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Chemical and Nutrient Analysis of Baobab (*Adansonia digitata*) Fruit and Seed Protein Solubility

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Abstract. The baobab seed and pulp were analyzed for proximate composition, mineral content, and amino acid composition. The seed oil and protein were evaluated for their fatty acid profile and protein solubility. The seed was found to be a good source of energy, protein, and fat. Both the kernel and the pulp contain substantial quantities of calcium, potassium, and magnesium. Amino acid analyses revealed high glutamic and aspartic acid contents and the sulfur-containing amino acids as being the most limited amino acid. The fatty acid profile showed that oleic and linoleic were the major unsaturated fatty acids, whereas palmitic was the major saturated acid. Of the several solvents tested to solubilize the seed protein, 0.1 *M* NaOH was found to be the most effective. The protein was more soluble at alkaline than acidic pH, with the lowest solubility at pH 4.0.

Key words: baobab, amino acids, fatty acids, antinutritional factors

Introduction

In view of the increasing demand for protein and energy to support the growing world population, researchers have directed their efforts at exploring new and nonconventional sources of food that grow in the arid and semiarid land regions of the world. Baobab trees (*Adonsonia digitata*) are indigenous to these regions. The trees are tolerant to high temperatures and long spans of drought, and are grown for their sour fruit and leaves. The fruit consists of large seeds embedded in a dry, acidic pulp and shell. The leaves are used to make soup [1], and the pulp is used as a beverage and in food preparation [2]. Fermented seeds are used as flavoring soups, where the roasted seed is used as a side dish substituting peanut [3]. The seeds are pressed for oil, but the by-product baobab oilseed meal is typically underutilized. Most of the previous studies on the baobab fruit have focused on the seed oil. Therefore, the purpose of this study is to determine the chemical composition and the amino acid composition of baobab fruit pulp and seed, and to evaluate the seed oil fatty acid profile and protein solubility.

Materials and Methods

Baobab fruit was obtained from a local source. The pulp was manually separated from the seeds using a knife. The seeds were ground in a hammer mill to pass through a 40 mesh screen, then placed in an airtight plastic jar and stored at −20 °C until use. The oil was extracted using *n*-hexane.

Proximate Analysis

Moisture, crude protein, fat, ash, crude fiber and mineral content of the baobab seed and fruit pulp were determined according to AOAC [4] methods. Total carbohydrate content was estimated by difference. Metabolizable energy values (kcal/100 g) were calculated by multiplying the grams of protein, fat, and carbohydrate by the factors of 4, 9, and 4 kcal/g, respectively.

Amino Acid Analysis

Amino acid compositions of the seed and the pulp were determined following the Spackman et al. method [5]. Duplicate samples were hydrolyzed by transferring about 50 mg of precisely weighed sample into a 15-ml ampoule, adding 5 ml 6.0 *N* HCl, sealing the vial under vacuum, flushed with nitrogen, and digesting at 110 °C for 24 hours. The sulfur-containing amino acids were determined using performic acid. Amino acid analyses were performed by high performance liquid chromatography (Shimadzu, G-C-14A, Kyoto, Japan).

Antinutritional Factors

Trypsin Inhibitor Activity (TIA). Trypsin inhibitor activity was assayed according to Kakade et al. [6] using BAPA *N*-benzoyl-DL-arginine-*P*-nitroanilide hydrochloride and trypsin type III from bovine pancreas. TIA expressed as trypsin inhibitor unit per milligram of sample (TIU/mg sample) was calculated from absorbance read against blank in a spectrophotometer. One trypsin unit is defined as an increase of 0.01 absorbance unit at 410 nm per 10 ml of reaction mix.

Phytic Acid. Phytic acid analysis was performed according to the method of Mohamed et al. [7] using chromophore reagent. Phytic acid (dodecasodium salt) from corn was supplied by Sigma chemical company and used as a standard.

Tannin. The modified vanillin–HCl method of Price et al. [8] was followed with minor modification. One gram of sample was extracted with 10 ml 1% HCl in methanol for 24 hours at room temperature followed by centrifuging at

5000 rpm. Vanillin–HCl reagent was prepared by mixing prior to use, equal volumes of 8% HCl in methanol with 2% vanillin in methanol. One milliliter of supernatant was mixed with 5 ml of vanillin–HCl reagent. The absorbance was read at 500 nm after 20 min of incubation at room temperature.

Fatty Acid Composition and Physicochemical Characteristics of the Oil

Fatty acid composition was determined according to the Metcalf method [9] using gas–liquid chromatography (Shimadzu, HP-5840A, Kyoto, Japan) equipped with a flame ionization detector. Specific gravity (25 °C/25 °C), refractive index (27 °C), iodine, and saponification values were determined according to AOAC methods [4].

Protein Solubility

The kernal protein solubility by various extractants and at different pH was carried out as described by Sathe [10], with minor modification. Protein content in the supernatant was determined using the method of Lowry et al. [11].

Results and Discussion

The proximate compositions of baobab seed and fruit pulp are shown in Table 1. The seed is good source of fat, protein, and crude fiber, whereas the fruit pulp is an excellent source of carbohydrate. The seed contains relatively high amounts of protein (18.4 ± 0.5%), crude fat (12.2 ± 0.2%), and crude fiber (16.3 ± 9.3%), and low carbohydrate (45.1 ± 1.7%). The fruit pulp contains a high amount of carbohydrate (76.2 ± 1.0%), low protein (8.2 ± 0.1%), and extremely low fat (0.3 ± 0.0%). The proximate composition of the fruit pulp was similar to that reported by Nour et al. [12]. The protein content of the seed was higher than that of baobab seed from northeastern Nigeria [13], but lower than that from Burkina Faso [14]. The seed oil content was similar to that of baobab seed oil from Madagascar [15], but lower than that from Nigeria [13]. These differences can be attributed to soil, climate, and strain.

Table 1. Proximate composition of the seed and fruit pulp of baobab

Constituent	Seed (%)	Fruit pulp (%)
Moisture	4.3 ± 0.1	10.4 ± 0.4
Protein	18.4 ± 0.5	3.2 ± 0.1
Fat	12.2 ± 0.1	0.3 ± 0.0
Ash	3.8 ± 0.1	4.5 ± 0.2
Crude fiber	16.2 ± 0.9	5.4 ± 0.3
Carbohydrate (by difference)	45.1 ± 1.7	76.2 ± 1.0
Metabolizable energy, kcal/100 g	363.8 ± 9.7	320.3 ± 4.4

Table 2. Mineral content of baobab seed and fruit pulp

Element	Seed	Fruit pulp
Macroelements (mg/100 g)		
Potassium	910 ± 20	1240 ± 30
Sodium	28.3 ± 2.2	27.9 ± 0.10
Calcium	410 ± 10	295 ± 10
Magnesium	270 ± 30	90 ± 2
Microelements (mg/100 g)		
Iron	6.4 ± 0.2	9.3 ± 0.2
Copper	2.6 ± 0.2	1.6 ± 0.1
Zinc	5.2 ± 0.0	1.8 ± 0.0

The mineral content of baobab seed and fruit pulp is shown in Table 2. The seed and fruit pulp are excellent sources of potassium, calcium, and magnesium, but poor sources of iron, zinc, and copper. The fruit pulp mineral contents are comparable to those reported for baobab fruit from Sudan [12]. The pulp showed an exceptionally high calcium content; similar finding was reported by Prentice et al. [16]. The high calcium contents of the seed and fruit pulp make the baobab fruit attractive as a natural source of calcium supplementation for pregnant and lactating women, as well as for children and the elderly.

Amino acid compositions of the baobab seed and fruit pulp are shown in Table 3. Both the seed and the fruit pulp contained high amounts of glutamic acid, aspartic acid, and arginine, and low amounts of the sulfur-containing amino acids. The seed contains a relatively high amount of essential amino acids. Except for arginine which was higher, the amino acid profile agreed well with that reported for baobab from Burkino Faso [14]. In contrast to other plant seed proteins, baobab seed protein contains a high amount of lysine. Because lysine is limited in most cereal plants, it may be

Table 3. Amino acid composition of the baobab seed and fruit pulp

Amino acid	Seed (gm/100 gm protein)	Fruit pulp (gm/100 gm protein)
Aspartic acid	10.3	6.4
Glutamic acid	23.7	6.5
Serine	6.1	3.2
Histidine	2.2	1.2
Glycine	8.6	2.9
Threonine	3.8	2.8
Arginine	8.0	7.6
Alanine	7.1	3.3
Prolamine	6.9	2.2
Tyrosine	1.5	20.6
Methionine	1.0	0.2
Valine	5.9	4.8
Phenylalanine	4.0	4.4
Isoleucine	3.6	2.2
Leucine	7.0	4.3
Lysine	5.0	1.7
Cysteine	1.5	1.0

Table 4. Trypsin inhibitor activity, and concentrations of phytic acid and tannin in baobab seed and fruit pulp

Compound	Seed	Fruit pulp
Trypsin inhibitor activity (TIU/mg sample)	5.7 ± 0.6	5.8 ± 0.3
Phytic acid (mg/100 g)	73.0 ± 0.9	2.6 ± 0.4
Tannin (% catechin equivalent)	23.0 ± 21.8	0.9 ± 0.0

possible to use baobab seed protein to improve cereal protein quality, especially in arid and semi-arid lands where the population depends heavily on sorghum grain for food.

The baobab fruit, in common with plant fruits, contains naturally occurring antinutritional substances, such as trypsin inhibitor, phytate, and tannin, that can interfere with utilization of the baobab seed and pulp. The trypsin inhibitory activity (TIA), phytic acid (PA), and tannin levels are summarized in Table 4. TIA analyses showed that the seed and the pulp had similar and low level, whereas the seed had a high level, of PA and tannin compared to fruit pulp. The seed trypsin inhibitor level (5.7 TIA mg/sample) was lower than those reported for tepary bean [17], soybean [18], peanut [19], and Lima bean [20]. Trypsin inhibitor has been implied to be one of the factors responsible for growth suppression and pancreatic hypertrophy in the experimental animals. Phytic acid (PA) level of baobab seed and pulp are lower than those of legumes such as black gram, mung bean, and pigeon pea [21]. Tannin content of both seed and pulp were lower than the values reported for winged bean [22], velvet bean [23], chick pea, mung bean, black grain, pigeon pea [24], and sorghum [25]. Proll et al. [26] found baobab seed to have high digestibility, biological value (BV), and net protein utilization (NPU) among unconventional tropical crop seed. This high digestibility, BV, and NPU of baobab seed could be attributed to the low levels of trypsin inhibitor phytic acid and tannin and the excellent amino acid profile.

Table 5. Fatty acid profile of baobab seed oil

Fatty acid	%
Saturated	
C14:0	0.2
C16:0	24.2
C18:0	4.6
C20:0	1.3
C22:0	0.7
C24:0	0.2
Monounsaturated	
C17:1	0.3
C18:1	35.8
2C0:1	0.9
Polyunsaturated	
C18:2	30.7
C18:3	1.0

Table 6. Physiochemical characteristic of baobab seed oil

Specific gravity	0.9 ± 0.0
Refractive index	1.5 ± 0.0
Iodine value	88.0 ± 4.1
Saponification number	210.0 ± 0.09

Baobab seed oil is an excellent source of mono- and polyunsaturated fatty acids (Table 5). 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, which comprises 35.8%, followed by linoleic (30.7%) and palmitic (24.2%). These results were similar to those for African baobab oils [13, 27, 15].

The physicochemical characteristics of baobab seed oil are shown in Table 6. The saponification number of the oil was high, but the iodine value was low, indicating good stability. A similar iodine value has been reported for baobab seed oil from Madagascar [28]. Values for specific gravity and refractive index are within the range found for vegetable oils. The high content of mono- and polyunsaturated fatty acids suggests that baobab seed oil would be useful as a food oil.

The solubility of baobab seed protein in various solvents is shown in Table 7. The highest protein solubility was obtained with 0.1 *M* NaOH, followed by 0.1 *M* Na_2 CO_3 and 0.1 *M* NaCl. By contrast the protein was the least soluble in DDH_2O and 0.1 *M* $NaC_2H_3O_2$ buffer (pH 4). These results were similar to those observed for flour of different seeds, such as cashew nut [10], great Northern bean [29], peanut seed [30], and pistachio nuts [31]. Figure 1 shows the solubility profile of baobab seed protein at different pH values. The seed protein again exhibited the lowest solubility (16.6%) at pH 4, with higher solubilities below pH 4 and above pH 6. Protein solubilities were higher at alkaline pH compared to solubilities at acid pH. The maximum protein solubility of 97.7% was obtained at pH 8. Increasing the pH above 8 did not increase protein solubility. Similar protein solubility pattern has been reported for tepary bean

Table 7. Baobab seed protein solubility in various solvents

Solvent	Protein concentration (mg/100 mg defatted flour)
DDH_2O (Deionized distilled water)	13.5 ± 0.7
0.1 *M* Sodium chloride	34.6 ± 0.6
0.1 *M* Sodium hydroxide	43.3 ± 0.67
0.1 *M* Sodium bicarbonate	19.4 ± 0.6
0.1 *M* Sodium carbonate	38.3 ± 2.2
0.1 *M* Sodium sulphite	25.9 ± 1.1
0.1 *M* Sodium phosphate buffer, pH 7.0	27.6 ± 2.3
0.1 *M* Tris–Hcl, pH 8.0	21.7 ± 0.8
0.1 *M* Sodium acetate buffer, pH 4.5	13.9 ± 0.9

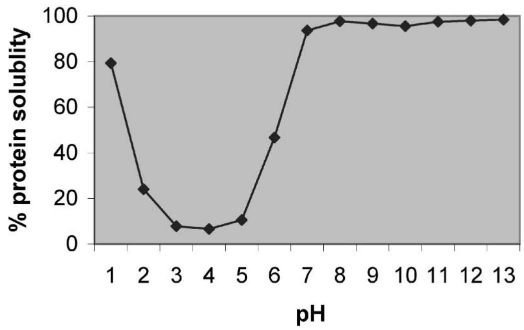

Figure 1. Protein solubilty profile at different pH.

flour [32], Great Northern bean [29], and peas and faba bean [33]. Because lysine is destroyed at high alkaline pH, the occurrence of the optimum solubility of baobab kernel protein at pH 8 indicates that the likelihood of lysine loss is minimal.

In conclusion, the results of this study have shown that the rich energy, protein, and mineral contents of baobab kernel give it potential usefulness as a food protein source in tropical and subtropical regions. As a beverage ingredient, the fruit pulp may also serve as a calcium supplement because of its high calcium content. The high protein solubility at acidic and alkaline pH suggests that the baobab seed protein could be a desirable food ingredient.

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