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REVIEW

A review of baobab (*Adansonia digitata*) fruit processing as a catalyst for enhancing wealth and food security

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Abstract

Scientific study on non-timber forest products with potential for use by humans has recently experienced a resurgence. Baobab is one of these non-timber forest products, and every part of the baobab has been shown by studies to be useful. Because the fruit products of the baobab tree contain enormous amounts of phytochemicals, these products have found uses in food, cosmetics, and pharmaceuticals. Hence, this study examined, among other things, the role of the physical and mechanical properties of the baobab seeds in relation to design of equipment for processing as well as the phytochemicals found in the fruit products. It also discussed the traditional and orthodox uses of the baobab product. Along with vitamins and amino-acids found in the pulp, other minerals were also reviewed. High quantities of proteins, lipids, essential amino acids, and fatty acids, including linoleic, oleic, and palmitic acids, as well as Omega 3, 6, and 9, are present in baobab seeds and the seed oil. Antinutrients present in baobab seeds have the potential to be harmful to human health when consumed. The study examined different processing techniques used to lessen these antinutrients present in the seeds. To fully realize the potential of baobab fruit products, areas for further research have been highlighted in this review.

Keywords: Phytochemicals, Processing, Antinutrients, Physical Property, Proximate

Introduction

One of the most serious challenges of our time is food and nutritional security, which affect communities all over the world. The world population is expected to increase from 7.8 billion in 2020 to 10 billion in 2050, during which food production needs to be doubled to ensure food security (FAO, 2017a). Africa is particularly susceptible continent of food insecurity. The enormity of the challenge has prompted responses from a wide range of organizations, including universities, research institutions, and the private sectors, all of which are researching commercial non-timber forest products (NTFPs) to supplement well-known food products in mainstream nutrition. According to an FAO report from 2014, over 805 million people worldwide are undernourished, with 162 million children under the age of five suffering from stunting, primarily in poor rural families (UNICEF, 2014). In furtherance to this, 15 of the 21 high-burden countries with child stunting rates of 40 % are in Sub-Saharan Africa. This dreadful state is also accompanied by a rapid loss of biodiversity (Chappell and La Valle, 2011). According to the FAO (2017b) data, the number of undernourished people increased from 777 million to 815 million between 2015 and 2016, reflecting a 10.6-11 percent increase. Sub-Saharan Africa, Southeast, and Western Asia's accounted for the majority of this figure. Unfavourable meteorological conditions are exacerbating the food crisis, resulting in low harvests and livestock losses.

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In Africa, the Sustainable Development Goal 2 (SDG 2) of eradicating hunger and halving poverty by 2025 remains in limbo. This is owing to the continent's current state of starvation and malnutrition. High post-harvest losses and food waste (PHLAW) across the Continent identified by the African Postharvest Conference in 2021 as contributing factors to the continent's incapacity to achieve, ending hunger and food security by 2025. Some NTFPs have been found to provide vital services to rural communities by supplying energy and nutrients such as vitamins, minerals, and proteins, particularly during times of famine and food scarcity. These NTFPs can improve nutrition, increase food security, promote rural development, and assist sustainable landscape management (Gebauer *et al.* 2007). Shea tree (*Vitellaria paradoxa*), African locust bean (*Parkia biglobosa*) commonly known as "*dawadawa*," kapok (*Ceiba pentandra*), baobab (*Adansonia digitata*), and other NTFPs found in Ghana and the sub-region of Africa provide alternative food, cosmetics, and nutraceutical products. In recent years, there has been a resurgence in scientific research into this wild plants of which baobab (*Adansonia digitata*) has been identified as a potential for human use in the cosmetics, pharmaceutical, and the nutrition industries, where chemists and product developers are always on the lookout for new and healthy plant components for product formulation. The baobab tree found across Ghana's ecological zones is densely populated in the savannahs and the semi-deciduous forest (Volta region area) agro-ecological zones. In the Africa continent sub-regions, there is a wealth of information and data on proximate compositions of baobab fruit products. However, there is paucity of data on processing and engineering properties of baobab fruit products found in Ghana as well as in the sub-region of Africa where the product is found.

The goal of this study is to offer a review of the role of non-timber forest products as a complement to food security is the first section of the review, and it is preceded by section two, which delves into the traditional and orthodox usage of baobab products. The third section looks at physical and mechanical properties of baobab seeds in relation to the design of equipment for handling and processing, as well as their proximate composition. The fourth part examines processing to reduce antinutrients found in baobab fruit products. The fifth section examines the anti-nutritional factors, phytochemicals, minerals, and fatty acid components of baobab seed products. Section six of the review looks at additional issues and gaps for further research as the concluding remarks.

In order to do this, scientific publications that had been published on the subject were searched for using search engines and databases like Google Scholar, Scopus, and others. The papers were assessed, and the most pertinent ones were selected, reviewed, and summarized. Researchers like Sabina *et al.* (2020), Abubakar *et al.* (2016), and Asogwa *et al.* (2021), among others, have reviewed baobab fruit products. To improve the potential of baobab fruit products, further study is needed in the areas that have been highlighted in this review.

The role of non-timber forest products and food security

The promotion of edible wild foods has a lot of potential for augmenting agriculture-based food supplies. This also means, there is a possibility of exploring and utilizing the wide range of plant flavours, textures, and aromas in wild edible food. Only about 50 fruit tree species have been extensively domesticated and are commercially grown worldwide (Leakey and Tomich, 1999). Africa has the wildest edible fruit species (1200) compared to tropical America and Asia (Gebauer *et al.,* 2016). The diversity of wild edible fruits in Africa implies significant horticultural potential and important genetic resources that, once domesticated, might be used to integrate new commercially useful species and cultivars into existing farming systems. Wild indigenous fruit trees (IFTs), also known as non-timber forest products (NTFPs), are widely employed in Sub-Saharan Africa for a variety of uses, including both subsistence and commercial goals (Leakey, 2012).

NTFPs provide a source of income for a large portion of the African population (Timko *et al.,* 2010). It is impossible to overstate the importance of mobilizing and commercializing these products (NTFPs) within the sub-region, and specifically in Ghana, to complement notable food staples. For many people, NTFPs remain a key source of household food security, nutrition, and health. NTFPs encompasses food (edible nuts, mushrooms, fruits, herbs, and aromatic plants), fibers (used in construction, furniture, and clothing), resins, gums, plant and animal products used for medicinal, cosmetic, or cultural purposes for human use (Agbogidi, 2010). These NTFPs are a key component of household nutrition and health in Africa, and they are an integral aspect of the livelihood strategy of rural communities in the tropics (WHO, 2010).

The extensive exploration of baobab fruit products in Africa began in 2008, when the European Union (EU) approved Phyto-Trade Africa's request to accept the product into its market under EC regulation No. 258/97 (Jackson, 2015), and the Food and Drug Administration (FDA) approval of the product as a food ingredient in the United States of America (Sabina *et al.,* 2020). The baobab tree, fruits, seeds with pulp, and seeds are depicted in Figures 1 to 5.

Figure 1 A baobab tree

Figure 2 Fruits of baobab

Figure 3 Baobab seeds with pulp

Figure 4 Pulp from baobab

Figure 5 Baobab seeds

The traditional and orthodox utilization of baobab products

The baobab (*Adansonia digitata*) tree has a long history of multiple traditional applications throughout Africa and other parts of the world, providing food as well as non-food items such as clothes, fodder, fuel, shelter, and medication. Every part of the baobab tree (roots, seeds, pulp, flowers, leaves, and bark) is useful to humans (Gebauer *et al.,* 2002).

The exposed roots near the soil's surface are cut up and utilized as fuel (Lisao *et al.,* 2017). The roots, as well as the green bark, are utilized as a source of soluble red dye for decoration (Donatien *et al.,* 2011). The inner bark, which is a good source of strong fibre, is used to make ropes (Sidibe and Williams, 2002). Methanolic preparations of the roots, bark, and leaves have been shown to have potent antiviral and antibacterial effects. The alkaloid discovered in the bark is thought to have anti-malaria and anti-fever properties (Namratha and Sahithi, 2015). The bark is used to cure fevers as a quinine alternative in Ghana, and it's also a good source of catalyst for the brewing industries "pito," a local drink (GNA, 2020). Though the baobab roots and bark have enormous potential for use in nutrition, medicine, and other aspects of human life, their commercialization is restricted when compared to the baobab's other parts (leaves pulp, seeds). Since the roots and bark serve as the plant's primary anchor and nourishment conduit.

The fruit pulp is added to other foods to boost the mineral intake of humans, and the seeds are sometimes used as a coffee replacement (Lisao *et al.,* 2017). In African traditional medicine, baobab fruit pulp is used to cure fever, diarrhoea, dysentery, smallpox, measles, haemoptysis (blood in the cough), and pain relief (Lisao *et al.,* 2017). Oil extracted from seeds is used for treating inflamed gums and to ease diseased teeth (Sidibe and Williams, 2002). The shells are fed to goats and cattle as a supplement to their diets. The potash-rich vegetable salts are commonly extracted from the fruit pods and utilized as ingredient for soap making (Asogwa *et al.,* 2021). African baobab seeds can be ground into a powder and used as a thickening ingredient in soups, they can also be fermented and used as a flavouring agent or roasted and consumed as a snack (Sidibe and Williams, 2002).

The leaves have been used to treat fever, kidney and bladder problems, asthma, and diarrhoea (Sidibe and Williams, 2002). De Caluwé *et al.* (2010) recommend using the leaves and fruit pulp as a febrifuge and immunological stimulant. Leaves can also be dried, crushed, and used as sauces in porridge and thickening gruels of grains and cereals. The popular soup 'Miyan kuka' is made from dried baobab leaves and is popular in Northern Nigeria and parts of West Africa (Ogbaga *et al.,* 2017).

Processing of Baobab Fruit Products

The role of physical and mechanical properties in the processing and handling of baobab seeds

Among the engineering properties of biological materials, physical and mechanical properties are essential quantities to consider when selecting and developing equipment for handling and processing. These fundamental data on agricultural biological materials' physical and mechanical properties are useful not just to engineers, but also to individuals who may be able to harness these features and develop new uses for the plant material (Mohsenin, 1986). The study of diverse engineering properties of food crops, particularly those properties that influence the design of equipment for planting, harvesting, handling, storage, and processing, has dominated research in recent years. Because research has demonstrated that conclusions derived from a specific set of data for a biological material cannot be extrapolated to the same biological material from multiple ecological zones (Müller *et al.,* 2015), these features are critical during processing. Due to seasonal fluctuations and environmental conditions, biological materials in general can show considerable compositional variations, inhomogeneities, and anisotropic structures. Physical and mechanical properties of biological materials are important in a variety of issues associated with the design of a specific machine or the explanation of a product's behaviour during processing (Onwe *et al.,* 2020). To overcome these issues, you will need to know about the biological material's physical and mechanical features in context. Geometric and arithmetic mean diameters, for example, important dependent properties when screening solids to remove foreign contaminants and developing grading equipment (Jan *et al.,* 2019). Furthermore, the size, shape, and moisture content of the biological material all influence the power required for size reduction (Sahin and Sumnu, 2006). Angle of repose is a feature that is used to calculate loads in storage bins, grain hopper size, and silo flow patterns (Kibar *et al.,* 2014). Particle and bulk densities are useful characteristics for separating foreign objects from seeds (Alonge and Udofot, 2012).

In the oil extraction or expression process, the mechanical strength of crop seed is critical. Most agricultural products are viscoelastic in nature (Mohsenin, 1986), which means they react differentially to tensile and compressive stresses, as well as when they are vibrated (Tanko *et al.,* 2019). Agricultural materials and food products, in general, deform in response to applied forces, and the amount of force necessary to create a particular quantity of deformation varies greatly between materials (Nyorere and Uguru, 2018). The dependence between compressive force and deformation of a given oil-bearing crop can also be used to estimate the energy which is characterized by the area under the force-deformation curve. Saiedirad *et al*. (2008) discovered that the power and energy required to rupture cumin seeds increased with seed size and moisture content. The study also claims that the force required for vertical seed orientation rupture is less than that required for horizontal loading. The selection and designing of equipment to handle and process baobab seeds for optimum quality gain, it is fundamental to have data on the seeds' engineering properties so as not to compromise quality and safety of the final product. For a fair approach to the design of agricultural machinery and facilities, it is necessary to understand the behaviour of these engineering properties of the material. Apart from physical properties, engineers working with agricultural products must be familiar with mechanical attributes (properties that have to do with the behaviour of agricultural products under applied forces) such as stress, strain, hardness, and compressive strength in order to better incorporate such properties in the design of equipment for handling and processing.

Proximate compositions of baobab fruit products

Proximate analysis is a useful tool for determining and categorizing the nutritional content of dietary components. It determines the macronutrient values in food samples. These values are normally established as nutritional data on the labels of finished food products, but they can also be determined during the manufacturing process. The nutritional contents of baobab plant parts from various ecological zones where this plant is found are documented in the literature. Nutritional differences have been found to exist even within the same country, according to studies.

Aluko *et al.* (2016) discovered a significant difference in proximate composition in fructose content between baobab pulp samples from three different Tanzanian locals. Parkouda *et al.* (2015) also found substantial difference in nutrient from three different nations in the West African Sahel. According to Chadare *et al.* (2008), these discrepancies could be caused by a variety of factors, including soil structure and chemical composition, possible genetic factors, treatment prior to analysis, storage conditions, processing methods used, sample quality, and sample provenance. Even though different writers have documented different nutritional contents on baobab plant parts, baobab plant parts still have a large potential in the medicinal, food, and cosmetic industries around the world (Rahul *et al.,* 2015). The proximate composition of baobab pulp and seed by different authors are shown in Table 1.

Processing of baobab fruit and its effects on the nutritional and anti-nutritional properties

From raw materials to finished or ready-to-eat foods, a variety of processing methods are utilized during the handling of food. The shelf life, safety, sensory, physical, and chemical qualities of foods are all influenced by processing techniques used. Some of the effects of food processing are desirable, such as prolonged shelf life due to microbial inactivation, higher digestibility, and improved texture, flavour, and edibility. Processing, on the other

Table 1 Proximate composition of baobab pulp and seed from selected authors

Nutrient/ Plant parts	Moisture content (%)	Protein (%)	Carb (%)	Ash (%)	Fat (%)	Fibre (%)	Energy kJ (kcal)/100g	Author(s)
Pulp	10.40	3.20	76.20	4.50	0.30	5.4	320.3	Osman (2004)
Pulp	10.20 ±0.30	2.16 ± 0.03	73.87 ±0.00	7.67 ±0.29	0.40 ±0.00	5.7± 0.3	307.6± 0.0	Adebisi *et al.* (2012)
Pulp	19.90 ±0.01	15.3 ± 0.3	58.80 ±0.1	1.90 ±0.1	4.1 ±0.2	NA	NA	Obizoba and Amaechi (1993)
Pulp	NA	2.04 - 3.24	78.30 - 78.90	5.5 - 6.60	0.4 - 0.70	45.8-53.90	NA	Africa (2009)
Seed	7.90 ±0.10	90.9 ±0.1	0.30 ±0.1	0.2 ±0.1	6.2 ±0.1	0.26 ±0.05	NA	Adenekan et *et al.* (2017)
Seed	4.41 ±0.25	29.79 ±0.03	25.91 ±0.54	7.29 ±0.08	20.45 ±0.05	12.15±0.05	NA	Abubakar *et al.,* (2016)
Seed	5.40	14.26	42.32	7.25	31.40	7.87	NA	Edogbanya *et al.* (2016)
Seed	NA	16.60	60.4	5.5	17.50	14.94	1883.0	Ezeagu, (2005)
Seed	4.30	18.00	45.1	3.8	12.20	16.2	363.8	Osman (2004)

hand, can induce unfavourable changes in food's physicochemical, sensory, and nutritional properties (Abong' *et al.,* 2021). The baobab fruit has been transformed from a cheap commodity to a high-value speciality food as a result of being packed well (Darr *et al*., 2020). Anti-nutrients such as tannins, phytic acid, amylase inhibitors, and trypsin inhibitors hinder the acceptability and optimal usage of baobab products. It is well recognized that some processing procedures can deplete a food's nutritional value (Anaemene and Fadupin, 2022).

However, processing, on the other hand, may improve food nutritional quality by lowering or eliminating anti-nutrients (Donatien *et al.,* 2011). Fermentation, boiling, germination, and roasting, according to Kumar *et al.* (2010), have helped to transform food ingredients into healthier food items with higher nutritional content, ensuring nutrient security for the population in poor nations. Thermal processing of food enhances the nutritional value of food items while also deactivating or eliminating microorganisms in food that cause poisons when eaten. Fermentation reduced the protein level of the baobab seeds (Addy *et al.,* 1995; Nnam and Obiakor, 2003) when compared to unfermented seeds. They also predicted that the fermented seeds would have less carbohydrate and more fat. In furtherance, the study claim that the amylolytic enzymes, which hydrolyze starch and oligosaccharides to simpler free soluble sugars during fermentation, are responsible for the drop in carbohydrate (Nnam and Obiakor, 2003). The tannin content of baobab seeds was reduced as a result of dehulling, cold-water, hot-water, hot-alkali, and acid treatments (Addy *et al.,* 1995; Igboeli *et al.,* 1997). Ilori *et al.* (2015) found a substantial difference in potassium concentration in the dehulled baobab seed compared to the whole baobab seed. Further, anti-nutritional content testing was found that the intact seed (0.485±0.012) has more tannin than the dehulled seed (0.175±0.0008). This backs up Donatien *et al.* (2011), that processing has an influence on the seeds' anti-nutritional content. Ogbaga *et al.* (2017) found significant changes in the nutrient variables in a study on phytochemicals, elemental, and proximate analysis of leaves of the baobab plant at varied drying conditions. They recommend that more study be done on the effects of storage duration and processing methods on the nutrient variables in order to increase value addition of baobab fruit products in underdeveloped nations. Cooking is considered to improve the nutritional and functional qualities of plant seeds when used as a processing technique (Yagoub and Abdalla, 2007).

To improve the quality and safety of processed food, Rahul *et al.* (2015) recommend using suitable processing methods, storage, and handling along the food value chain. While processing enhances the organoleptic qualities of food, it can also deplete some critical nutrients. Boiling caused a larger loss of glucose and fructose than sucrose due to the loss of carbohydrates and micronutrients into the processing water (Dandago, 2009). The effect of processing methods (sun-drying, roasting, and fermentation) on the chemical composition of baobab pulp and seed revealed some significant differences in the proximate composition of the pulp and seed, particularly for protein, which was higher during the six day fermentation than during cooking and sun-drying (Obizoba and Amaechi, 1993). Msalilwa *et al.* (2020) observed an increase in the fatty acid compositions of baobab seed oil with increasing temperature, however that cyclopropenoid fatty acids (CPFA) compositions decreased with time at a temperature of 250 °C. The free amino acid (FAA) content of fermented baobab seed was found to be greater than that of unfermented baobab seed when analysed from a locally produced food (*Maari*) found in the various West African countries (Parkouda *et al.,* 2015).

With these processing methods (alkali, acid, and fermentation), the extractable oil yield of baobab seed was found to be high (Addy *et al.,* 1995). Although numerous processing methods have been used to analyse their effect on the chemical compositions of baobab seeds, the extent to which these processing methods affect the yield and quality of baobab seed oil is still unknown. In order to achieve not only the desired objectives of a food processing method, but also to preserve the activity and quality of natural health-promoting constituents or bioactive compounds, optimal processing methods should be chosen.

Anti-nutritional factors, phytochemicals, minerals, and fatty acid components of baobab seed products

The anti-nutritional factors of baobab seeds

Anti-nutritional factors such as trypsin inhibitors, protease inhibitors, tannins, phytic acid, oxalate, alkaloids, phytate, and amylase inhibitors hinder the acceptability and maximum usage of baobab seed as a protein source in human and livestock (Osman, 2004). The species of *Adansonia* contain cyclopropene and cyclopropane fatty acids. Whereas cyclopropane fatty acids appear to have no adverse effect on normal fatty acid metabolism, cyclopropene fatty acids or sterculic acid can have adverse effects (Sidibe and Williams, 2002). Osman (2004) observed 5.7 TIU/mg Trypsin Inhibitor Activity (TIA), 73 mg/100 g phytic acid, and 23 % catechin, equal to tannin in baobab seeds. The phytic acid content of African baobab is around 13 mg/100 g, and the catechin content is about 23.5 mg/100 g (Osman, 2004). Saulawa *et al.* (2014) discovered trypsin inhibitors, tannins, cyanogenic glycosides, oxalate, phytic acid, and alkaloids in the seeds of baobab.

Studies have shown that the anti-nutritional properties in baobab seed protein limit its use as a dietary element in human and animal diets. Nonetheless, research (Saulawa *et al.,* 2014) has demonstrated that the anti-nutrients found in baobab seed can be reduced by using different processing factors and methods, which eventually will result in increased bioavailability of critical nutrients in food and feed. When the antinutrients content of the seed is lowered, the seed's nutrient accessibility will improve, and the acceptability, usage, and economic value of baobab products will increase as the products obtained from baobab are determined to be safe for ingesting.

Phytochemicals and minerals of baobab products

Studies have shown that baobab seed and pulp contain a significant number of phytochemicals which can provide the body with the daily recommended intake (DRI) of most macro (sodium, potassium, calcium, magnesium, and phosphorus) and micro (iron, copper, zinc, and manganese) minerals (Sabina *et al*., 2020). Buhari *et al.* (2014) discovered that an ethanol extract of baobab seeds contains wide range of phytochemicals, including glycosides, alkaloids, flavonoids, terpenes, carbohydrates, phytosterols, and antioxidant and cytotoxic effects. They assert the chemical identified in baobab seed could be a breakthrough in cancer treatment. The antioxidant capabilities of the baobab seed are obvious in its medicinal, nutraceutical, and cosmeceutical applications (Asogwa *et al*., 2021).

Baobab pulp contains significant levels of vitamins, minerals, micronutrients, and antioxidants, as well as ascorbic acid, calcium, tartaric acid, and potassium bitartrate (Afolabi and Popoola, 2005). Lockett *et al*. (2000) found large amount of carbs (70 %) and crude fiber (11.2 %), as well as a low amount of ash (5.7 %), protein (2.2 %), and very little fat (0.4 %) in fruit pulp. The fruit pulp contains several amino acids, including alanine, arginine, glycine, lysine, methionine, proline, serine, and valine (Glew *et al.,* 1997); vitamins (B1, B2, B3, A, C) (UNCTAD, 2005); and minerals (Cu, Fe, K, Mg, Mn, Na, P, Zn) (Glew *et al.,* 1997). The dominance of phytochemicals make it utile as a dietary supplement, particularly in the rural areas, as well as for the creation of commercial products. African baobab pulp's high iron (Fe), potassium (k), and critical blood-clotting ingredients can help the circulatory system, while its high fiber content helps the digestive system (Namratha and Sahithi, 2015). The mineral compositions of baobab seed and pulp from various countries are shown in Tables 2 and 3.

Althwab *et al.* (2019) discovered that African baobab fruit pulp protects rats from oxidative stress caused by a high-fat diet. Interestingly, they concluded that African baobab fruit pulp can be used as a functional food for the natural treatment and prevention of hyperlipidemia-related health abnormalities by increasing antioxidant enzyme activity. According to Afolabi and Popoola (2005), baobab fruit pulp can be used as a preservative in meals by reducing the oxidation of lipids. The fruit pulp tends to reduce high body temperatures while having no effect on regular body temperatures (Ramadan *et al.,* 1994). They further claim that the presence of sterols, saponins, and triterpenes in the pulp gives it analgesic properties.

The baobab seed oil fatty-acid components and utilisation

Due to the significant intrinsic antioxidants and phyto-

Table 2 Mineral compositions of baobab seed selected from different countries

Country	Na	K	Ca	Fe	Cu	Zn	Mg	Mn	Cd	Pb	P	Author(s)
Nigeria (mg/100g)	228	1429	212	11.13	2.55	8.41	353	2.1			924.5	Ezeagu (2005)
Nigeria (mg/g)			0.013	0.004	0.033	0.003	0.195	0.001	0.00	0.00		Abubakar *et al.* (2016)
India (µg/g)	19.6		3950	19.30		25.7	3520	10.6			6140	Rahul *et al*. (2015)
Nigeria (mg)		0.6	0.05	0.63	0.02	1.29					326.33	Nnam and Obiakor (2003)
Ghana (mg/100g)	320	990	398	13.2		23	5287	66	92	441	15.1	Affo and Akande, (2011)

Note: Sodium (Na); Potassium (K); Calcium (Ca); Iron (Fe); Copper (Cu); Zinc (Zn); Magnesium (Mg); Manganese (Mn); Cadmium (Cd); Lead (Pb); Phosphorus (P)

Table 3 Mineral compositions of baobab pulp selected from different countries

Country	**Na**	**K**	**Ca**	**Fe**	**Cu**	**Zn**	**Mg**	**Mn**	**Cd**	**Pb**	**P**	**Author(s)**
Nigeria Conc (ppm)			3.2	0.77	1.05	0.39	46.27	0.08	0.07	0.05		Fatokun and Akanji, (2012)
South Africa (mg/100g)	7.0-31.1	2010.0 - 2390.0	257.0 - 370.0	3.95 - 9.13	0.53 - 0.75	0.70 - 1.02	126.0-179.0	0.65 - 1.30			56.10 - 73.30	Africa, PT (2009)
Southampton UK. (µg/100g)	54.6		3410	17		10.4	2090				733	Sidibe and Williams, (2002).
Ghana (mg/100g)	360	1890	555	17.1		31.2	1257	69	92	395	4.4	Affo and Akande, (2011)

Note: Sodium (Na); Potassium (K); Calcium (Ca); Iron (Fe); Copper (Cu); Zinc (Zn); Magnesium (Mg); Mangenese (Mn); Cadmium (Cd); Lead (Pb); Phosphorus (P).

chemicals present in the oil, baobab seed oil has drew a lot of attention recently as a unique plant ingredient beneficial in the cosmetic, pharmaceutical, and food industries. When applied directly to the skin, baobab seed oil has hydrating, moisturizing, and plosive effects (Muthai *et al.,* 2019), and it is widely used as a vegetable oil for food in various African countries. Hypertension, diabetes, obesity, and stomach problems can all be treated with baobab seed oil (Chadare *et al.,* 2009). Essential fatty acids such as linoleic acid, oleic acid, palmitic acid, cyclopropenic acid, and cyclopropanic acid, as well as omega 3, 6, and 9, are found in baobab seed oil. It is also high in antioxidants and contains vitamins D, E, and K (Msalilwa *et al.,* 2020). The oil's nutritious makeup and low level of unsaturation make it appropriate for human and animal consumption (Abubakar *et al.,* 2016).

Furthermore, baobab seed oil has a high level of monounsaturated and polyunsaturated fatty acids (78.04 %) compared to saturate fatty acids (22.51 %), indicating that it could be a useful source of food ingredients. Linoleic acid (36 %), oleic acid (25.1 %), and palmitic acid (28.8 %) were found as the primary fatty acids in baobab seed (Komane *et al.* (2017), with trace fatty acids accounting for 10.1 %. Palmitic acid (22.02 %), palmitoleic acid (1.87 %), tariric acid (7.08 %), elaidic acid (41.29 %), oleic acid (35.72 %), linoleic acid (27.80 %), myristic acid (0.19 %), and margaric acid (0.30 %) were found in baobab seed oil by the study carried out by Lifa and Zacharia (2010), whereas Msalilwa *et al.* (2020) observed that of the baobab population hotspots in Tanzania is dominated with palmitic, oleic, and linoleic acids. The extractible yield of baobab seed oil is reported to be in the range of 15–35 %, (Affo and Akande, 2011; Abubakar *et al.,* 2016), and is dependent on the processing and extraction method used (Msalilwa *et al.,* 2020). The demand for baobab seed oil exports from various African countries to European, Asian, and North American markets has significantly increased. South Africa, Sudan, Tanzania and Zimbabwe are the niche markets substantially exporting baobab seed oil. According to Kamatou *et al.* (2011), reported by Komane *et al.* (2017), Zimbabwe's yearly baobab seed oil production is estimated to be around 20,000 litres, with a value of $100,000. Because of the antioxidant presence in baobab seed oil, Donkor *et al.* (2014) advocated baobab seed oil as a valuable ingredient for food and nutraceutical uses in the promotion of health in Ghana.

Additional issues of baobab products and concluding remarks

From the discussion, promoting and commercialization of these natural products arguably will improve livelihoods by increasing the value of the products, increasing employment opportunities, and resulting in an income for the citizenry. Lack of knowledge on the nutritional value of baobab fruit products in Ghana may be the cause of their low commercial usage. It is well established that a variety of factors, including packing, storage settings, and processing procedures, affect the final product. For new studies in these areas of baobab fruit products, there is currently a research gap. It is necessary to clarify the impact of processing techniques, packaging materials, and length of storage on the phytochemicals found in baobab products. This will give detailed information on the types of packaging, processing techniques, and storage procedures to use to guarantee that the nutritional value of the finished baobab product is not severely impacted and is safe for consumption. Another niche area for research on the baobab food products is the study of the presence of heavy metals, mycotoxins, microbial, and pesticide levels, which have not been delved into in the baobab products found in the sub-region. Designing equipment for processing requires knowledge of data on the engineering properties of the baobab seed to make well-informed choices in the development of locally equipment. There is a paucity of such information about the engineering properties of baobab products found in Ghana. Product initiators and developers will appreciate the inclusion of baobab products in product formulations when available data suggests the potency of the baobab products.

The packed phytochemicals present in baobab fruit products and their potential for supplementing nutrition in mainstream food products have been discovered in this review. Further, it has been shown that harnessing the product has the potential to create jobs and improve the livelihoods of rural folks, as well as provide an alternative ingredient for product initiation and formulation in the food, cosmetic and pharmaceutical industries. In addition, the study has also uncovered areas for further research. As a recommendation, there should be a collaborative effort by scientists, academia, and industries to do purposeful research into the baobab products found in Ghana and the sub-region and how to commercialize them for job and wealth creation. Governments must provide an enabling environment for the up-scale production, processing, and marketing of baobab products.

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Declaration of Conflict of Interest

There is no conflict of interest to declare for this review paper.

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