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Baobab Food Products: A Review on their Composition and Nutritional Value

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Several authors have published about baobab food products. Data on macronutrients, micronutrients, amino acids, and fatty acids were collected from literature for pulp, leaves, seeds, and kernels of the baobab tree. The results show that baobab pulp is particularly rich in vitamin C; consumption of 40 g covers 84 to more than 100% of the Recommended Daily Intake (RDI) of pregnant women (19–30 years). The leaves are particularly rich in calcium (307 to 2640 mg/100 g dw), and they are known to contain good quality proteins with a chemical score of 0.81. The whole seeds and the kernels have a relatively high lipid content, 11.6 to 33.3 g/100 g dw and 18.9 to 34.7 g/100 g dw, respectively. The pulp and leaves exhibit antioxidant properties with a higher activity in the pulp than in the leaves. Reported nutrient contents of different baobab parts show a large variation, which may have arisen from various factors. Three recommendations are given 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, 3. The effect of storage and processing on the nutritional value of baobab products needs to be assessed.

Keywords nutrients, antioxidant capacity, baobab pulp, baobab leaves, baobab seeds, baobab kernels

INTRODUCTION

The African baobab tree (*Adansonia digitata*) and its related species belong to the family of Malvacea (Alverson et al., 1999). The tree occurs naturally in dry areas of Africa, mainly in the Sahelian, Soudano-Sahelian, and Soudanian zones; the distribution extends through the woodlands, savannas, and grasslands of sub-Saharan Africa to about 25°S. It is characterized by its massive size, reaching to a height of 18–25 m. Crown shape ranges from depressed ovoid through globose to obovoid. The bark is smooth, reddish-brown, greyish-brown or purplish-grey, soft, and fibrous. Leaves are 2–3 foliate at the start of the season and they are early deciduous; more mature ones are 5–7(−9) foliate. Leaves of young trees are often simple. They are glabrous to tomentose; the former are preferred for food. The fruits are very variable, usually globose to ovoid but sometimes oblong-cylindrical, often irregular in shape, apex pointed, or obtuse, covered by velvety yellowish or greenish hairs (Sidibe and Williams, 2002). The fruits are indehiscent; they are broken open by chimpanzees, baboons, etc. or will crack open if they fall on a stony surface. They contain reniform seeds and powdery pulp (Baum, 1995).

The baobab is a multi-purpose tree with products having numerous food uses and medicinal properties, and a fibrous bark that is used for various applications (Sidibe and Williams, 2002; Codjia et al., 2001; Wickens, 1982). The pulp of the fruit, the seeds, and the leaves are all utilized and are essentially wild-gathered foods. They are consumed daily by rural populations in Africa and are also commercialized. The tuberous taproot of seedlings and young saplings are also eaten, especially in times of famine. Baobab products (leaves, fruits, craft products, and bark) are sold on local, informal markets. Middlemen also operate and trade in the larger urban markets (Sidibe and Williams, 2002). In Benin, for instance, 6923 kg of pulp was sold for about 1370 euros in a rural market of Boukoumbe district in northern Benin by 48 vendors in the period from January to March 2001 (Codjia et al., 2003). In developed countries, e.g., Italy, baobab fruits are used to produce dietary supplements and cosmetics.

Previously published biochemical analyses revealed that baobab's edible parts (pulp, leaves, seeds) are rich in nutrients (Sidibe and Williams, 2002; Codjia et al., 2001; Yazzie et al.,

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1994; Sena et al., 1998; Nordeide et al., 1996; Barminas et al., 1998; Sidibe et al., 1996). Literature reviews on baobab by Sidibe and Williams (2002) and Diop et al. (2005) provide substantial information on the species taxonomy, distribution, properties, utilization, agronomy, and agroecology. However, these reviews did not deal in detail with the nutritional value of baobab food products. Information on the nutrient composition of food is essential to estimate adequate nutrient intake both at individual and group levels (Joyanes and Lema, 2006). The present review investigates the nutritional value of baobab food products based on data from various authors and critically evaluates the similarities and divergences of the values in relation to the research methods used. Research needs are identified on the basis of our review. For each component, the reported values are, as much as possible, converted into the same unit, and their average, minimum, and maximum values are calculated and reported in Table 1. Nonconverted data are shown as reported originally.

LEAVES

Macronutrients

Nordeide et al. (1996) and Lockett et al. (2000) found that the water content (Table 1) of dried baobab leaves was 6.4 and 8.2%, respectively. The average water content is then 7.3%. Oomen and Grubben (1978) investigated the moisture content of fresh leaves and found a value of 77%. The reported energy value varies from 1180 kJ/100 g dw (Becker, 1983) to 1580.6 kJ/100 g dw (Nordeide et al., 1996) with an average of 1380.3 kJ/100 g. The carbohydrate content varies from 40 g/100 g dw (Lockett et al., 2000) to 69 g/100 g dw (Nordeide et al., 1996); the average is 56.4 kJ/100 g. Crude protein contents vary from 10 g/100 g dw (Yazzie et al., 1994; Lockett et al., 2000) to 14.9 g/100 g dw (Nordeide et al., 1996). The reported values for fat content are generally low and vary from 4 g/100 g dw (Becker, 1983) to 6.3 g/100 g dw (Lockett et al., 2000). The ash content ranges from 11.5 g/100 g dw (Nordeide et al., 1996) to 15.9 g/100 g dw (Lockett et al., 2000).

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. The time-temperature combination used to determine water and ash contents were different. Energy was calculated using Atwaters' coefficients while carbohydrates were determined by difference. The fat content was determined either by the Soxtec system or gravimetrically, while the protein content was determined by Kjeldahl analysis. However, the number of authors who investigated the macronutrient composition of the leaves, is rather low.

Minerals

Baobab leaves are very rich in calcium according to literature (Table 1). With an average of 1582.3 mg/100 g dw, the reported values range between 1470 mg/100 g dw (Sena et al., 1998) and 2640 mg/100 g dw (Yazzie et al., 1994). However, lower values of 307 and 315 mg/100 g dw were mentioned by Yazzie et al. (1994), who studied different specimens of baobab leaves. Boukari et al. (2001) also measured the Ca content of selected African foods and mentioned that baobab dried leaves contain 2240 mg/100 g dw; among the 24 foods analyzed, baobab was ranked fifth after sorrel leaves (*Hibiscus sabdariffa*) (3630 mg/100 g dw), amaranth (*Amaranthus spp*.) leaves (3590 mg/100 g dw), okra (*Abelmoschu esculentus*) leaves (2850 mg/100 g dw), and onion (*Allium cepa*) leaves (2540 mg/100 g dw). The reported magnesium content ranges from 93.6 mg/100 g dw (Smith et al., 1996) to 549 mg/100 g dw (Glew et al., 1997). Smith et al. (1996) investigated the mineral content of dark, fine light, and rough light leaves and found a large variability in Mg content (93.6 mg/100 g dw for the dark leaves, 121.7 mg/100 g dw for the fine light leaves and 274.2 mg/100 g dw for the rough light leaves). It is presumed that the connotations "fine" and "rough," with respect to the leaves, refer to their pubescence. The potassium contents vary greatly from 140 mg/100 g dw to 1080 mg/100 g dw (Yazzie et al., 1994) with an average of 531 mg/100 g. The reported sodium contents range from 3.8 mg/100 g dw (Sena et al., 1998) to 163 mg/100 g dw (Glew et al., 1997); the average of the reported values is 83.4 mg/100 g dw. Smith et al. (1996) reported a copper content of 0.29 mg/100 g dw and most of the other values are between the latter and 1.6 mg/100 g dw, which is the highest value reported by Glew et al. (1997). The manganese content varies from 1.9 to 9.8 mg/100 g dw (Yazzie et al., 1994), and phosphorus contents range from 115 mg/100 g dw (Lockett et al., 2000) to 875.6 mg/100 g dw (Barminas et al., 1998). Zinc levels generally vary between 0.7 mg/100 g dw (Smith et al., 1996) and 4.0 mg/100 g dw (Yazzie et al., 1994). However, a higher value of 22.4 mg/100 g dw was reported by Barminas et al. (1998). The iron content varies greatly from 1.2 mg/100 g dw for rough leaves (Smith et al., 1996) to 100 mg/100 g dw (Yazzie et al., 1994). The molybdenum content is generally lower than 2 mg/100 g dw.

Lockett et al. (2000) used atomic absorption spectroscopy to determine most elements except P, whereas Sena et al. (1998) and Glew et al. (1997) used inductively coupled argon plasma atomic emission spectroscopy. Barminas et al. (1998) and Nordeide et al. (1996) used atomic absorption spectrophotometry, Smith et al. (1996) atomic absorption and Yazzie et al. (1994) atomic emission spectrophotometry.

The structure and the color of the leaves seem to be related to the mineral content (Smith et al., 1996). This apparent relation requires further investigation. Moreover, in future research better descriptions of analyzed leaf material are required to allow comparison.

To our knowledge, the bioavailability of these minerals has not been investigated. However, this is necessary to determine to which extent baobab leaves can be used to combat certain micronutrient deficiency problems.

Table 1 Composition of baobab pulp, leaves, seeds and kernels.

	Pulp				Leaves				Whole seeds				Kernels			
	Average	min	max	References	Average	min	max	References	Average	min	max	References	Average	min	max	References
Macronutrients																
Water (%)	11.6	2.0	27.5	(Busson, 1965; Wehmeyer, 1966; Becker, 1983; Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Lockett et al., 2000; Murray et al., 2001; Osman, 2004; Soloviev et al., 2004)	7.3	6.4	8.2	(Nordeide et al., 1996; Lockett et al., 2000)	7.2	6.1	8.2	(Proll et al., 1998; Lockett et al., 2000)	7.24	6.38	8.1	(Obizoba and Amaechi, 1993; Igboeli et al., 1997)
Energy (kJ/100 g dw)	1274	849	1495	(Saka and Msonthi, 1994; Murray et al., 2001; Osman, 2004)	1380	1180	1581	(Becker, 1983; Nordeide et al., 1996)	1762	1590	1935	(Proll et al., 1998; Osman, 2004)	1965	1965	1965	(Igboeli et al.,1997)
Carbohydrates (g/100 g dw)	74.9	46.6	87.7	(Wehmeyer, 1966; Becker, 1983; Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Lockett et al., 2000; Murray et al., 2001; Osman, 2004)	56.4	40.2	69.0	(Becker, 1983; Nordeide et al., 1996; Lockett et al., 2000)	31.7	5.2	56.8	(Arnold et al., 1995; Proll et al., 1998; Lockett et al., 2000; Osman, 2004)	34.52	22.1	48.1	(Obizoba and Amaechi, 1993; Igboeli et al., 1997; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Crude Protein (g/100 g dw)	5.3	2.5	17	(Wehmeyer, 1966; Nour et al., 1980; Becker, 1983; Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Glew et al., 1997; Sena et al., 1998; Lockett et al., 2000; Murray et al., 2001; Osman, 2004)	12.8	10.1	15.0	(Becker, 1983; Nordeide et al., 1996; Lockett et al., 2000)	21.4	14.4	36.7	(Arnold et al., 1995; Glew et al., 1997; Proll et al., 1998; Lockett et al., 2000; Osman, 2004)	24.7	14	32.7	(Obizoba and Amaechi, 1993; Igboeli et al., 1997; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Crude lipids (g/100 g dw)	3.6	0.2	15.5	(Wehmeyer, 1966; Nour et al., 1980; Becker, 1983; Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Glew et al., 1997; Sena et al., 1998; Lockett et al., 2000; Murray et al., 2001; Osman, 2004)	4.9	4.0	6.3	(Becker, 1983; Nordeide et al., 1996; Lockett et al., 2000)	18.4	11.6	33.3	(Arnold et al., 1995; Glew et al., 1997; Proll et al., 1998; Lockett et al., 2000; Osman, 2004)	27.8	18.9	34.7	(Obizoba and Amaechi, 1993; Igboeli et al., 1997; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Fibre (g/100 g dw)	13.7	6.0	45.1	(Busson, 1965; Wehmeyer, 1966; Nour et al., 1980; Becker, 1983; Saka and Msonthi, 1994; Lockett et al., 2000; Murray et al., 2001; Osman, 2004)	19.2	11.0	27.5	(Becker, 1983; Lockett et al., 2000)	28.3	16.9	49.7	(Arnold et al., 1995; Lockett et al., 2000; Osman, 2004)	21.2	21.2	21.2	(Ajayi et al., 2003)

Ash (g/100 g dw)	4.9	1.9	6.4	(Busson, 1965; Wehmeyer, 1966; Nour et al., 1980; Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Lockett et al., 2000; Murray et al., 2001; Osman, 2004)	13.7	11.5	15.9	(Nordeide et al., 1996; Lockett et al., 2000)	5.3	4.0	6.4	..(Arnold et al., 1995; Proll et al., 1998; Lockett et al., 2000; Osman, 2004)	6.50	5	7.9	(Obizoba and Amaechi, 1993; Igboeli et al., 1997; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Minerals (mg/100 gdw)																
Ca	302	3.0	701	(Nour et al., 1980; Obizoba and Amaechi, 1993; Prentice et al., 1993; Saka and Msonthi, 1994; Arnold et al., 1995; Glew et al., 1997; Sena et al., 1998; Lockett et al., 2000; Osman, 2004)	1582	307	2640	(Oomen and Grubben, 1978; Prentice et al., 1993; Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Barminas et al., 1998; Sena et al., 1998; Lockett et al., 2000; Boukari et al., 2001)	252	29.6	395	(Arnold et al., 1995; Glew et al., 1997; Lockett et al., 2000; Osman, 2004)	1.36	0.43	3.76	(Obizoba and Amaechi, 1993; Odetokun, 1996; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Cu	0.9	0.2	1.8	(Obizoba and Amaechi, 1993; Sena et al., 1998; Lockett et al., 2000; Osman, 2004)	0.8	0.3	1.6	(Smith et al., 1996; Glew et al., 1997; Barminas et al., 1998; Lockett et al., 2000)	2.3	1.3	3.0	(Arnold et al., 1995; Lockett et al., 2000; Osman, 2004)	1.54	0.02	5.36	(Obizoba and Amaechi, 1993; Odetokun, 1996; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Fe	4.3	1.1	10.4	(Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Arnold et al., 1995; Glew et al., 1997; Sena et al., 1998; Lockett et al., 2000; Osman, 2004)	65.3	1.2	254	(Yazzie et al., 1994; Nordeide et al., 1996; Smith et al., 1996; Glew et al., 1997; Barminas et al., 1998; Sena et al., 1998; Lockett et al., 2000)	5.1	1.8	7.1	(Arnold et al., 1995; Glew et al., 1997; Lockett et al., 2000; Osman, 2004)	1.39	0.63	2.39	(Obizoba and Amaechi, 1993; Odetokun, 1996; Ajayi et al., 2003; Nnam and Obiakor, 2003)
K	1794	726	3272	(Saka and Msonthi, 1994; Sena et al., 1998; Osman, 2004)	531	140	1080	(Yazzie et al., 1994; Sena et al., 1998)	908	428	1387	(Arnold et al., 1995; Osman, 2004)	6.6	0.6	17.4	(Odetokun, 1996; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Mg	195	100	300	(Saka and Msonthi, 1994; Arnold et al., 1995; Glew et al., 1997; Sena et al., 1998; Lockett et al., 2000; Osman, 2004)	339	93.6	549	(Yazzie et al., 1994; Smith et al., 1996; Glew et al., 1997; Barminas et al., 1998; Sena et al., 1998; Lockett et al., 2000)	402	282	696	(Arnold et al., 1995; Glew et al., 1997; Lockett et al., 2000; Osman, 2004)	0.65	0.2	1.1	(Odetokun, 1996; Ajayi et al., 2003)

(Continued on next page)

Table 1 Composition of baobab pulp, leaves, seeds and kernels. *(Continued)*

	Pulp				Leaves				Whole seeds				Kernels			
	Average	min	max	References	Average	min	max	References	Average	min	max	References	Average	min	max	References
Mn	0.7	0.4	1.0	(Sena et al., 1998; Lockett et al., 2000)	6.0	1.9	9.8	(Yazzie et al., 1994; Smith et al., 1996; Glew et al., 1997; Sena et al., 1998; Lockett et al., 2000)	1.1	1.1	1.1	(Glew et al., 1997; Lockett et al., 2000)	1.49	0.15	2.84	(Odetokun, 1996; Ajayi et al., 2003)
Na	14.8	0.8	31.1	(Saka and Msonthi, 1994; Glew et al., 1997; Sena et al., 1998; Osman, 2004)	83.4	3.8	163	(Glew et al., 1997; Sena et al., 1998)	2.3	1.9	2.7	(Arnold et al., 1995; Glew et al., 1997)	0.91	0.17	1.64	(Ajayi et al., 2003; Nnam and Obiakor, 2003)
P	106	0.0	425	(Nour et al., 1980; Obizoba and Amaechi, 1993; Saka and Msonthi, 1994; Arnold et al., 1995; Glew et al., 1997; Sena et al., 1998)	274	115	875	(Prentice et al., 1993; Yazzie et al., 1994; Glew et al., 1997; Barminas et al., 1998; Sena et al., 1998; Lockett et al., 2000)	453	5.6	738	(Arnold et al., 1995; Glew et al., 1997; Lockett et al., 2000)	109	0.38	326	(Obizoba and Amaechi, 1993; Odetokun, 1996; Nnam and Obiakor, 2003)
Zn	1.7	0.5	3.2	(Obizoba and Amaechi, 1993; Arnold et al., 1995; Glew et al., 1997; Sena et al., 1998; Lockett et al., 2000; Osman, 2004)	4.1	0.7	22.4	(Yazzie et al., 1994; Nordeide et al., 1996; Smith et al., 1996; Glew et al., 1997; Barminas et al., 1998; Sena et al., 1998; Lockett et al., 2000)	5.0	2.6	7.3	(Arnold et al., 1995; Glew et al., 1997; Lockett et al., 2000; Osman, 2004)	1.42	0.10	3.57	(Obizoba and Amaechi, 1993; Odetokun, 1996; Ajayi et al., 2003; Nnam and Obiakor, 2003)
Vitamins (mg/100 g)																
B1 Thiamine	0.3	0.0	0.6	(Santos Oliveira, 1975; Becker, 1983; Arnold et al., 1995)					—	—	—	—				
B2 Riboflavin	0.1	0.1	0.1	(Santos Oliveira, 1975; Becker, 1983; Arnold et al., 1995)					—	—	—	—				
B3 Niacin	2.2	1.8	2.7	(Santos Oliveira, 1975; Becker, 1983; Arnold et al., 1995)					—	—	—	—				
Vitamin A	—	—	—	—					—	—	—	—				
Vitamin C	290	209	360	(Nour et al., 1980; Becker, 1983; Arnold et al., 1995)					—	—	—	—				

Amino Acids (g/100 g proteins)												—	—
Alanine	5.6	3.3	8.2	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	6.4	5.8	7.5	(Yazzie et al., 1994; Glew et al., 1997; Sena et al., 1998)	8.0	5.4	11.5	(Glew et al.,1997; Proll et al.,1998; Osman,2004)
Arginine	6.8	4.4	8.4	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	7.7	6.4	11.1	(Yazzie et al., 1994; Glew et al., 1997; Sena et al., 1998)	11.5	1.1	25.5	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Aspartic acid	7.5	5.2	11.0	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	10.6	8.1	12.5	(Yazzie et al., 1994; Glew et al., 1997; Sena et al., 1998)	16.9	10.3	23.4	(Proll et al., 1998; Osman, 2004)
Cysteic acid	1.3	1.0	1.7	(Sena et al., 1998; Osman, 2004)	2.3	1.5	3.9	(Yazzie et al.,1994; Glew et al., 1997; Sena et al., 1998)	2.8	1.5	5.2	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Glutamic acid	8.4	4.1	14.6	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	10.5	7.4	12.9	(Yazzie et al., 1994; Glew et al., 1997; Sena et al., 1998)	35.9	23.7	59.2	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Glycine	6.2	2.9	11.4	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	5.5	4.8	6.7	(Yazzie et al., 1994; Glew et al., 1997; Sena et al., 1998)	8.8	5.3	12.5	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Histidine	2.0	1.2	3.4	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	2.1	1.7	2.6	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	3.4	2.2	5.4	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Isoleucine	3.6	2.2	5.1	(Glew et al., 1997; Osman, 2004)	5.7	4.7	7.5	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	5.8	3.6	9.6	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Leucine	5.4	4.1	7.6	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	8.3	7.2	9.7	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	10.6	7.0	17.8	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Lysine	4.0	1.7	6.0	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	5.6	4.7	6.7	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	6.9	5.0	10.1	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Methionine	1.9	0.2	4.9	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	1.7	0.9	2.6	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	1.9	1.0	3.4	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)
Phenylalanine	3.5	2.1	4.4	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	5.5	4.8	6.5	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	7.2	4.0	12.3	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)

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Table 1 Composition of baobab pulp, leaves, seeds and kernels. *(Continued)*

	Pulp				Leaves				Whole seeds				Kernels			
	Average	min	max	References	Average	min	max	References	Average	min	max	References	Average	min	max	References
Prolamine	3.7	2.2	5.1	(Sena et al., 1998; Osman, 2004)	—	—	—	—	6.9	6.9	6.9	(Osman, 2004)				
Proline	7.0	5.4	8.7	(Glew et al., 1997; Sena et al., 1998)	5.6	4.9	6.6	(Yazzie et al., 1994; Glew et al., 1997; Sena et al., 1998)	9.1	4.9	13.3	(Glew et al., 1997; Proll et al., 1998)				
Serine	3.3	2.2	4.4	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	4.3	3.6	5.6	(Yazzie et al., 1994; Glew et al., 1997; Sena et al., 1998)	8.3	5.8	12.9	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)				
Threonine	2.7	2.4	2.8	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	3.9	3.4	4.8	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	5.8	3.8	7.9	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)				
Tryptophan	3.5	0.7	6.4	(Glew et al., 1997; Sena et al., 1998)	1.9	1.0	3.0	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	2.6	1.4	3.7	(Glew et al., 1997; Proll et al., 1998)				
Tyrosine	8.5	0.9	20.6	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	4.0	3.4	5.1	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	3.9	1.5	7.4	(Glew et al., 1997; Proll et al., 1998; Osman, 2004)				
Valine	4.9	3.8	6.0	(Glew et al., 1997; Sena et al., 1998; Osman, 2004)	6.0	5.2	7.0	(Yazzie et al., 1994; Nordeide et al., 1996; Glew et al., 1997; Sena et al., 1998)	8.5	5.9	13.5	(Glew et al., 1997; Proll et al., 1998; Osman ,2004)				
Fatty acids (mg/g dw)																
C:8 (Caprylic)	—	—	—		0.01	0.01	0.01	(Sena et al., 1998)								
C:12 (Lauric)	—	—	—		0.09	0.09	0.09	(Sena et al., 1998)								
C14:0 (Mystiric)	0.2	0.2	0.2	(Sena et al., 1998)	0.37	0.37	0.37	(Sena et al., 1998)								
C16:0 (Palmitic)	13.6	0.2	27.0	(Glew et al., 1997; Sena et al., 1998)	1.72	0.24	3.2	(Glew et al., 1997; Sena et al., 1998)								

C16:1 (Palmi-toleic)	—	—	—		0.11	0.01	0.21	(Glew et al., 1997; Sena et al., 1998)
C18:0 (Stearic)	3.3	3.3	3.3	(Sena et al., 1998)	0.19	0.04	0.35	
C18:1 (Oleic)	25	25	25	(Sena et al., 1998)	0.22	0.06	0.39	(Glew et al., 1997; Sena et al., 1998)
C18:2 (Linoleic)	13.5	0.0	27.0	(Glew et al., 1997; Sena et al., 1998)	0.55	0.1	1	(Glew et al., 1997; Sena et al., 1998)
C18:3 (Linolenic)	0.5	0.2	0.9	(Glew et al., 1997; Sena et al., 1998)	2.09	0.08	4.1	(Glew et al., 1997; Sena et al., 1998)
C20:0 (Arachidic)	0.7	0.7	0.7	(Sena et al., 1998)	0.15	0.15	0.15	(Sena et al., 1998)
C20:1 (Gadoleic)	0.04	0.04	0.04	(Sena et al., 1998)				

Table 2 Vitamin A contents of baobab leaves

	Sun dried			Shade dried		
Leaves	α carotene (μg/g)	β carotene (μg/g)	Retinol equivalent (μg/g)	α carotene (μg/g)	β carotene (μg/g)	Retinol equivalent (μg/g)
Young trees, small leaves	5.7	74.5	12.9	12.9	156	27.2
Young trees, large leaves	6.7	54.0	9.3	5.1	130	22.0
Old trees, small leaves	9.9	87.0	15.3	19.4	147	26.2
Old trees, large leaves	4.1	69.0	11.5	7.1	107	18.5

Source: Scheuring et al. (1999).

Vitamins

Only few authors have investigated the vitamin A content of baobab leaves. Scheuring et al. (1999) found that the simple practice of drying baobab leaves in the shade protects against deterioration of provitamin A. The selection of small leaves (which is tree specific) further increased provitamin A by 20%. 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 (Table 2). Other authors mention the carotenoid content of baobab leaves (Table 3). Vertuani et al. (2002) found that baobab leaves have an Integral Antioxidant Capacity (IAC) of 8.7 mmol/g. The IAC represents the sum of the antioxidant capacity of hydrophilic and lipophilic antioxidants, calculated as mmol equivalents in activity of Trolox, determined in the best experimental conditions for the sample. The antioxidant activity may be due to the presence of carotenoids or other phenolic compounds, but this needs to be checked.

The type of leaves analyzed, young or old, sun or shade dried, is not indicated by Sena et al. (1998) and Nordeide et al. (1996) and their reported values are far below the general range of the ones reported by Scheuring et al. (1999). Becker (1983) reported thiamine, riboflavin, and niacin content of 0.13, 0.82, and 8.06 mg/100 g dw, respectively.

Amino Acids

Concerning the amino acid content, the highest averages from the reported values were found for aspartic acid (10.6 g/100 g protein), glutamic acid (10.5 g/100 g protein), leucine (8.3 g/100 g protein), and arginine (7.7 g/100 g protein), whereas the lowest values were found for methionine (1.7 g/100 g protein) and tryptophan (1.9 g/100 g protein) (Table 1). Nordeide et al. (1996) mentioned that the limiting amino acid for baobab leaf products is lysine. The authors also computed the chemical score (FAO/WHO/UNU, 1985) using the reference amino acid pattern for preschool children (2–5 years) and found that it was 81% for baobab leaves. The amino acid chemical score should be in the order of 60 and above (Nordeide et al., 1996). This implies that the leaves of *A. digitata* are potentially valuable protein sources to be used to complement the amino acid profile of local dishes, namely in order to improve the protein quality of agricultural products that are not deficient in lysine, e.g., cereals. Similarly, Yazzie et al. (1994) calculated the chemical score using tryptophan, the most limiting essential amino acid and found that baobab leaf contains significant amounts of all the essential amino acids. The variation in the reported amino acid contents is relatively low between authors, and also between different specimens analyzed by the same author. A comparison with other forest leaves showed that the chemical scores of *Tamarindus indica* dried leaves, *Parkia biglobosa*, *Amaranthus viridis* dried leaves, and *Allium cepa* dried leaves are 79%, 61%, 51%, and 47%, respectively (Nordeide et al., 1996).

Table 3 Carotenoid contents of baobab leaves

Authors	Lutein	α-Carotene	β-carotene	Vitamin A total Retinol equivalent
Sena et al. 1998 (μg/g dw) (Niger)	50.9	0.92	17.2	
Nordeide et al., 1996 (μg/100 g) (Mali)		trace	670	112
Nordeide et al., 1996 (μg/g)*			6.7	1.12

*Converted values.

Fatty Acids

Few authors investigated the fatty acid content of baobab leaves, and the reported data by Sena et al. (1998) and Glew et al. (1997) show many differences. The leaves mainly seem to contain oleic and palmitic acid.

Antinutrients

Baobab leaves contain some toxicants (Andy and Eka, 1985). Phytic acid content varies from 0.04 mg/100 g in market samples to 0.05 mg/100 g in field samples. Total oxalic acid ranges from 4.37 mg/100 g in field samples (with 40% soluble oxalate) to 5.26 mg/100 g in market samples (with 37% soluble oxalate). Baobab leaves contain also 37.2 g/100 g (market samples) to 40.4 mg/100 g (field samples) hydrocyanic acid. Tannins levels are 17.8 mg/100 g and 19.8 mg/100 g in market samples and field samples, respectively. These values are below the known toxic

levels but may interfere with the nutrients and possibly decrease their digestibility and availability (Andy and Eka, 1985).

THE PULP

Macronutrients

Water

The reported water content (Table 1) varies considerably between authors, and ranges from 2% to 27.5%. Values lower than 10% (namely 2% to 8.7%) are mentioned (Becker, 1983; Busson, 1965; Murray et al., 2001; Nour et al., 1980; Wehmeyer, 1966), while higher values varying from 10 up to 27.5% are also reported (Lockett et al., 2000; Soloviev et al., 2004; Obizoba and Amaechi, 1993; Osman, 2004; Saka and Msonthi, 1994). The average of all reported values is 11.6%. This average water content is a bit high for a powdery type of product such as baobab pulp and may negatively influence its shelf life.

Carbohydrates

Reported carbohydrate contents (Table 1) range from 46.6 g/100 g dw (Murray et al., 2001) to 88 g/100 g dw (Wehmeyer, 1966). The average of the reported values is 79.9 g/100 g dw. Most authors determined carbohydrates by difference, so these values are not expected to be very accurate. However, Murray et al. (2001) determined different types of carbohydrates and only the fraction containing monosaccharides and disaccharides was calculated by difference. The presence of sugar was also mentioned by Soloviev et al. (2004), who found a total soluble sugar content of 7.2–11.2 g/100 g dw in baobab pulp, while Nour et al. (1980) reported 23.2% of total sugars and 19.9% of reducing sugars. 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.

Crude Proteins

Generally, the reported crude protein content (Table 1) varies from 2.5 g/100 g dw (Lockett et al., 2000) to 3.6 g/100 g dw (Osman, 2004). However, Obizoba and Amaechi (1993) reported higher values of 15.3 g/100 g dw for protein in the pulp, using analytical methods similar to those applied by the other researchers. Most authors used Kjeldahl analysis with the conversion factor of 6.25 to determine the protein content of baobab pulp. Moreover, after amino acid analysis, Sena et al. (1998) mentioned a total protein content of 17 g/100 g dw. The value mentioned by Sena et al. (1998) is comparable to the one of Obizoba and Amaechi (1993), despite the hydrolysis procedure before amino acid analysis.

Crude Lipid

The reported crude lipid contents (Table 1) of baobab pulp vary from 0.21 g/100 g dw (Nour et al., 1980) to 15.5 g/100 g dw (Glew et al., 1997) with an average of 3.6 g/100 g dw. The value reported by Glew et al. (1997) was obtained after fatty acids analysis (hydrolysis of sample before determination) and was quite similar to the one reported by Sena et al. (1998), who mentioned a total lipid content of (12.7 g/100 g dw). The highest values without fatty acid analyses, 4.3 and 4.1 g/100 g dw, respectively, were reported by Saka and Msonthi (1994) and Obizoba and Amaechi (1993), who however used (a) dilute acid hydrolysis and hexane extraction and (b) the method using the Soxtec system (extractable materials readily passed from the sample and dissolved in the organic solvent, similar to a tea bag in hot water for a duration of 1 h), respectively. The latter method was also used by Lockett et al. (2000), who found a very low fat content of 0.41 g/100 g dw. The Soxhlet and the gravimetric method were also mentioned, but all results were different; the great variation observed may have an origin other than the method used.

Energy

The energy value varies from 848.9 kJ/100 g dw (Murray et al., 2001) to 1494.9 kJ/100 g dw (Osman, 2004) (Table 1). The values reported averaged 1275 kJ/100 g. Note that the method for carbohydrate determination of Murray et al. (2001) was different from the generally used method of difference, and that this may have affected his result. Furthermore, the coefficients used by authors to compute the energy value are sometimes slightly different.

Fibers

Fiber contents are lower than 12.5% in most cases (Table 1), ranging generally from 6.0 g/100 g dw (Osman, 2004) to 12.5 g/100 g dw (Lockett et al., 2000). However, Murray et al. (2001) mentioned a high value of 45.1 g/100 g dw, which is the maximum of the reported values. The average of the reported values is 13.7 g/100 g dw. Murray et al. (2001) measured the fibers (after extraction of fat) by a gravimetric method, while the others used AOAC methods (Nour et al., 1980; Osman, 2004) or an acid and alkaline hydrolysis method (Saka and Msonthi, 1994).

Ash

The reported ash contents (Table 1) are from 4.1 (Busson, 1965) to 6.4 g/100 g dw (Lockett et al., 2000) with the exception of the very low value of 1.9 g/100 g dw reported by Obizoba and Amaechi (1993). The methods used by the authors vary considerably with respect to the time temperature combinations.

Other Measurements

The pH of the pulp is about 3.3 (Nour et al., 1980). Soloviev et al. (2004) investigated total free acidity and their results show that baobab pulp contains 6.5–11.2 g equivalent malic acid per 100 g dw (Table 1). These results indicate the acidic character of the pulp.

Minerals

The reported mineral contents of baobab pulp show a great variability between authors (Table 1). The values for magnesium vary from 100.5 mg/100 g dw (Osman, 2004) to 300 mg/100 g (Sena et al., 1998) with an average value of 195.1 mg/100 g. For potassium, the reported average value is 1793.8 mg/100 g dw and it varies from 726 mg/100 g dw to 3272 mg /100 g dw (Saka and Msonthi, 1994). Reported values for the calcium content are generally between 390 mg/100 g dw (Prentice et al., 1993) and 700.9 mg/100 g dw (Nour et al., 1980). However, a very low value of 3.0 mg/100 g dw was reported by Obizoba and Amaechi (1993). The average of the reported values is 301.8 mg/100 g dw. The reported sodium content varies from 0.8 (Sena et al., 1998) to 31.2 mg/100 g dw (Osman, 2004) with an average of 14.8 mg/100 g dw. For copper, it goes from below the detection level (Glew et al., 1997) to 1.8 mg/100 g dw (Osman, 2004); the average is 0.9 mg/100 g dw. The manganese content varies from below the detection level (Glew et al., 1997) to 1.0 mg/100 g dw (Sena et al., 1998). The average value is 0.7 mg/100 g dw. For phosphorus, reported contents vary greatly from 0.04 mg/100 g dw (Obizoba and Amaechi, 1993) to 425 mg/100 g dw (Sena et al., 1998). The reported zinc content is generally low, ranging from 0.5 (Lockett et al., 2000) to 3.2 mg/100 g dw (Sena et al., 1998) with an average of 1.7 mg/100 g dw. The iron content varies strongly from 1.1 mg/100 g (Arnold et al., 1995) to 10.4 mg/100 g dw (Osman, 2004).

The methods used by the different researchers to determine minerals were generally atomic absorption methods. For instance, apart from P for which Lockett et al. (2000) used the Technicon Auto-analyser methodology, they used a flame atomic absorption spectroscopy method for the other minerals. Sena et al. (1998) used the same method as Glew et al. (1997), namely the inductively coupled argon plasma atomic emission spectroscopy. Saka and Msonthi (1994) estimated P colorimetrically by the ammonium molybdate method, determined Ca, Mg, and Fe by the atomic absorption technique using a Perkin-Elmer 500 spectrophotometer, and analyzed K and Na using a corning 400 flame photometer. Obizoba and Amaechi (1993) used the polarized Zeeman atomic absorption spectrophotometry. In contrast to the others, Nour et al. (1980), who also used a molybdenum colorimetric method to determine P, determined the other minerals using a thiocyanate method for Fe, oxalate precipitation for Ca, and estimated Mg. The large variation in the reported data may be due to the methods used, but may also have other origins, that will be discussed further.

Vitamins

Authors have investigated mainly vitamin C. There is a great variability and the average of the reported values is 283 mg/100 g. Scheuring et al. (1999) found that there is a remarkable tree-to-tree variability in the vitamin C content of the fruit pulp, ranging from 150 to 500 mg/100 g, which constitutes actually the minimum and the maximum of the reported values. The figures were found to be quite stable from one year to the next (Scheuring et al., 1999). Possible explanations given for this variability are soil type, genetic make-up, and morphotypes. Sena et al. (1998) investigated the carotenoid content of the pulp and found that it contains 1.53 μg/g dw of lutein, 0.17 μg/g dw of α-carotene and 0.17 μg/g dw of β-carotene.

The investigation of group B vitamins in the pulp also showed large variations. Data ranged from 1.8 to 2.7 mg/100 for vitamin B3, niacin, as reported by Santos Oliveira (1975) and Arnold et al. (1995), respectively. The riboflavin content ranges from 0.07 mg/100 g (Becker, 1983) to 0.14 mg/100 g (Arnold et al., 1995). The methods used to determine each vitamin seldom are described, which makes it hard to evaluate these figures critically.

Amino Acids

There is a large variability in the reported amino acid contents of baobab fruit pulp (Table 1), despite the fact that the authors (Sena et al., 1998; Glew et al., 1997; Osman, 2004) used similar methods for determination. They all hydrolyzed the samples in the described procedures. The results show that most essential amino acids are present. The highest average contents were found for tyrosine (8.5 g/100 g protein), glutamic acid (8.4 g/100 g protein), aspartic acid (7.5 g/ 100 g protein), arginine (6.8 g/100 g proteins), and glycine (6.2 g/100 g protein). The lowest values were found for the sulphur containing amino acids, namely cystein (1.3 g/100 g protein) and methionine (1.9 g/100 g protein).

Fatty Acids

Most fatty acids in the pulp do not reach detectable levels. Similarly to the amino acids, the variability in the reported values is high (Table 1), despite the use of identical methods by the researchers. The content of oleic acid is the highest reported value among all fatty acids (25 mg/g dw).

Antinutrients

The baobab fruit pulp, as other plant fruits, contains naturally occurring antinutritional substances. Tannin content of the pulp varies between 0.0051% and 0.0062% (Ghani and Agbejule, 1986). This level is too low to cause any harmful effects on consumers (Ghani and Agbejule, 1986). Other harmful components

estimated by Ghani and Agbejule (1986) include: hydrocyanic acid (HCN) (0.0049% dw) and total oxalate (0.0044% dw). However, the detected levels were not alarming (Ghani and Agbejule, 1986).

THE WHOLE SEEDS

Macronutrients

Two authors reported the water content of the whole seeds to be 6.1% (Proll et al., 1998) and 8.2% (Lockett et al., 2000). They also reported an energy value of 1935 kJ/100 g dw and 1589.8 kJ/100 g dw, respectively. The average carbohydrate content is 31.7 g/100 g dw, with values ranging from 5.2 g/100 g dw (Arnold et al., 1995) to 56.8 g/100 g dw (Proll et al., 1998). The crude lipid content ranges from 9 g/100 g dw (Glew et al., 1997) to 33.3 g/100 g dw (Arnold et al., 1995). Ezeagu et al. (1998) mentioned a fat content of 14.8% on fresh weight basis, which is lower than that of some soybean varieties (*Glycine max* TGX 1660-15F, TGX 1740-6F, TGX 1740-2F, TGX 1649-11F, TGX 1681-3F), of which the fat content varied from 18.6 to 22.2% on fresh weight basis. The fiber content is reported to vary from 16.9 g/100 g dw (Osman, 2004) to 49.7 g/100 g dw (Lockett et al., 2000), while the ash content has an average value of 5.3 g/100 g dw. The crude protein content varies from 14.4 g/100 g dw (Proll et al., 1998) to 36.7 g/100 g dw (Arnold et al., 1995) with an average value of 21.4 g/100 g dw (Table 1). The time-temperature combination for the moisture and ash measurements differs from one author to another. The crude protein contents are mostly measured according to Kjeldahl methods using 6.25 as conversion factor, except for a determination after measurement of amino acids by Glew et al. (1997).

Minerals

The mineral levels in whole seeds are presented in Table 1. The magnesium content of the whole seeds is reported to vary from 282.2 mg/100 g dw (Osman, 2004) to 696.3 mg/100 g dw (Arnold et al., 1995) with an average value of 402 mg/100 g dw. This is much higher than reported for the kernels. The same was observed for potassium and calcium, that range from 428.5 mg/100 g dw (Osman, 2004) to 1387.2 mg/100 g dw (Arnold et al., 1995) with an average of 908 mg/100 g dw; and from 29.6 mg/100 g dw (Osman, 2004) to 395 mg/100 g dw (Glew et al., 1997) with an average of 252 mg/100 g dw, respectively. The sodium content varies from 1.9 mg/100 g dw (Glew et al., 1997) to 2.7 mg/100 g dw (Arnold et al., 1995) and the average is 2.3 mg/100 g dw. The average copper content is 2.3 mg/100 g dw and values range from 1.3 mg/100 g dw (Lockett et al., 2000) to 3 mg/100 g dw (Arnold et al., 1995). The average manganese content 1.1 mg/100 g dw. The average zinc content is 5.0 mg/100 g dw and values range from 2.6 mg/100 g dw (Glew et al., 1997) to 7.3 mg/100 g dw (Arnold et al., 1995). The iron content varies from 1.8 mg/100 g dw (Glew et al., 1997) to 7.1 mg/100 g dw (Arnold et al., 1995) with an average value of 5.1 mg/100 g dw. The phosphorus contents vary greatly from 5.6 mg/100 g dw (Arnold et al., 1995) to 738.3 mg/100 g dw (Lockett et al., 2000) (Table 1) with an average value of 453 mg/100 g dw. A comparison of these data with those of the kernels (described below) shows how rich the coat is in several minerals, namely Ca, P, and Mg.

Vitamins

Not much has been reported on the vitamin content of the whole seeds. However, Arnold et al. (1995) found that the seeds contain 0.25 mg/100 g dw, 0.14 mg/100 g dw and 1.0 mg/100 g dw of thiamine, riboflavin, and niacin, respectively. The method used for the determinations was not specified.

Amino Acids

The levels of amino acids in whole seeds are presented in Table 1. Considering the average value, whole seeds are very rich in glutamic acid (35.9 g/100 g protein), aspartic acid (16.9 g/100 g protein), arginine (11.6 g/100 g protein), leucine (10.6 g/100 g protein), proline (9.1 g/100 g protein), glycine (8.8 g/100 g protein), serine (8.3 g/100 g protein), phenylalanine (7.2 g/100 g protein), and lysine (6.9 g/100 g protein). The lowest average value was found for methionine (1.9 g/100 g protein).

Fatty Acids

The fatty acid content of the whole seeds is presented in Table 4. The presence of a relatively high quantity of oleic acid can be observed (Glew et al., 1997).

Antinutritional Factors

Baobab seeds contain some antinutritional factors that can be removed or inactivated by different processing methods. Osman (2004) investigated the antinutritional 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. Igboeli et al. (1997) investigated the effects of some processing techniques on the antinutrient composition of baobab seeds and found that cold water, hot water, hot alkali, and acid treatments reduced the tannic acid concentration in baobab seeds significantly. However, dehulling did not lead to significant decreases (from 400 μg tannic acid/g in the whole seeds to 390 μg tannic acid/g in the dehulled seeds). The activity of amylase inhibitors in the seeds was reduced significantly by dehulling (from 35 to 10 μg/100 g), cold water, and hot alkali treatments. Moreover, fermentation reduced the antinutrient

Table 4 Reported fatty acid content of baobab whole seeds

Authors	C14:0 mystiric	C16:0 palmitic	C16:1 palmitoleic	C16:2 hexade cadienic	C17:1	C18:0 stearic	C18:1 oleic	C18:2 linoleic	C18:3 linolenic	C20:0 arachidic	C20:1 gadoleic	C22:0 behenic	C24:0 lignoceric
Glew et al., 1997 (mg fatty acid/g dw material)	trace	1.43	0.02			0.16	2.14	1.38	0.016	trace			
Glew et al., 1997 (g fatty acid/100 g dw material)*		0.14	0.002			0.016	0.21	0.13	0.002				

*Converted values

contents (phytate and tannins) of baobab seeds (Nnam and Obiakor, 2003).

THE KERNELS

The cream-colored kernels are obtained by removing the shell from the whole seeds. Traditionally, the whole seeds are soaked and boiled for 2–3 hours. Afterwards, the seeds are individually and manually dehulled. Next, the kernels are dried. This operation is one of the most difficult ones in the traditional processing of baobab parts.

Macronutrients

As presented in Table 1, the average reported water content is 7.2%. It ranges from 6.4% (Igboeli et al., 1997) to 8.1% (Obizoba and Amaechi, 1993). The energy value mentioned by Igboeli et al. (1997) is 1965.5 kJ/100 g dw. The carbohydrate content ranges from 22.1 g/100 g dw (Ajayi et al., 2003) to 48.1 g/100 g dw (Nnam and Obiakor, 2003). The average of the reported crude protein contents is 24.7 g/100 g dw, ranging from 14 g/100 g dw (Nnam and Obiakor, 2003) to 32.7 g/100 g dw (Obizoba and Amaechi, 1993). The crude lipid content has an average of 27.8 g/100 g dw. A fiber content of 21.2 g/100 g dw is mentioned (Ajayi et al., 2003) and the average ash content is 6.5 g/100 g dw. The kernels appear to be a good source of protein and energy and may be an interesting ingredient for designing formulated infant foods.

Minerals

The kernels were investigated for their mineral content by several authors (Table 1). They were reported to have an average potassium content of 6.6 mg/100 g dw, with a minimum of 0.6 mg/100 g dw (Nnam and Obiakor, 2003) and a maximum of 17.3 mg/100 g dw (Ajayi et al., 2003). The magnesium content ranges from 0.2 mg/100 g dw (Odetokun, 1996) to 1.1 mg/100 g dw (Ajayi et al., 2003) with an average of 0.7 mg/100 g dw. The calcium content ranges from 0.4 mg/100 g dw (Ajayi et al., 2003) to 3.8 mg/100 g dw (Obizoba and Amaechi, 1993); the sodium content from 0.2 mg/100 g dw (Ajayi et al., 2003) to 1.6 mg/100 g dw (Odetokun, 1996); copper from 0.02 mg/100 g dw (Nnam and Obiakor, 2003) to 5.4 mg/100 g dw (Odetokun, 1996); manganese from 0.2 mg/100 g dw (Ajayi et al., 2003) to 2.8 mg/100 g dw (Odetokun, 1996); zinc from 0.1 mg/100 g dw (Ajayi et al., 2003) to 3.6 mg/100 g dw (Obizoba and Amaechi, 1993); and iron from 0.6 mg/100 g dw (Nnam and Obiakor, 2003) to 2.4 mg/100 g dw (Obizoba and Amaechi, 1993). The phosphorus content is reported to vary greatly from 0.4 mg/100 g dw (Obizoba and Amaechi, 1993) to 326.3 mg/100 g dw (Nnam and Obiakor, 2003).

For the determination of minerals, Ajayi et al. (2003) used the method described by Idouraine et al. (1996), while Nnam and Obiakor (2003) used the atomic absorption spectrophotometer. Odetokun (1996) determined Na and K by a flame photometer and the other minerals by atomic absorption spectrophotometry. Obizoba and Amaechi (1993) determined Ca, Zn, Cu, P, and Fe by polarized Zeeman atomic absorption spectrophotometry.

The huge differences found may be due to the use of different methods, but may also have other causes.

Vitamins

No published reports on the vitamin content of the kernels were encountered.

Amino Acids

Amino acid contents have been investigated in the whole seeds, but not specifically for the kernels.

Fatty Acids

The data reported by Ajayi et al. (2003) and Odetokun (1996) show that the kernels are rich in oleic acid (26.1 to 58.2%) and linoleic acid (23.3% to 39.4%) as indicated in Table 5. Moreover, Ajayi et al. (2003) mention 2.1% cerotic acid and 3.2% of other (unspecified) acids; in total, the seed oil contains 26.9% of saturated fatty acids and 73.1% of unsaturated fatty acids. It is

Table 5 Fatty acids content of the baobab kernels.

Authors	C12:0 lauric	C14:0 mystiric	C16:0 palmitic	C16:1 palmitoleic	C18:0 stearic	C18:1 oleic	C18:2 linoleic	C18:3 linolenic	C20:0 arachidic	C20:1 gadoleic	C22:0 behenic	C24:0 lignoceric
Ajayi et al., 2003 (% of total fatty acid)			4.43		3.98	26.07	39.4		2.26	4.01	3.46	10.7
Odetokun, 1996 (% of total fatty acid)	0.34	1.46	2.22	1.65		58.71	23.3	8.2		3.64		

recognized that an increased dietary intake of saturated fat and (to a lesser extent cholesterol), raises plasma/serum total and low-density lipoprotein (5LDL)- cholesterol, and of polyunsaturated fatty acids (PUFA) decreases these levels (Li and Sinclair, 2002). Because of its high proportion of unsaturated fatty acid, baobab kernels may have a positive effect on human health.

SOME CHARACTERISTICS OF SEED OIL

Sterols

The Baobab Fruit Company (www.baobabfruitco.com) collected data from literature and presented some results on sterols. Some data are also provided by Gaydou et al. (1979). Table 6 shows that the seed oil contains 75–81% of β-sitosterol followed by campesterol (6–6.3%). β-sitosterol, campesterol, and stigmasterol are the main sterols in plants and constitute bioactive compounds that can decrease the plasma/serum levels of lipids and lipoprotein lipids (Li and Sinclair, 2002).

Fatty Acids

According to Osman (2004), baobab seed oil is an excellent source of mono- and polyunsaturated fatty acids (Table 7a). The oil is composed of approximately 31.7% saturated fatty acids, 37% monounsaturated fatty acids, and 31.7% polyunsaturated fatty acids. The major fatty acid is oleic acid, which comprises 35.8%, followed by linoleic (30.7%) and palmitic (24.2%) acids. Reported by Gaydou et al. (1979), saturated fatty acids accounted for 34.6% of the fatty acids in baobab seed oil. However, the genus *Adansonia* has been reported to contain a particularly large proportion of cyclopropenoic fatty acids in their seed oil. Baobab oil from *Adansonia* sp. was reported to contain 6.3% malvalic acid, and 6.5% sterculic acid (12.8% total cyclopropenes). More specifically, *Adansonia digitata* seed oil contains 3.1–6.2% malvalic acid; 1.0–1.9% sterculic acid and then 4.1–8.1% total cyclopropenes (Table 7) (Aitzetmüller, 1996). Cyclopropenoic fatty acids are toxic with a higher toxicity with sterculic acid compared to malvalic acid (Andrianaivo-Rafehivola et al., 1994a). Biological effects are growth restriction and dysfunction of genital systems in chicken, rats, and mice as well as an induction of liver cancer in hardhead (*Oncorhynchus mykiss*), when cyclopropenes are combined with aflatoxins (Andrianaivo-Rafehivola et al., 1994a). Cyclopropenoic fatty acids, when present in an edible oil, have to be removed during refining to render the oil edible; Andrianaivo-Rafehivola et al. (1994b) showed that heating at 180°C or 220°C reduces the cyclopropenoic fatty acid content of oil by 60% or 96%, respectively. This implies that locally produced baobab seed oil should be refined before consumption.

Table 6 Sterols in baobab seeds oil

Sterol compostion	Sidibe and Williams, 2002 (% of total sterol)	Gaydou et al., 1979 (% of total sterol)
Cholesterol	2	1.9
Campesterol	6	6.3
Stigmasterol	1-2	
β-Sitosterol	75	81
Δ5-Avenasterol	0.5	3.4
Δ7-Stigmasterol	0.6	4.8
Δ7-Avenasterol	12	0.6
Stigmasterol		2.0

Indices

The specific gravity, the refractive index at different temperatures, as well as the iodine value, saponification value, and other indices are presented in Table 7b. The reported values for the specific gravity do not vary much and have a value of approximately 0.9 at 25°C. The refractive index is in the range of 1.5. The iodine value varies from 49.5 (Ajayi et al., 2003) to 88 (Osman, 2004).

DISCUSSION AND CONCLUSION

Variation in Reported Data

This review shows that the reported values of nutrient contents of baobab parts vary greatly. The causes of these variations are not well known but several assumptions can be made. This variation may be due to the quality of the sample (mixture of samples, or samples obtained from markets or samples from individual trees), the provenance of the samples, the age of the sample, the treatment before analysis, the analytical methods

Table 7 Characteristics of baobab seed oil

Authors	C14:0 mystiric	C16:0 palmitic	C16:1 palmitoleic	C16:2 hexade cadienic	C18:0 stearic	C18:1 oleic	C18:2 linoleic	C18:3 linolenic	C20:0 arachidic	C20:1 gadoleic	C22:0 behenic	C24:0 lignoceric	malvalic	sterculic
(a) Fatty acids content of baobab seed oil														
Ezeagu et al., 1998 (g fatty acid/100 g oil)	0.19	15.5	0.20	0.70	3.12	24.69 + 0.71 = 25.4		0.39 + 1.58 = 1.97	0.74	0.19	0.36	0.31		
Osman, 2004 (% of total fatty acid)	0.2	24.2			0.3	4.6	35.8	30.7	1.0	1.3	0.9	0.7		
Eteshola and Oraedu, 1996 (% of total fatty acid)	38.4	19.7			3.2	22.4	16.2							
Gaydou et al., 1979 (% of total fatty acid)		26.7				41.9	20.6							
Aizetmüler, 1996 (%)													3.1–2.6	1.0–1.9

Authors	Specific gravity		Refractive Index	Iodine value	Saponification value	Acid value	Free fatty acid as oleic acid	Peroxide value	Ester value	Density	Viscosity	Color
(b) Indices of baobab seed oil												
	25/25°C	25°C	27°C									
Osman, 2004	0.9		1.5	88	210							
Ajayi et al., 2003	0.85	1.46 not sure about temp		49.5	230	5.2	2.6	5.2	224.8	0.42	11.5	
Odetokun, 1996	0.94	1.46		82.4	133	7.8 mg/gKOH	6.5	5.1				Light yellow

used, the storage conditions, the processing method, a probable genetic variation, and the soil structure and its chemical composition.

The composition of a food can be influenced significantly by the environment such as soil type, fertilizer, water or sunlight intensity. For instance, Maranz et al. (2004) investigated the chemical composition of 42 populations of the Shea butter or Karité tree (*Vitellaria paradoxa*) in 11 countries and found very high variability in all measured parameters, both within and between populations. The mineral content of the soils needs to be considered when dealing with the mineral content of the plant. The variation found in the reported data on the composition of baobab parts may be partially explained by the fact that baobab trees grow on a wide range of soils, ranging from deep, consolidate sands to well-drained clayey soils and coal limestone.

If the biochemical composition of a food depends on its genetic make-up, variability can also be attributed to genetic factors. In Benin, for instance, a genetic variability has been identified for baobab populations by Assogbadjo et al. (2006) but the relation with the composition of the food products from these baobab populations is not yet known. However, in Mali, measurements of bulked fruit samples from many baobab trees consistently resulted in vitamin C values of around 220 mg/100 g. It was only when researchers measured bulked fruit from individual trees that a threefold range of values from 150 to 500 mg/100 g vitamin C was discovered (Anonymous, 1998). According to Diop et al. (2005), variations are obviously also due to the variability of the raw material (habitat, maturity, and storage conditions of samples). Indeed, the investigated literature shows that the analyzed samples were selected and handled differently. For instance, some researchers purchased their baobab material from local markets, e.g. Nnam and Obiakor (2003), Lockett et al. (2000), Obizoba and Amaechi (1993) and Yazzie et al. (1994). In Mali for instance, it has been noticed that β-carotene and vitamin C levels were much lower in market samples than in any sample that was gathered directly from trees; market samples are frequently adulterated with worthless material such as cereal stalk pulp (Scheuring et al., 1999; Anonymous, 1998). However, some authors like Soloviev et al. (2004) and Scheuring et al. (1999), collected their material in the field. In this case, the degree of maturity of the biological material matters, and is linked to the method of harvesting; fruit harvested by knocking on branches or cutting from the tree will invariably include unripe fruit. Such unripe fruits do not show any ascorbic acid content until the moisture of baobab pulp decreases below 75% (Carr, 1958). Moreover, the storage conditions before analysis differ; while Osman (2004) stored his samples at –20°C in tight plastic jars before analysis, Nnam and Obiakor (2003) boiled and dried the seeds before keeping them in Kilner jars for analysis. The form in which the product is analysed also matters (Joyanes and Lema, 2006). In the present literature review, it was observed that leaves, for example, were analyzed after drying but that the method of drying (sun or shade for instance) was seldom specified. It was found in Mali that baobab leaves dried in the shade may contain twice as much Retinol Equivalent (pro-vitamin A) than sun-dried leaves, even though sun drying is the common local practice (Anonymous, 1998). The age of the samples may also induce some variability in their composition. In the case of vitamin C, for instance, pulp samples stored in clear glass bottles and partly exposed to sunlight showed 6.4 to 14.1% loss of ascorbic acid. Samples exposed to a longer storage (14 months), direct sunlight and exposure to air showed losses of up to 45.5% of ascorbic acid (Carr, 1958). In addition, an entire leaf consists of a petiole and a number of leaflets and it is often not specified whether the analyses concern leaflets or entire leaves.

Apart from the variability in the material, the analytical methods (sampling plans, sampling methods, analytical methods, analytical quality control) and inherent variability may also be a cause of variability. Considering seed oil, for instance, the method of extraction of the oil may affect its composition.

Moreover, some of the micronutrients, such as vitamins and minerals, are biologically active. They can interact with other nutrients and change in their bioavailability; because they are biological material, there is a natural variation in their composition (Joyanes and Lema, 2006).

Our review shows that more attention must be paid to all stages involved in performing analyses before we can make reliable statements on the variation in composition of baobab food products.

Contribution to Recommended Daily Intake

Note: in the following calculation, digestibility and bioavailability could not be taken into account, because of lack of data. Therefore, the values given should be seen as maximum values; in reality they are probably lower.

Leaves

Without considering the conversion factor or the effect of processing, such as cooking, the consumption of 20 g of dry leaf material would cover 10 to 16% of the protein RDI for children (4–8 y). Considering the highest reported values, 20 g would be enough to cover 89% of the zinc RDI and 66% of the calcium RDI for children (Table 8). Similarly, consumption of 20 g will cover 53% of the calcium RDI and 41% of the zinc RDI for pregnant women when considering the highest reported values (Table 9). The large gap between the lowest and highest reported values of iron makes it difficult to make a reliable prediction for this mineral. A bioavailability study is necessary to obtain a reliable assessment. Finally, the introduction of baobab nurseries for leaf production is becoming increasingly popular. The nutritional composition and digestibility of these leaves also require investigation.

Pulp

Irrespective of the variation in the reported values, the data reveal the high vitamin C content of the pulp. A comparison

Table 8 Baobab pulp, leaf and kernel composition with the Recommended Daily Intakes (RDI) for individuals: children, 4–8 y

Nutrients:	Energy		Carbohydrates		Proteins		Ca		Zn		Fe		Vit C	
RDI for children (4-8y) (g/d):	6691 Kj/d	6691 Kj/d	130	130	19	19	0.8	0.8	0.005	0.005	0.01	0.01	0.025	0.025
Pulp composition (g/100 g):	Highest*	Lowest*	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest
	1495 (Kj/100 g)	849 (Kj/100 g)	88	46.6	15.3	2.5	0.7	0.0029	0.0032	0.00053	0.01	0.001	0.3	0.2
% RDI covered by consumption of 20 g/d	4.5	2.5	13.5	7.2	16.1	2.6	17.5	0.1	12.7	2.1	20.8	2.0	240.0	143.2
% RDI covered by consumption of 40 g/d	8.9	5.1	27.1	14.3	32.2	5.2	35.0	0.1	25.4	4.2	41.5	4.0	480.0	286.4
% RDI covered by consumption of 60 g/d	13.4	7.6	40.6	21.5	48.3	7.7	52.6	0.2	38.2	6.4	62.3	6.0	720.0	429.6
% RDI covered by consumption of 100 g/d	22.3	12.7	67.7	35.8	80.5	12.9	87.6	0.4	63.6	10.6	103.8	10.0	1200.0	716.0
Leaf composition (g/100 g):	Highest*	Lowest*	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest
	1581 (Kj/100 g)	1179 (Kj/100 g)	69	40.2	14.9	10	2.6	0.3	0.022	0.00074	0.3	0.0012	0.05	0.05
% RDI covered by consumption of 20 g/d	4.7	3.5	10.6	6.2	15.7	10.5	66.0	7.7	89.6	3.0	500.0	2.3	40,0	40.0
% RDI covered by consumption of 40 g/d	9.5	7.1	21.2	12.4	31.4	21.1	132.0	15.4	179.2	5.9	1000.0	4.7	80,0	80.0
% RDI covered by consumption of 60g/d	14.2	10.6	31.8	18.6	47.1	31.6	198.0	23.0	268.8	8.9	1500.0	7.0	120,0	120.0
% RDI covered by consumption of 100 g/d	23.6	17.6	53.1	30.9	78.4	52.6	330.0	38.4	448.0	14.8	2500.0	11.7	200,0	200.0
Kernels composition (g/100 g):	One value		highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest	—	—
	1966 (Kj/100 g)		48.1	22.1	32.7	14.0	0.0037	0.00043	0.0036	0.0001	0.0024	0.00063	—	—
% RDI covered by consumption of 20g/d	5.9		7.4	3.4	34.4	14.7	0.1	0.0	14.3	0.4	4.8	1.3	—	—
% RDI covered by consumption of 40 g/d	11.8		14.8	6.8	68.8	29.5	0.2	0.0	28.6	0.8	9.6	2.5	—	—
% RDI covered by consumption of 60g/d	17.6		22.2	10.2	103.3	44.2	0.3	0.0	42.8	1.2	14.3	3.8	—	—
% RDI covered by consumption of 100 g/d	29.4		37.0	17.0	172.1	73.7	0.5	0.1	71.4	2.1	23.9	6.3	—	—

Source: Recommended Daily Intakes for individuals for Energy: http://www.fnri.dost.gov.ph/reni/renitable1.htm, 06-03-2006.
Source: Other Recommended Daily Intakes for individuals: http://www.iom.edu/CMS/3788.aspx, 07-03-2006.
*Highest and lowest values reported by different authors for nutrient composition of baobab pulp.

Table 9 Baobab pulp, leaf, and kernels composition with the Recommended Daily Intakes (DRI) for pregnant women, 19–30 y

Nutrients:	Energy		Carbohydrates		Proteins		Ca		Zn		Fe		Vit C	
RDI for pregnant women, 19-30y (g/d):	9033 Kj/d	9033 Kj/d	175	175	71	71	1	1	0.011	0.011	0.027	0.027	0.085	0.085
Pulp composition (g/100 g):	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest
	1495 (Kj/100 g)	849 (Kj/100 g)	88	46.6	15.3	2.5	0.7	0.0029	0.0032	0.00053	0.01	0.001	0.3	0.2
% RDI covered by consumption of 20g/d	3.3	1.9	10.1	5.3	4.3	0.7	14.0	0.1	5.8	1.0	7.7	0.7	70.6	42.1
% RDI covered by consumption of 40 g/d	6.6	3.8	20.1	10.7	8.6	1.4	28.0	0.1	11.6	1.9	15.4	1.5	141.2	84.2
% RDI covered by consumption of 60g/d	9.9	5.6	30.2	16.0	12.9	2.1	42.1	0.2	17.3	2.9	23.1	2.2	211.8	126.4
% RDI covered by consumption of 100 g/d	16.5	9.4	50.3	26.6	21.5	3.5	70.1	0.3	28.9	4.8	38.4	3.7	352.9	210.6
Leaf composition (g/100 g):	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest	highest	lowest
	1581 (Kj/100 g)	1179 (Kj/100 g)	69	40.2	14.9	10	2.6	0.3	0.022	0.00074	0.3	0.0012	0.05	0.05
% RDI covered by consumption of 20g/d	3.5	2.6	7.9	4.6	4.2	2.8	52.8	6.1	40.7	1.3	188.1	0.9	11.8	11.8
% RDI covered by consumption of 40 g/d	7.0	5.2	15.8	9.2	8.4	5.6	105.6	12.3	81.5	2.7	376.3	1.7	23.5	23.5
% RDI covered by consumption of 60g/d	10.5	7.8	23.7	13.8	12.6	8.5	158.4	18.4	122.2	4.0	564.4	2.6	35.3	35.3
% RDI covered by consumption of 100 g/d	17.5	13.1	39.4	23.0	21.0	14.1	264.0	30.7	203.6	6.7	940.7	4.3	58.8	58.8
Kernels composition (g/100 g):	One value		highest	Lowest	highest	lowest	highest	Lowest	Highest	lowest	highest	lowest	—	—
	1966 (KJ/100 g)		48.1	22.1	32.7	14.0	0.0037	0.00043	0.0036	0.0001	0.0024	0.00063	—	—
% DRI covered by consumption of 20g/d	4.4		10.1	5.3	9.2	3.9	0.1	0.01	6.5	0.2	1.8	0.5	—	—
% DRI covered by consumption of 40 g/d	8.7		20.1	10.7	18.4	7.9	0.2	0.02	13	0.4	3.5	0.9	—	—
% DRI covered by consumption of 60g/d	13.1		30.2	16.0	27.6	11.8	0.2	0.03	19.5	0.6	5.3	1.4	—	—
% DRI covered by consumption of 100 g/d	21.8		50.3	26.6	46.1	19.7	0.4	0.04	32.5	0.9	8.9	2.3	—	—

Source: Recommended Daily Intakes for individuals for Energy: http://www.fnri.dost.gov.ph/reni/renitable1.htm, 06-03-2006.
Source: Recommended Daily Intakes for individuals: http://www.iom.edu/CMS/3788.aspx, 07-03-2006.
*Highest and lowest values reported by different authors for nutrient composition of baobab pulp.

with the Recommended Daily Intake (RDI) for children (4–8 y) and for pregnant women (19–30 y) is presented in Tables 8 and 9, respectively.

A consumption of 20 g of pulp by a child (4–8 y) will cover 143% of the RDI, considering the lowest reported vitamin C content by the authors. If the highest reported vitamin C content is considered, the coverage will even be 240% for the same quantity. In other words, 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 of such a child. Moreover, according to Carr (1955), the bulk of the vitamin C in baobab pulp is present in the reduced form (307 mg/100 g of reduced form out of 328 mg/100 g vitamin C). As the major metabolites of ascorbic acid in the human body are dehydroascorbic acid, 2,3-diketogulonic acid and oxalic acid (the reduced form of vitamin C), it can be concluded that about 93% of the vitamin C present in baobab pulp may be well absorbed.

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. The great variation in the reported iron, zinc, and calcium contents renders it difficult to estimate the contribution of baobab pulp to the RDI of these minerals. However, considering the highest reported values, the consumption of 40 g of baobab pulp is enough to cover 41.5% of the RDI for iron; 25.4% of the RDI for zinc, and 35% of the RDI for calcium. The energy content of the pulp is rather low when compared with the RDI for children.

A similar trend is observed for pregnant women (19–30 y). The consumption of 40 g of pulp by a pregnant woman 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. Moreover, a consumption of 100 g pulp will cover 26 to 50% of the carbohydrate RDI for pregnant women. As mentioned for the children, the coverage of iron, zinc, and calcium RDI is possible only when the highest reported values are considered for the pulp. Consumption of 60 g and 100 g would cover 23.1% and 38.4 % of the RDI for iron; 17.3% and 28.7% of the RDI for zinc; 42.1% and 70.1% of the RDI for calcium; 30.2% and 50.3% of the RDI for carbohydrates, respectively. The energy content is also low for the RDI for pregnant women.

Table 10 Antioxidant capacity of baobab pulp compared to other fruits

Integral antioxidant capacity (IAC) corresponding to the sum of the corresponding water and lipid soluble antioxidants capacity	
Products	IAC (mmol Trolox equivalent/g fresh weight, uncooked portion)
Baobab Fruit pulp	11.1
Baobab Dry leaves	8.7
Baobab Fruit glycolic extract	1.02
Baobab Leaves glycolic extract	4.41
Kiwi fruit pulp	0.34
Orange fresh pulp	0.10
Strawberry fresh pulp	0.91
Apple fresh pulp	0.16

Source: Vertuani et al. (2002)

There is no doubt that baobab pulp is a valuable source of vitamin C. If an added value would be given to the pulp by improving its handling, its quality, and storage stability using adequate processing methods, this might help to enhance interest about the pulp and lead to a better organization of this food chain in developing countries where the tree occurs and its food is well appreciated. At present, the preservation of the pulp, despite all its importance, is not properly controlled by the population, leading to undesirable losses. Subsequently, research is important to overcome problems in prolonging the shelf-life of the pulp in order to retain its nutritive value and sensorial properties. Bioavailability studies are necessary for a better appreciation of the contribution to human health since the dietary intake can never be fully utilized by the human body.

Kernels

The kernels are known for their high protein content. Consumption of 20 g can cover 15 to 34% of the protein RDI for children (Table 8), while for pregnant women 60 g can cover 27% of the RDI based on the highest reported content (Table 9). Moreover, consumption of 100 g can cover 22% of the energy RDI for pregnant women and 29.4% of energy RDI for children. Oil is extracted from the kernel and used for food and medicinal purposes. It is important to keep in mind that these data are related to the raw product and that further studies are required to evaluate the effect of cooking or other processing operations on the nutritive value of these products.

Antioxidant Capacity of Pulp and Leaves

Consuming antioxidant-rich foods can contribute to the prevention of oxidation in the human cell, hence of some diseases. In addition to the general chemical composition of baobab pulp and leaves discussed previously, Vertuani et al. (2002) investigated their antioxidant capacity and compared this with that of other common fruits (Table 10), using the photochemiluminescence method. They indicated that the antioxidant property of the pulp (measured as the Integral Antioxidant Capacity—IAC—value) was 100 times higher than that of orange pulp. This antioxidant capacity may vary depending on the measuring method used, but the comparison with other fruits could still give similar trends. Cook et al. (1998) also investigated the antioxidant content of the aqueous extract of wild plants and found that baobab leaves have an antioxidant content of 7.7 μmol/g dw expressed as Trolox equivalents. This result is almost 1000 times lower than the one reported by Vertuani et al. (2002), who found that the water-soluble antioxidant capacity of dry baobab leaves was 6.4 mmol Trolox equivalent/g.

These antioxidant activities were measured in fresh raw material and the effect of cooking and storage is not well known. Only Tarwadi and Agte (2005) investigated the antioxidative activity of some fruits and root vegetables before and after cooking. The antioxidant activity was measured as the inhibition

of thiobarbituric acid reactive substances (TBARS), superoxide radical scavenging activity (SOSA), and ferrous iron chelating ability (FICA). They found that there were significant cooking losses for each of the assessed antioxidant parameters.

More research is needed on the antioxidative activity of baobab pulp and leaves during various processing operations, as well as the concentration of the related water soluble and fat-soluble compounds.

CONCLUDING REMARKS

From this literature review on baobab pulp, leaves, whole seeds, and kernels, it can be concluded that reported data show considerable variation although a fair number of investigations have been published about baobab products. We suggested some reasons to explain those variations. There is a lack of information on the vitamin content of baobab parts except for vitamin C. Whatever the variability, baobab pulp is apparently rich in vitamin C, the leaves are rich in good quality proteins and minerals, and the kernels in fat. Most essential amino acids are present in the leaves. The pulp and the leaves also exhibit antioxidant activity. During future research, care should be taken to limit variability in collecting material, and in chemical analysis, and the data related to the environment of the samples should be described in detail. Further research is necessary to improve the quality and the shelf-life of the pulp, to investigate the antioxidant activity of the pulp and the leaves, to provide information about the bioavailability of macronutrients and micronutrients, and the effects of cooking and other processing techniques on the overall nutritional value of the products in order to improve present day practices as a measure to support the nutritional status of rural populations that incorporate baobab food products in their diet.

With respect to future research we recommend that:

1. More attention should be given to sampling, sample pretreatment, accuracy, and precision in analyses in order to get more reliable information about biological variation.
2. Nutritional research should focus on digestibility and bioavailability for a better nutritional evaluation of baobab products.
3. Detailed studies should be carried out on the effects of processing and storage on nutrient composition.

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