The Compositional Analysis of *Adansonia digitata* (baobab) and *Tamarindus indica* (tamarind) Fruit Seeds

J. K. Kilungu[1] and C. K. Njoroge[2]

[1]Brookside Dairies, P.O. Box 236 Ruiru; [2]Food Science Technology Department, Jomo Kenyatta University of Agriculture and Technology, P. O. Box 62000, Nairobi, KENYA.

ABSTRACT

Seeds from two indigenous wild trees namely *Adansonia digitata* (baobab) and *Tamarindus indica* (tamarind) were analyzed. From this study, the protein contents were observed to be 24.98% and 17.99 % for baobab and tamarind respectively. These values are fairly high compared to cereals and root crops such as whole maize 9.3% and fresh cassava 1.2% which are the main staples in the regions where baobab and tamarind grow. The oil contents were observed to be 14.50% and 4.32% for baobab and tamarind respectively. The level in baobab is adequate for commercial extraction. The fatty acid profile in baobab oil, revealed 25.26%, 36.25% and 37.57% for palmitic, oleic and linoleic acids respectively. This kind of oil should render itself to long term storage, as its degree of unsaturation is not too high. The seeds were observed to have 4.69% and 1.95% ash in baobab and tamarind respectively with high levels of macro and micronutrients that are of dietary importance like calcium, iron, potassium, zinc and manganese. The study revealed that the seeds from both sources have the potential to be used as food, while baobab seeds have a potential to be used for industrial oil extraction.

1.0 INTRODUCTION

In a survey of fruit trees carried out since 1987, over 200 indigenous plant species with edible fruits were identified (Gilbert 1989). Some of these, especially *Adansonia digitata* (baobab) and *Tamarindus indica* (tamarind), are used as regular items of local diet, in the regions where they grow. Baobab and tamarind are among the species of plants found in the driest regions of tropical Africa. In Kenya baobab and tamarind grow widely along the Coastal regions and Eastern Province (Gilbert 1989; Tim and Ann 1989).

Baobab belongs to the family Bombacaceae, which consists of about fifty genera growing around the world and can be a potential source of human food and oil extraction (Gilbert 1989). It is a source of staple diet for some communities in South, Central and

West African countries, and also in some parts of Coastal and Eastern regions of Kenya. It is more widely used during famine, but in some regions, it forms part of the regular diet. The white powdery pulp found in the fruit is rich in vitamin C (1690 mg/kg) (Sidibe *et al.* 1996). The pulp is edible, though mealy and slightly sour. It can be mixed with milk and then seasoned to make a curdled product. The powdery pulp is incorporated in boiling water as a source of flavour to fermented porridge that the Akamba of Kenya call '*usuu mukaatu*' (Gilbert 1989). It is also used as a food seasoner and appetiser as well as a drink in time of scarcity as pap or gruel (Tyozabura 1976).

The baobab seeds are edible when fresh or dry and can be eaten in cooked or uncooked form. They are acidic and taste like almond and when roasted are used as a coffee substitute. The Akamba of Kenya use the baobab pulp as a fermenting agent in making of traditional beer. The seeds are rich in oil and can be used for oil extraction (Gilbert 1989). In Ghana, the seeds are fermented to prepare a savoury condiment similar to "dawa dawa" prepared from *Parkia* spp. The seeds are also crushed, powdered and fermented to make "kantog" which is used to flavour relishes and soups (FAO 1983). Its leaves, roots and bark have been used for treatment against asthma in Togo and have also been identified to have some anti-microbial properties (Anani *et al.* 2000).

Tamarindus indica belongs to the family Fabaceae. It is an evergreen, unarmed Savannah tree. Like baobab, it has potential for utilization as human food and oil extraction (Tyozabura 1976). Its origin is said to be in Africa. It grows naturally in tropical and sub-tropical regions and is one of the most important plant resources used as food materials (Tsuda *et al.* 1994). Its pulp is used in spices and seasoning and it is accepted as a herb medicine (Anani *et al.* 2000). The flower and leaf are eaten as vegetables. The germ obtained from seeds is used for manufacturing tamarind gum and it has been added to many types of food in Japan to improve their viscosity. It has also been demonstrated that its seed coat has natural antioxidant components with potential for use in the food industry (Tsuda *et al.* 1994). This is particularly important as most artificial antioxidants have been found to be carcinogenic (Hirose *et al.* 1994).

Tamarind fruit is often eaten in pressed form with seeds, or used in drinks, preserves, curries, jellies, syrups and sauces. In Africa the seeds are fermented into "dawa dawa", a seasoning for native dishes. They are also used in chutneys. Seeds alone are eaten after

roasting or used as source of edible oil. Flowers, leaves, young ponds and sprouts are also edible (Tyozabura 1976).

Baobab and tamarind trees survive in dry areas and can also withstand drought, hence could be a valuable income earner for arid regions, which have limited income generating activities (Ngulube and Kananji 1989). The trees grow wild and therefore do not require elaborate agricultural practices, hence the fruits could be produced at very low cost. The seeds when dry and unshelled are non perishable and can be stored for many years under ambient storage conditions, with almost no postharvest losses (Gilbert 1989).

In Kenya the baobab and tamarind fruits are not fully utilized despite their abundance in Coast and Eastern Provinces. Most of them go to waste. This project was therefore carried out in order to determine the composition of these seeds, thus enhancing their utilization. By knowing their nutritive values and the characteristics of their oils, these fruits could assume greater commercial importance. Their utilization as food sources in arid and semi-arid regions could therefore be based on a more sound scientific information.

2.0 METHODOLOGY

Dry baobab and tamarind seeds were collected within Mtito-Andei Division in Makueni District, in the Eastern Province of Kenya, and transported to Food Science and Postharvest Department, Jomo Kenyatta University of Agriculture and Technology, where all the analyses were done. The seeds were sorted for defects and cleaned in cold water to remove the pulp. For the oil extraction the seeds were conditioned in boiling water for 15 minutes and then dried to a moisture content of 15%. The seeds were then ground using laboratory hammer mill (Mitamura Riken Kogyo Inc. Model EFOU-KT, Tokyo) before storage at 5°C.

1. Moisture content determination by dry air oven

The moisture content for the ground seeds was determined by heating 5g of the ground sample in a hot air oven (Mitamura Riken Kogyo Inc. Model DO-COD) at 100-110°C for one hour at first. Cooling in a dessicator was done and after weighing, further

heating was carried out until a constant weight was obtained (AOAC 1980, Method 14.004). The amount of moisture was then calculated using the formula shown below.

$$\text{Moisture (\%)} = \frac{\text{Weight of moisture evaporated} \times 100}{\text{Weight of sample}}$$

2. Crude Protein determination

This was done as described by Kjeldhal method (AOAC 1980, Methods 2.055, 2.056 and 2.057). The sample was digested using boiling concentrated sulphuric acid to oxidize carbon and hydrogen and transform protein nitrogen into ammonium sulphate. Distillation was done using sodium hydroxide (40%), which was added to liberate ammonia as the digest was being heated. The ammonia was absorbed into a known volume of 4% boric acid solution. The liberated ammonia was determined by titration using 0.02N-HCl and the percentage protein in the sample, calculated using the formula shown below.

$$\text{Nitrogen (\%)} = (V_1 - V_2) \times N \times F \times 0.014 \times \frac{100}{V} \times \frac{100}{S}$$

Where V_1= Titre for sample (ml); V_2 = Titre for blank (ml); N = Normality of standard Hcl solution (0.02); S = Weight of sample taken (g); F = Factor of standard Hcl solution; V = Volume of diluted digest taken for distillation (10ml);

Protein (%) = Nitrogen (%) x (Protein factor of 6.25). The protein factor was calculated as described by Pearson (1973).

$$\text{Protein factor} = \frac{\text{Mean of total nitrogenous matter by difference } (P_N)}{\text{Mean of total nitrogen (by Kjeldhal) } (N_K)}$$

(P_N) = 100 – (%water + %fat + %ash + %carbohydrate + %fibre)

3. Crude fibre determination

This was determined as described by AOAC (1980), method 7.061. It involved the digestion of a known weight of sample using 1.25% sulphuric acid, followed by filtering the digest and washing with boiling water until free from acid. Boiling was done again in 1.25% sodium hydroxide, followed by washing with 1% HCl, and then washed in boiling water until free of alkali. Washing was done twice with alcohol and thrice with ether, before drying in an oven at 100°C for 1 hour (h). The sample was then cooled in a dessicator and weighed. Incineration was done in muffle furnace at 500°C for 1 h,

followed by cooling in a dessicator and then weighed. The crude fibre content was then calculated as shown below:

$$\text{Crude fibre \%} = \frac{\text{Weight before incineration - Weight after incineration}}{\text{Weight of sample taken}}$$

4. Crude ash determination

A known weight of sample was heated in a low flame in a crucible to oxidize the carbon matter and then heating done in a muffle furnace at 500°C for 2 h. Cooling was then done in a dessicator before weighing and quantifying the ash using the formula shown below (AOAC 1980, method 31.012).

$$\text{Crude ash (\%)} = \frac{\text{Weight of ash remained x 100}}{\text{Weight of sample}}$$

5. Mineral determination

The ashed samples were analysed for minerals using Atomic Absorption Spectroscopy (Shimadzu, AA-630-R). Appropriate lamps for each specific mineral were used. The levels of minerals were obtained using known standard solutions (AOAC (1980), methods 3.006, 2.11 and 2.112).

6. Carbohydrate determination

It was determined by difference from the other determinations i.e 100 - (%Moisture, %Protein, %Fibre, %Fat and %Ash).

7. Oil Extraction

The ground sample was used for the oil extraction using Soxhlet, and Modified Bligh and Dyer methods as described by Hamilton and Hamilton (1992). The sample sizes were 5 g and 1 g for Soxhlet, and Modified Bligh and Dyer methods respectively. Appropriate analyses as indicated below were then carried out.

a) Fatty acid profile analysis

This was carried out according to Hamilton and Hamilton (1992). The lipid obtained by Modified Bligh and Dyer method was methylated using 5% methanolic-hydrochloric

acid. Two microlitres (2µ) of the methylated sample was injected into the Gas Chromatograph (Shimadzu, GC-9A) and fattv acid profile determined. The operating condition for the Gas Chromatograph were; injection temperature 220°C, column temperature 170°C and a flame ionization detector at 220°C.

The column used was glass type (1m long) packed with diethylene glycosuccinate coated on 5% shimolite solid support.

b) Separation and analysis of lipid classes

This was done using thin layer chromatograph (TLC) as described by Hamilton and Hamilton (1992). For neutral lipids, hexane-ethyl ether-acetic acid (80:20:1V/V) mixture was used for separation by one-dimensional TLC. For polar lipids, chloroform-methanol-water (65:25:4V/V) mixture was used for separation by the same method. 50% aqueous sulphuric acid and iodine vapours were used separately as detection agents for identification of neutral and polar lipids. The lipid sample from Modified Bligh and Dyer extraction method, together with known standards was spotted onto a 10 cm x 20 cm TLC plate and developed either in neutral or polar solvents before viewing the spots in iodine vapour. The developed TLC plates were then sprayed with 50% aqueous sulphuric acid. The TLC plates were then held in an oven at 100°C for 10 minutes. The percentages of the separated lipids were then determined by densitometric method.

The TLC plate was fixed to the scanning stage within the densitometer (Shimadzu CS-9000). During the operation of the densitometer, a light beam in the form of a slit variable in width and length was moved over the charred sample zones to be quantified. The beam was moved in a straight line to sample the background adsorbent at either side of the component zone. This was done at a single wavelength of 350 nm.

The densitometer was linked to a data processing system comprising of Shimadzu, GDU- 10 cm screen, Shimadzu, FDU-3 floppy disk unit and Shimadzu, DR-13 control unit. These recorded the measurements from the scanner, in form of peaks based on the density of each spot. The denser or the more charred the spot was, the more the light absorbed hence the sharper the peak on the screen, indicating high amounts of that particular component.

3.0 RESULTS AND DISCUSSION

Table 1 indicates the composition of baobab and tamarind seeds. Baobab and tamarind seed kernels contained 24.98% and 17.99% protein respectively.

Table 1. The proximate analysis (dry weight basis) of baobab and tamarind seeds

SEED TYPE	CONSTITUENT (%*)					
	Moisture	Crude protein	Crude fibre	Crude fat	Carbohydrates	Crude Ash
Tamarind	15.72 ± 0.04	17.99 ± 0.08	5.35 ± 0.01	4.32 ± 0.20	54.67 ± 0.13	1.95 ± 0.03
Baobab	7.64 ± 0.04	24.98 ± 0.17	24.20 ± 0.14	14.50 ± 0.29	24.01 ± 0.52	4.69 ± 0.08

* Each value is a mean of three replications and standard deviation.

Lockett and Calvert (2000) have reported protein values for baobab and tamarind seeds to be 15.12% and 18.31% respectively. These values are higher compared to sorghum and fox tail millet, which contain 9.50% and 10.50% protein respectively, but lower than that in some leguminous seeds such as soyabean, which contain 34.30% (Tomohiro 1990).

Baobab and tamarind seeds contained 24.20% and 5.35% crude fibre respectively. Lockett and Calvert (2000) have reported fibre content to be 49.72% and 16.73% in baobab and tamarind seeds respectively. Fibre contributes to food bulkiness, thus contributing in low calorie intakes. It also plays an important role in digestion, hence preventing constipation and possibly colon cancer. It is also documented to have an effect on blood cholesterol, although the mechanism involved is not clearly understood. However fibre has been observed to result in lower levels of low-density lipoprotein in the blood, and the latter has been associated with coronary heart disease (Latham 1979).

Crude fat content was 14.50% and 4.32% for baobab and tamarind seeds respectively (Table 1). Lockett and Calvert (2000) reported crude fat values to be 11.56% and 3.03% in baobab and tamarind seeds respectively. Research done in Miombo Woodlands of South Africa, indicated that baobab seeds contained 29.55% crude fat (Saka 1992). The levels are generally lower than the 17.50% reported in soya beans. The level in baobab, though low, could be commercially exploited but that of tamarind is not economical to extract.

Tamarind had 54.67% carbohydrates, while that of baobab was 24.01% (Table 1), compared to reported values of 59.35% and 17.84% for tamarind and baobab seeds respectively (Lockett and Calvert, 2000). The carbohydrate levels in both tamarind and baobab seeds were low compared to most consumed cereals and root crops e.g. maize 73.7%, yam flour 80% (Latham 1979).

Ash content was found to be 4.69% and 1.95% for baobab and tamarind respectively (Table 1), compared to reported ash values of 5.76% and 2.58% for baobab and tamarind seeds respectively (Lockett and Calvert 2000). The ash for soya bean, which is 5.00% (Tomohiro 1990) compares well with that of baobab.

Both baobab and tamarind seeds were found to have appreciable amounts of trace elements namely iron, zinc and manganese. The major minerals in baobab seeds were manganese, calcium, potassium, magnesium and sodium (Table 2). The mineral composition for baobab reported in other studiesis (mg/100g); 115.6 calcium, 209 magnesium, 5.8 iron, 2836 potassium and 18.8 sodium. Tamarind seeds were reported to have; 142 calcium, 201 magnesium, 9.09 iron, 3.12 zinc (Saka and Msonthi 1994).

Table 2. The mineral content of baobab and tamarind seeds

SEED TYPE	MINERALS (MG/100G*)						
	Iron	Calcium	Magnesium	Zinc	Manganese	Sodium	Potassium
Baobab	9.12±0.28	35.30±0.88	434.49±1.28	5.19±0.09	1.76±0.04	21.54±0.2	1371.51±10.29
Tamarind	4.99±0.03	17.43±0.02	223.06±1.78	2.56±0.08	0.93±0.01	8.0±0.09	609.11±4.46

*Each value is a mean of three replications and standard deviation

Lockett and Calvert (2000) reported: 264 calcium, 278 magnesium, 4.35 iron, 4.29 zinc for the baobab seeds and; 17.1 calcium, 128.2 magnesium, 6.8 iron, 1227 potassium and 11.1 sodium for tamarind seeds in Nigeria. Tamarind seeds contained both trace and major minerals in relatively smaller quantities compared to baobab seeds (Table 2). Calcium is a major nutrient required in human diet particularly to lactating mothers and children (Latham 1979). Calcium levels in tamarind and baobab were (mg/100g); 35.30 and 17.43 compared to maize cassava and human milk which have; 12.0, 68.0 and 30.0 respectively. Iron levels were also high in both tamarind and baobab seeds compared to maize, cassava

and even human milk, which have (mg/100g); 3.8, 1.9 and 0.2 respectively (Latham 1979). Iron deficiency is a leading cause of ill health in many parts of the world, including much of Africa. Iron in blood is linked to hemoglobin, which carries oxygen from lungs to the rest of the body parts and carbon dioxide from the body parts to the lungs. Iron deficiency in the body is known to cause anaemia, a problem that is more serious with women than men. Baobab and tamarind seeds could come in handy in alleviating diseases associated with deficiency of iron.

The level of zinc was 5.19 mg and 2.56 mg for baobab and tamarind seeds respectively. Other studies report 4.29 and 3.12 for baobab and tamarind respectively (Lockett and Calvert 2000). The levels of potassium were 1371 and 609 for baobab and tamarind respectively. The levels of manganese, another micro-nutrient, were 1.79 and 0.93 for baobab and tamarind seeds respectively. Lockett and Calvert (2000) reported manganese values of 1.01 and 0.70 for baobab and tamarind seeds respectively. These microelements are important in the human diet. Zinc deficiency may contribute to a rare form of dwarfing found in the Near East. Zinc is also essential for pregnant women, as it is necessary for fetal development (Keen and Zindenberg-Cherr 1994). Potassium plays a physiological role in maintaining osmotic pressure in the body. Others may act as co-factors in enzymic systems (Latham 1979). In dry tropical regions, cereals and roots crops are the major food sources. Most of them tend to be poor sources of these minerals. Tamarind and baobab seeds could therefore be vital complement to root crops and cereal-based foods.

Both from proximate composition and mineral analysis of the seeds, it is evident that some of the values in our studies agree with those reported in literature, while others do not. It should also be evident that the values are different in the various studies reported. These discrepancies are not unusual, as they have been reported elsewhere. They have been attributed to genera, soils and climatic differences in various regions (Saka and Msonthi, 1994). To exemplify this, Saka and Msonthi (1994) in Malawi, reported the proximate composition of baobab fruit as 5.0% ash, 3.1% protein, 4.3% fat, 8.3% fibre and 79.4% carbohydrate. Lockett and Calvert (2000) in Nigeria, reported the same as, 5.71% ash, 2.19% protein, 0.37% fat, 11.15% fibre and 70.03% carbohydrates.

The results reported in this study indicate that the fatty acid profile in baobab oil is different from those of soyabean, sunflower and corn oils. Baobab oil is rich in palmitic acid (25.26%), while soyabean, sunflower and corn oils have 11.0%, 8.0%, and 13.0% of the same acid respectively. However, baobab oil has less linolenic acid (0.38%) compared to soyabean oil (8.0%), while the others are lacking in this acid. Linoleic acid in baobab oil was 37.57 compared to 51%, 65% and 54% in soyabean, sunflower and corn oils respectively (Ory 1979). Linoleic acid is an essential fatty acid and is supposed to be high in oils used for culinary purposes (Sridha and Lakshiminarayana 1993). The oil from baobab seed also contains little amounts of arachidic acid, which is a polyunsaturated fatty acid and which appears to be lacking in soyabean, sunflower and corn oils. Oils in peanut and macadamia nuts have 2.70% and 1.70% arachidic acid respectively, while olive oil has up to 0.10% (Tomohiro 1990). Generally, the major fatty acids in baobab oil are palmitic, oleic and linoleic (Table 3).

Table 3. Fatty acid profile expressed as a percentage of total fatty acids for baobab seeds

Type of fatty acid	Palmitic	Palmitoleic	Oleic	Linoleic	Linolenic	Arachidic	Unidentified
Percentage	25.26± 3.37	0.14± 0.03	36.26±3.36	37.57±2.09	0.38 ±0.02	0.61± 0.01	0.41± 0.02

*Each value is a mean of three replications and standard deviation

Among the derived lipids, baobab oil was found to contain 12.74%, 1.61% and 3.17% while tamarind oil contained 16.63%, 0.78% and 0.88% sterols, free alcohols and free fatty acids respectively (Table 4).

Table 4. The identification of neutral lipids (% of total lipids) in baobab and tamarind seeds

Seed type	Type of lipid (%*)									
	Waxes	Triglycerides	Free fatty acids	Free alcohols	Glycerides	Diglycerides	Monoglycerides	Free sterols	Unidentified	Origin (polar)
Baobab	7.93± 0.25	14.64± 0.06	3.17± 0.09	1.161± 0.09		5.16± 0.40	1.25± 0.10	12.74± 0.43	7.64 ±0.12	45.85± 0.60
Tamarind	5.23± 0.11	11.20± 0.19	0.88 0.07	0.78± 0.04	2.40± 0.35			16.63± 0.42	9.72± 0.35	53.15± 0.22

*Each value is a mean of three replications and standard deviation

Crude palm oil could have as high as 5.00% free fatty acid hence the values obtained are acceptable for crude oils (Hoffman 1989). The level of free fatty acids is directly

proportional to refining costs and inversely proportional to yield of refined oils. Upon refining, oil should contain mainly triglycerides, which are the principal constituents of edible refined fat or oil. Free fatty acids are acceptable at a level of 0.1% in refined oil.

Baobab oil was observed to have 5.16% and 1.25% diglycerides and monoglycerides respectively (Table 4). Presence of these glycerides could be as a result of hydrolysis of triglycerides during the storage of seeds. They are also intermediates in the synthesis of triglycerides. During seed development, glycerides are transformed from monoglycerides to diglycerides and finally to triglycerides. For the tamarind oil, presence of glycerides (2.40%) was reflected but due to poor separation on the TLC plate, it was difficult to distinguish between mono and diglycerides (Table 4). Monoglycerides play a major role in food industries as emulsifiers.

The polar lipids in baobab and tamarind oils are shown in Table 5. They include the phospholipids the total quantity of which was 21.5% and 24.33% of the total polar lipids for baobab and tamarind seeds respectively.

Table 5. The identification of polar lipids (% of total polar lipids) in baobab and tamarind seeds

Seed type	Type of ripid (%*)							
	Neutral	Sterylglucoside	Acelatedsterylglucoside	Phosphotidylethanolamine	Digalactosyldiacylglycerol	Phosphotidylcholine	Phosphotidylinositol	Unidentified
Baobab	43.64 ± 0.38	2.24 ± 0.36	0.77 ± 0.17	0.83 ± 0.39	1.31 ± 0.33	16.65 ± 0.02	3.92 ± 0.03	30.73 ± 0.34
Tamarind	35.65 ± 1.25	15.18 ± 3.34	1.41 ± 0.35	2.21 ± 0.58	0.98 ± 0.20	5.25 ± 0.88	16.87 ± 2.91	23.05 ± 1.97

*Each value is a mean of three replications and standard deviation

The reported levels of total phospholipids was 13.79% in tamarind leaves. The observed difference could in addition to the reasons given earlier (Saka and Msonthi 1994), be due to different levels of accumulation of different classes of lipids in both leaves and seeds (Sridhar and Lakshiminarayana 1993).

Among the phospholipids were; phosphotidylcholine, phosphotidylinositol and phosphatidylethanolamine. Phosphotidylcholine and phosphotidylinositol were the highest in baobab and tamarind oils respectively. Phosphotidylcholine, commonly known as lecithin, is an important emulsifying agent in food industries and, therefore, baobab oil could be a good source of it.

The other polar lipids were the neutral lipids (43.64% and 35.65%, in baobab and tamarind respectively) and glycolipids (4.62% and 17.57% in tamarind respectively). The values reported in literature are 80.17 and 6.03 neutral and glycolipids respectively, in tamarind leaves. The differences between our values and those reported in literature is due to the reasons given earlier.

During oil refining, the aim is to remove all the polar and other lipids and only leave triglycerides. Presence of waxes, sterols and polar lipids in cooking oil, results in formation of cloudy string-like components in the oil making it completely unappealing. Oils with relatively high amounts of waxes such as sunflower seed, maize and rice bran oils, need dewaxing during refining in order to remove it (Hoffman 1989). Dewaxing could therefore be applied to baobab oil which has 7.93% waxes for the same purpose. Presence of polar and some components of the neutral lipids, is an indication of an inefficient refining process.

4.0 CONCLUSION

From this study, it was found that both baobab and tamarind seeds are fairly rich nutritionally, with the former being superior as it has higher amounts of the determined constituents. They have appreciable levels of micro-elements, which are found in low quantities in other cultivated fruits and vegetables.

Due to their relatively high oil content, baobab seeds have a potential for commercial oil extraction. However, for this to be realized, a system of removing the hard kernels and recovering oil efficiently from the fibrous material has to be worked out.

The oil obtained from tamarind seeds was too low for commercial exploitation. It can therefore, be concluded that, both baobab and tamarind seeds are potential sources of foods especially in the dry tropical regions but only baobab has a potential for commercial oil extraction. However, for full utilization, further research should be undertaken to determine better methods for preparation and processing at both domestic and industrial levels.

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