and Beltrame (1974) all cited in Wickens, 1979). The leaves also have hyposensitive and antihistamine properties. Leaves are used to treat kidney and bladder diseases, asthma, general fatigue, diarrhoea, inflammations, insect bites and guinea worm (Burkill (ined.) cited in Wickens, 1979).

Bark

The widest use in tradition medicine comes from the baobab bark as a substitute for quinine in case of fever or as a prophylactic. A decoction of the bark deteriorates rapidly due to the mucilaginous substances present. This process can be prevented by adding alcohol or a small quantity of sulphuric acid to the decoction (Kings (2002) cited in Sidibe & Williams, 2002). Baobab bark is used in Europe as a febrifuge (antipyretic). In the Gold Coast (Ghana), the bark is used instead of quinine for curing fever (Shukla *et al.*, 2001). In Indian medicine, baobab bark is used internally as a refrigerant, antipyretic and antiperiodic. It is used as a decoction, 30 g/l of water, boiled down to two thirds (Sidibe & Williams, 2002). The activity of baobab bark as a febrifuge, however, has not been detected in experimental malaria treatments, although it is both diaphoretic and antiperiodic (Burkill (ined.) cited in Wickens, 1979). The bark, however, is certainly used for the treatment of fever in Nigeria (Oliver (1959) cited in Wickens, 1979). Moreover, the bark contains a white, semi-fluid gum that can be obtained obtainable from bark wounds and is used for cleansing sores (Burkill (ined.) cited in Wickens, 1979). According to Loustalot & Paga (1949, cited in Wickens, 1979) there are no alkaloids present in the bark, and accounts from Nigeria are inconclusive (Burkill (ined.) cited in Wickens, 1979). However, according to Watt & Breyer-Brandwijk (1962, cited in Wickens, 1979) the bark contains the alkaloid 'adansonin', which has a strophanthus-like action. In East Africa, the bark is used as an antidote to strophanthus poisoning. In Congo Brazzaville, a bark decoction is used to bathe rickety children and in Tanzania as a mouthwash for toothache (Burkill (ined.) cited in Wickens, 1979). Furthermore, a new flavanonol glycoside was reported in the root bark (Chauhan *et al.* (1984) cited in Ramadan *et al.*, 1993).

Baobab bark, fruit pulp and seeds appear to contain an antidote to poisoning by a number of Strophanthus species. The juice of these species has been widely used as an arrow poison especially in East Africa. In Malawi, a baobab extract is poured onto the wound of an animal killed in this way to neutralize the poison before the meat is eaten (Wickens, 1979; Wickens (1982) cited in Sidibe & Williams, 2002).

An infusion of roots is used in Zimbabwe to bathe babies to promote smooth skin (Wickens (1982) cited in Sidibe & Williams, 2002).

*Continent/ Country**	*Part(s) Used*	*Ethnomedical Uses*	*References*
Africa	leaves	diaphoretic, expectorant, prophylactic against fever, excessive perspiration, astringent, treatment kidney and bladder diseases, asthma, general fatigue, diarrhoea, inflammations, insect bites, Guinea worm, hyposensitive, antihistamine properties, *sources* with poultices	Wickens (1979 and 1982);
India		emollient, maturant, diuretic, diaphoretic, febrifuge	Kritikar (1993, cited in Shukla *et al.*, 2001)
-		anti-inflammatory, insect bites, Guinea worm sores	Shukla *et al.* (2001)
-		astringent, sudorific, tonic	Shukla *et al.* (2001)
-		earache, opthalmia	Shukla *et al.* (2001)
-		prevent Guinea pigs from asthmatic crisis induced by histamine aerosols	Shukla *et al.* (2001)
-		anti-asthmatic, antihistaminic, antitension properties, treatment of fatigue, insect bites, Guinea worm, internal pains, treatment of dysentery	Sidibe & Williams (2002)
-		diseases of the urinary tract, opthalmia, otitis	Sidibe & Williams (2002)
India		excessive perspiration	Sidibe & Williams (2002)
India		painful swellings	Sidibe & Williams (2002)

** When '-' is mentioned, no information about country, nor continent is mentioned in the reference.*

Table XVI. Ethnomedical Uses of Baobab.

Continent/ Country	*Part(s) Used*	*Ethnomedical Uses*	*References*
-	leaves, flowers	respiratory disorders	Addy *et al.* (1995, cited in Shukla *et al.*, 2001)
West Africa	pulp	fever, dysentery	Burkill (ined., cited in Wickens, 1979); FAO (1988, cited in Gebauer *et al.*, 2002)
West Africa		eye-drops in cases of measles	Burkill (ined., cited in Wickens, 1979); FAO (1988, cited in Gebauer *et al.*, 2002)
-		excipient in tablet formulation, lubricant, glidant and diluent properties	Arama *et al.* (1989, cited in Shukla *et al.*, 2001)
-		relief from bronchial asthma	Shukla *et al.* (2001)
-		diaphoretic in fever, diarrhoea, dysentery, haemo-pytosis	Shukla *et al.* (2001
-		against itching in case of allergy	Shukla *et al.* (2001
Konkan (India)		toothache, gingivitis	Shukla *et al.* (2001
India		internally with buttermilk in cases of diarrhoea, dysentery	Sidibe & Williams, 2002

Table XVI. Ethnomedical Uses of Baobab (Continued).

Continent/ Country	*Part(s) Used*	*Ethnomedical Uses*	*References*
-	pulp (continued)	immunostimulant, anti-inflammatory, analgesic , pesticide, antipyretic, febrifuge, astringent in treatment of diarrhoea and dysentery	Ramadan *et al.* (1993); El-Rawy *et al.* (1997); Tuani *et al.* (1994) (all cited in Al-Qarawi *et al.*, 2003)
-		hepatoprotective activity	Al-Qarawi *et al.* (2003)
-	leaves, pulp	antipyretic, febrifuge	Sidibe & Williams (2002)
-	pulp, seeds	dysentery, perspiration (i.e. a diaphoretic)	Sidibe & Williams (2002)
-	seeds	diarrhoea, hiccough	Sidibe & Williams (2002)
-		inflamed gums, easing of sore teeth	Sidibe & Williams (2002)
-		skin complaints, cosmetics	Sidibe & Williams (2002)
India	inner fibrous part of fruit shell	emmenogogue	Kritikar (1993, cited in Shukla *et al.*, 2001)
-	bark, fruit shell	stimulating and promoting granulation of foul sores	Addy *et al.* (1995, cited in Shukla *et al.*, 2001)

Table XVI. Ethnomedical Uses of Baobab (Continued).

Continent Country	*Part(s) Used*	*Ethnomedical Uses*	*References*
Nigeria	bark	febrifuge	Wickens (1982 cited in Sidibe & Williams, 2002)
Malawi		neutralizes the arrow wound in flesh of animal killed by poisoned arrow, before meat is eaten	Wickens (1979 and 1982)
Congo-Brazzaville		bathe rickety children	Wickens (1979 and 1982)
Tanzania		mouthwash for toothache	Wickens (1979 and 1982)
-		treatment of sores	FAO (1988, cited in Gebauer *et al.*, 2002)
Gold Coast		substitute of quinine for curing fever	Kritikar (1993, cited in Shukla *et al.*, 2001)
Europe		febrifuge (antipyretics), substitute for cinchona bark	Shukla *et al.* (2001)
-		substitute for quinine in cases of fever, prophylactic	Sidibe & Williams (2002)
India		internally as a refrigerant, antipyretic, antiperiodic	Sidibe & Williams (2002)
Nigeria		increase weight gain of infants	Lockett & Grivetti (2000)
Zambia	roots	bathe babies to promote smooth skin	Wickens (1979 and 1982)
-		tonic for malaria patients	FAO (1988, cited in Gebauer *et al.*, 2002)

Table XVI. Ethnomedical Uses of Baobab (Continued).

Conclusions

Adansonia digitata L. is a multipurpose tree species widely used for food and medicine.

The baobab fruit pulp is probably the most important foodstuff. It can be dissolved in water or milk. The liquid is then used as a drink, a sauce, a fermenting agent in local brewing, or as a substitute for cream of tartar in baking. The fruit pulp has a very high vitamin C content and is a rich *source* of calcium. The acidic pulp is rich in pectin, contains a high amount of carbohydrate, is low in protein, and extremely low in fat. Nevertheless, the fruit pulp can be considered as a rich *source* of amino acids and linoleic acid. It contains a very low amount of α-linolenic acid and iron.

Baobab seeds can be eaten fresh, or may be dried and ground into a flour which can either be added to soups and stews as a thickener, or roasted and ground into a paste, or boiled for a long time, fermented and then dried for use. The seeds can be classified as both protein- and oil-rich. They contain appreciable quantities of crude protein, digestible carbohydrates and oil, whereas they have high levels of lysine, thiamine, Ca, Mg and Fe. Baobab seeds contain high proportions of linoleic and oleic acid as well as palmitic and α-linolenic acid. Processing eliminates a number of anti-nutritional factors present in the seeds.

The leaves of the baobab tree are a staple for many populations in Africa. Young leaves are widely used, cooked like spinach, and frequently dried, often powdered and used for sauces over porridges, thick gruels of grains, or boiled rice. Baobab leaves are superior to fruit pulp in nutritional quality, and contain interesting levels of vitamin A. They appear to be a good *source* of protein, and contain particularly significant amounts of the amino acid tryptophan. Baobab leaves are a significant *source* of Fe, Ca, K, Mg, Mn, P and Zn.

Baobab bark is mainly used for its medicinal properties and for its fibres. The alkaloid 'adansonin' in the bark is thought to be the active principle for treatment of malaria and other fevers, as a substitute for quinine.

Several plant parts have interesting anti-oxidant, anti-viral and anti-inflammatory properties, and baobab has been used extensively since ancient times in traditional medicine. However, for baobab, the nutritional and medicinal data are widely scattered and research is fragmentary.

References

Addy, E.O.H.; Salami, L.I., Igboeli, L.C. Remawa, H.S. (1995). *Effect of processing on nutrient composition and anti-nutritive substances of African locust bean (Parkia filicoidea) and baobab seed (Adansonia digitata).* Plant Foods for Human Nutrition, 48, 113-117.

Afolabi, O.R., Popoola, T.O.S. (2005). *The effects of baobab pulp powder on the micro flora involved in tempe fermentation.* European Food Research and Technology, 220, 187-190.

Ajayi, I.A., Dawodi, F.A., Oderinde, R.A. (2003). Fatty acid composition and metal content of Adansonia digitata seeds and seed oil. La Rivista Italiana delle Sostanze Grasse, 80, 41-43.

Al-Qarawi, A.A., Al-Damegh, M.A. El-Mougy, S.A. (2003). *Hepatoprotective Influence of Adansonia digitata Pulp.* Journal of Herbs, Spices & Medicinal plants, 10 (3), 1-6.

Anani, K., Hudson, J.B., de Souzal, C., Akpaganal, K., Tower, G.H.N., Amason, J.T., Gbeassor, M. (2000). *Investigation of medicinal plants of Togo for antiviral and antimicrobial activities.* Pharmaceutical Biology, 38, 40-45.

Arnold, T.H., Wells, M.J., Wehmeyer, A.S. *Khoisan food plants: taxa with potential for future economic exploitation.* In: *Plants for Arid Lands*, Wickens, G.E.; Goodin, J.R.; Field, D.V. (eds.), Allen and Unwin, London, UK, 69-86.

Atawodi, S.E., Bulus, T., Ibrahim, S., Amed, D.A., Nok., A.J., Mamman, M., Galadima, M. (2003). *In vitro trypanocidal effect of methanolic extract of some Nigerian savannah plants.* African Journal of Biotechnology, 2, 317-321.

Barminas, J.T., Charles, M.; Emmanuel, D. (1998). *Mineral composition of non-conventional leafy vegetables.* Plant Foods for Human Nutrition, 53, 29-36.

Becker, B. (1983). *The contribution of wild plants to human nutrition in the Ferlo (Northern Senegal).* Agroforestry Systems, 1, 257-267.

Besco, E., Bracioli, E., Vertuani, S., Ziosi, P., Brazzo, F., Bruni, R., Sacchetti, G., Manfredini, S. (2007). *The use of photochemiluminescence for the measurement of the integral antioxidant capacity of baobab products.* Food Chemistry, 102, 1352-1356.

Boukari, I., Shier, N.W., Fernandez R, .X.E., Frisch, J., Watkins, B.A., Pawloski, L., Fly, A.D. (2001). *Calcium Analysis of Selected Western African Foods.* Journal of Food Composition and Analysis, 14, 37-42.

Bremer, B., Bremer, K., Chase, M.W., Reveal, J.L., Soltis, D.E., Soltis, P.S., Stevens, P.F., Anderberg, A.A., Fay, M.F., Goldblatt, P., Judd, W.S., Kallersjo, M.; Karehed, J., KRON, K.A., Lundberg, J., Nickrent, D.L., Olmstead, R.G., Oxelman, B., Pires, J.C., Rodman, J.E., Rudall, P.J., Savolainen, V., Sytsma, K.J., Van der Bank, M., Wurdack, K., Xiang, J.Q.Y., Zmarzty, S. (2003). *An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG II.* Botanical Journal of the Linnean Society, 141, 399-436.

Carr, W.R. (1955). *Ascorbic Acid Content of Baobab Fruit.* Nature, 176, 1273.

Chadare, F.J., Linnemann, A.R., Hounhouigan, J.D., Nout, M.J.R., Van Boekel, M.A.J.S. (2009). *Baobab Food Products: A Review on their Composition and Nutritional Value.* Critical Reviews in Food Science and Nutrition, 49, 254-274.

Cisse, M., Sakho, M., Dornier, M., Diop, C.M., Reynes, M., Sock, O. (2009). *Caractérisation du fruit du baobab et étude de sa transformation en nectar,* Fruits, 64, 19-34.

Diop, A.G., Sakho, M., Dornier., M., Cisse, M., Reynes, M. (2005). *Le baobab africain (Adansonia digitata L.): principales caractéristques et utilisations.* Fruits, 61, 55-69.

Ezeagu, I.E., Petzke, K.J., Lange, E., Metges, C.C. (1998). *Fat Content and Fatty Acid Composition of Oils Extracted from Selected Wild-Gathered Tropical Plant Seeds from Nigeria.* Journal of the American Oil Chemists' Society, 75, 1031-1035.

Gebauer, J., El-Siddig, K., Ebert, G. (2002). *Baobab (Adansonia digitata L.): a Review on a Multipurpose Tree with Promising Future in the Sudan.* Gartenbauwissenschaft, 67, 155-160.

Glew, R.H., VanderJagt, D.J., Lockett, C., Grivetti, L.E., Smith, G.C., Pastuszyn, A., Millson, M. (1997). *Amino Acid, Fatty Acid and Mineral Composition of 24 Indigenous Plants of Burkina Faso.* Journal of Food Composition and Analysis, 10, 205-217.

Hudson, J.B., Anani, K., Lee, M.X., De Souzâ, C., Arnason, J.T., Gbeassor, M. (2000). *Further investigations on the antiviral activities of medicinal plants of Togo.* Pharmaceutical Biolog, 38, 46-50.

ICRAF – World Agroforestry Centre. *ICRAF Agroforestry Tree Database: Adansonia digitata* L., URL http://www.worldagroforestrycentre.org (visited on 31.01.2007).

Igboeli, L.C., Addy, E.O.H., Salami, L.I. (1997). *Effects of some processing techniques on the antinutrient contents of baobab seeds (Adansonia digitata).* Bioresource Technology, 59, 29-31.

Lockett, C.T., Calvert C.C., Grivetti, L.E. (2000). *Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought.* Study of rural Fulani, Northeastern Nigeria. International Journal of Food Sciences and Nutrition, 51, 195-208.

Lockett, C.T., Grivetti, L.E. (2000). Food-related behaviors during drought: a study of rural Fulani northeast Nigeria. International Journal of Food Sciences and Nutrition, 51, 91-107.

Masola, S.N., Mosha, R.D., Wambura, P.N. (2009). *Assessment of antimicrobial activity of crude extracts of stem and root barks from Adansonia digitata (Bombacaceae) (African baobab).* African Journal of Biotechnology. 8, 5076-5083.

Modibbo, U.U., Aliyu, B.A., Nkafamiya, I.I. (2009). *The effect of mercerization media on the physical properties of local plant bast fibres.* International Journal of Physical Sciences, 4, 698-704.

Murray, S.S., Schoeninger, M.J., Bunn, H.T., Pickering, T.R., Marlett, J.A. (2001). *Nutritional Composition of Some Wild Plant Foods and Honey Used by Hadza Foragers of Tanzania.* Journal of Food Composition and Analysis, 14, 3-13.

Nicol, B.M. (1957). *Ascorbic Acid Content of Baobab Fruit.* Nature, 180, 287.

Nkafamiya, I.I., Osemeahon, S.A., Dahiru, D., Umaru, H.A. (2007). *Studies on the chemical composition and physicochemical properties of the seeds of baobab (Adansonia digitata).* African Journal of Biotechnology, 6, 756-759.

Nnam, N.M., Obiakor, P.N. (2003). *Effect of fermentation on the nutrient and antinutrient composition of baobab (Adansonia digitata) seeds and rice (Oryza sativa) grains.* Ecology of Food and Nutrition, 42, 265-277.

Nordeide, M.B., Harløy, A., Følling, M., Lied, E. (1996). *Oshaug A. Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in Southern Mali.* International Journal of Food Sciences and Nutrition, 47, 455-468.

Nour, A.A., Magboul, B.I., Kheiri, N.H. (1980). *Chemical composition of baobab fruit (Adansonia digitata L.).* Tropical Sciences, 22, 383-388.

Obizoba, I.C., Amaechi, N.A. (1993). *The effect of processing methods on the chemical composition of baobab (Adansonia digitata L.) pulp and seed.* Ecology of Food and Nutrition, 29, 199-205.

Obizoba, I.C., Anyika, J.U. (1994). *Nutritive value of baobab milk (gubdi) and mixtures of baobab (Adansonia digitata L.) and hungry rice, acha (Digitaria exilis) flours.* Plant Foods for Human Nutrition, 46, 157-165.

Odetokun, S.M. (1996). *The nutritive value of Baobab fruit (Adansonia digitata).* La Rivista Italiana delle Sostanze Grasse, 73, 371-373.

Osman, M.A. (2004). *Chemical and Nutrient Analysis of Baobab (Adansonia digitata) Fruit and Seed Protein Solubility.* Plant Foods for Human Nutrition, 59, 29-33.

Prentice, A., Laskey, M.A., Shaw, J., Hudson, G.J., Day, K.C., Jarjou, L.M.A., Dibba, B., Paul, A.A. (1993). *The calcium and phosphorus intake of rural Gambian women during pregnancy and lactation.* British Journal of Nutrition, 69, 885-896.

Proll, J., Petske, K.J., Ezeagu, I.E., Metges, C.C. (1998). *Low Nutritional Quality of Unconventional Tropical Crop Seeds in Rats.* Journal of Nutrition, 128, 2014-2022.

Ramadan, A., Harraz, F.M., El-Mougy, S.A. (1993). *Anti-inflammatory, analgesic and antipyretic effects of the fruit pulp of Adansonia digitata.* Fitoterapia, 65, 418-422.

Saka, J.D.K., Msonthi, J.D. (1994). *Nutritional value of edible fruits of indigenous wild trees in Malawi.* Forest Ecology and Management, 64, 245-248.

Scheuring, J.F., Sidibé, M., Frigg, M. (1999). *Malian agronomic research identifies local baobab tree as source of vitamin A and vitamin C.* Sight and Life, 1, 21-24.

Sena, L.P., VanderJagt, D.J., Rivera, C., Tin, A.C., Muhamadu, I., Mahamadou, O., Millton, M., Pastuszyn, A., Glew, R.H. (1998). *Analysis of nutritional components of eight famine foods of the Republic of Niger.* Plant Foods for Human Nutrition, 52, 17-30.

Shukla, Y.N., Dubey, S., Jain, S.P., Kumar, S. (2001). *Chemistry, biology and uses of Adansonia digitata - a review.* Journal of Medicinal and Aromatic Plant Sciences, 23, 429-434.

Sibibe, M., Williams, J.T. (2002). *Baobab – Adansonia digitata.* Fruits for the future 4, International Centre for Underutilised Crops, Southampton, UK, 96p.

Sidibe, M., Scheuring, J.F., Tembely, D., Sidibé, M.M., Hofman, P., Frigg, M. (1996). *Baobab - Homegrown Vitamin C for Africa.* Agroforestry Today, 8 (2), 13-15.

Smith, G.C., Clegg, M.S., Keen, C.L., Grivetti, L.E. (1996). *Mineral values of selected plant foods common to southern Burkina Faso and to Niamey, Niger, West Africa.* International Journal of Food Sciences and Nutrition, 47, 41-53.

Vertuani, S., Braccioli, E., Buzzoni, V., Manfredini, S. (2002). *Antioxidant capacity of Adansonia digitata fruit pulp and leaves.* Acta Phytotherapeutica, 2 (V), 2-7.

Wickens, G.E. Chapter 15: *The uses of the baobab (Adansonia digitata* L.) *in Africa.* In: *Taxonomic aspects of African economic botany*, editor, Kunkel, G., 1979.

Wickens, G.E. (1982). *The Baobab – Africa's upside-down tree.* Kew Bulletin, 37, 173-209.

Yazzie, D., VanderJagt, D.J., Pastuszyn, A., Okolo, A., Glew, H. (1994). *The Amino Acid and Mineral Content of Baobab (Adansonia digitata* L.) *Leaves.* Journal of Food Composition and Analysis, 7, 189-193.