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REVIEW

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Nutritional and pharmacological attributes of baobab fruit pulp

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Abstract

Foods, especially medicinal foods, play a vital role in providing nutrients for healthy growth and in the management of clinical disorders. Unfortunately, half of the global population lacks access to affordable healthcare and a nutritious diet. Therefore, it is important to identify traditional and scientifically proven therapeutic foods for disease management and the prevention of micronutrient deficiencies. Baobab, one of nature's gifts to mankind, is the focus of this study. The aim was to provide an overview of its medicinal and nutritional benefits through a literature search. Research indicates that baobab fruit pulp is a rich source of fiber, calcium, magnesium, potassium, and notably vitamin C, about five to 10 times the content found in oranges. Additionally, baobab fruit pulp has been found to possess various therapeutic properties, including antibacterial, anti-inflammatory, antidiabetic, anticancer, and antiulcer characteristics. Furthermore, it is considered safe for consumption. These findings emphasize the importance of increasing baobab plantations and raising public awareness about the health benefits of the fruit through educational initiatives. Further research is necessary to explore the potential of baobab fruit pulp as a therapeutic agent for improved health.

Keywords Baobab fruit pulp, Nutrients, Diseases, Toxicity, Fertility

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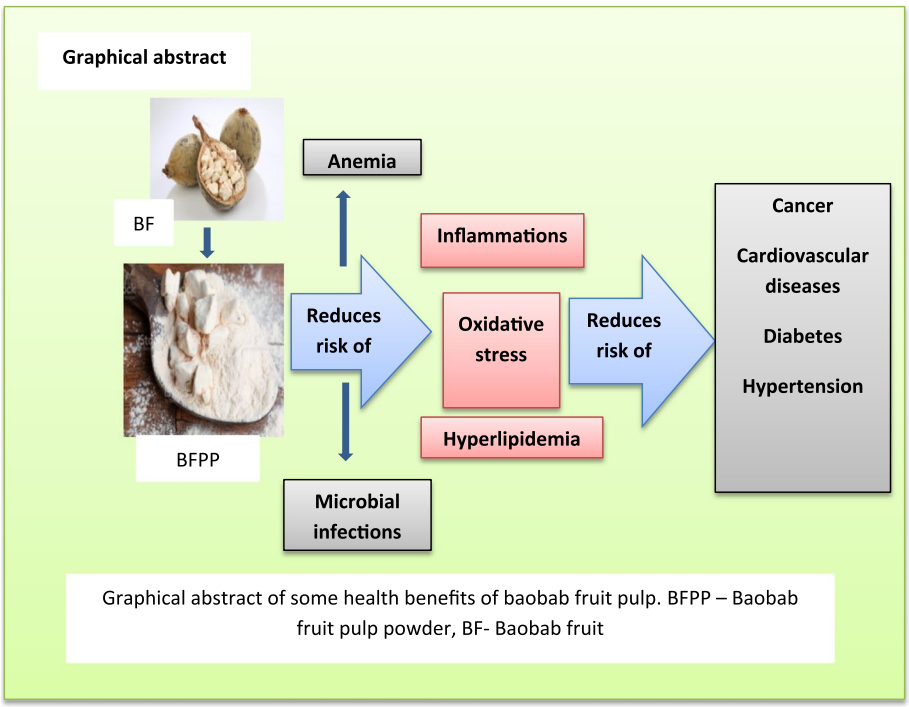
Graphical Abstract



Graphical abstract of some health benefits of baobab fruit pulp. BFPP – Baobab fruit pulp powder, BF- Baobab fruit

Introduction

Traditionally, humans have placed greater importance on wealth and material possessions than on good health. It is believed that having material things is essential for attaining life goals such as success, happiness, social status, and the approval of others. However, not everyone will have all of these things, and they may become insignificant if someone's health is compromised. Therefore, it is important for individuals to prioritize maintaining good health. This can be achieved by consuming the appropriate foods that meet one's nutritional requirements, thus ensuring nutrition security (Abdulwaliyu et al., 2023).

Nutrient deficiencies have been linked to the unfortunate fact that not everyone has the resources or expertise to eat the right foods, especially those living in underdeveloped nations (Abdulwaliyu et al., 2019). Fortunately, nature has endowed us with a variety of plants that are rich in micronutrients but have not yet been fully utilized. One such plant is the baobab. The baobab (*Adansonia digitata)* is a large tree that typically reaches heights between 10 and 25 m. It has a swollen trunk (Kabbashi et al., 2017). The thick, fibrous bark of baobab trees is frequently reddish-brown, grayish-brown, or purplish-gray in color. The fruit often has a length of 12 cm or more, has a hard, woody shell, and is covered in grayish-yellow hairs. The smooth seeds contain little to no endosperm and are encased in pale, powdery pulp. The fruit pulp is flavorful, similar to citrus fruits (Musyoki et al., 2022). Figure 1 shows a schematic representation of the baobab tree and its components.

This plant is native to Africa (Russo et al., 2020) and can be found in many African countries, including Sudan, Ethiopia, Kenya, Tanzania, Senegal, Mali, Niger, Benin, Namibia, South Africa, Mozambique, Zambia, Malawi, and Nigeria (Kehlenbeck et al., 2015). It belongs to the African baobab family *Malvaceae*, but its exact origins are still unclear. According to Heuzé et al. (2016), there are approximately six distinct Adansonia species found in Madagascar, namely *Adansonia grandidieri, Adansonia madagascariensis, Adansonia perrieri, Adansonia rubrostipa, Adansonia suarezensis, and A. za.* This may have been initially discovered.

Human health generally depends on nutrients found in the diet (Okoduwa & Abdulwaliyu, 2023). One could argue that baobab plants have various nutritional and therapeutic uses. Every part of the plant benefits people living in rural areas of Africa. High concentrations of antioxidants, minerals, and vitamins, particularly ascorbic acid, calcium, tartaric acid, and potassium, are known to be present. Baobab fruit pulp has traditionally

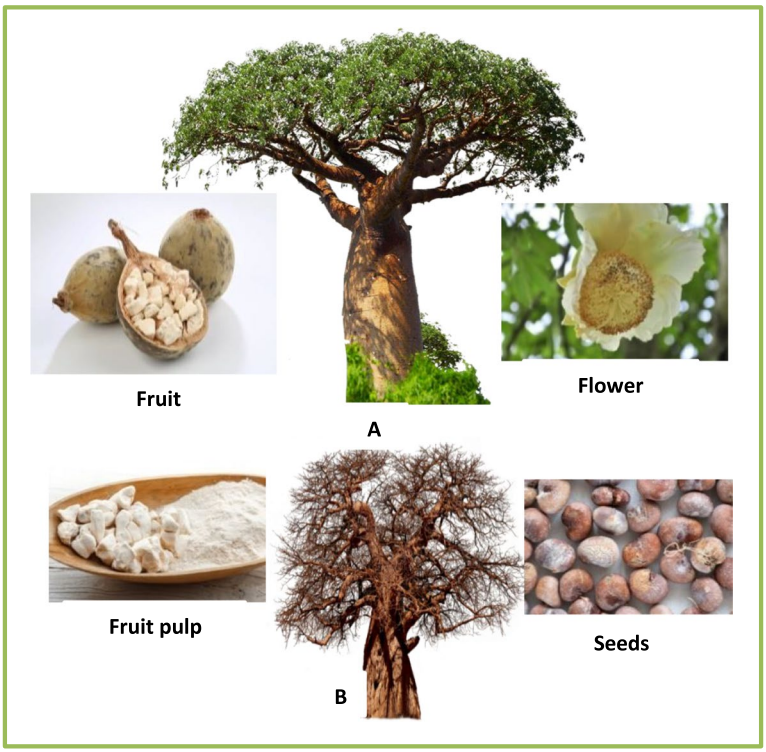


Fig. 1 Baobab tree during (**A**) rainy and (**B**) dry season

been consumed, particularly by adolescents and expectant mothers (Donkor et al., 2014). People use all parts of the plant—leaves, bark, roots, fruits, and seeds—for culinary and medicinal uses around the world, especially in regions where the plant is native. In fact, many Africans see baobab leaves as an essential part of their diet. They are used as a source of fresh vegetables in Malawi and Zimbabwe, replacing commercially grown leafy vegetables such as lettuce and cabbage, and as *miyan kuka* among the Hausa people in northern Nigeria (Bamalli et al., 2014). The fruit of the baobab is an important food source. It can be easily dissolved in milk or water, and can be utilized as a food sauce, drink, or fermenting agent in regional brewing (Gimba et al., 2020). Due to its high content of vitamin C, calcium, phosphate, fiber, potassium, and carbohydrates, baobab fruit pulp can be used as an appetizer or beverage (Rana et al., 2022). The supply of essential nutrients from consuming baobab fruit is reportedly better than that of staple food crops (Mwangi et al., 2023a). This, coupled with the satiety it provides, has led to an increased appreciation of the baobab tree in international markets. As a result, there is now increased export of baobab pulp to the European Union and the United States of America (USA) markets (Mwangi et al., 2023a).

There is a need to identify plants that have been scientifically proven to effectively manage diseases. This is due to the high cost of drugs, the absence of effective health systems that can meet the needs of a growing population, the poor health systems in rural communities (especially in African countries), and the side effects of conventional therapy. One of these plants is the baobab, which has various components that have been shown to reduce the risk of diabetes, cancer, hypertension, anemia, and more. The pulp of the baobab fruit is known to be rich in nutrients that can help address micronutrient deficiencies and combat hidden hunger, particularly among the impoverished. Additionally, the baobab fruit contains numerous bioactive compounds such as coumaric acid, khellin, visnagin, cinnamaldehyde, decursin (Baky et al., 2021), epicatechin and rutin (Chiacchio et al., 2022) that may have the potential to manage various human diseases. Given the nutritional, pharmacological, and economic benefits of baobab fruit pulp, planting more of it, especially in impoverished communities, could contribute to achieving Sustainable Development Goals 1 and 2, which aim to end poverty and hunger, and promote good health (SDG 3). Unfortunately, many people are still unaware of the therapeutic and nutritional advantages of baobab fruit pulp. In light of this, the study aims to provide an

overview of the nutritional and therapeutic properties of baobab fruit pulp.

Methods

A search of various databases, including PubMed, the Directory of Open Access Journals, Google Scholar, and African Journals Online, was conducted to find articles related to the health benefits of baobab fruit pulp. We used a combination of keywords such as "baobab fruit pulp and health," "baobab fruit pulp and nutrient content," "baobab fruit pulp and cancer," "baobab fruit pulp and lipid profile," "baobab fruit pulp and diabetes," "baobab fruit pulp and hypertension," "baobab fruit pulp and cardiovascular diseases," "baobab fruit pulp and antimicrobial properties," "baobab fruit pulp and ulcers," "baobab fruit pulp and fertility," and more. The results of the literature search are outlined below.

Nutritional attributes of baobab fruit pulp

Baobab fruit is notably an excellent source of fiber, carbohydrates, and key minerals (Table 1). The edible part of baobab fruits is a valuable source of vitamin C (175 ± 62 mg/100 g), potassium (1006 ± 280 mg/100 g), and calcium (375 ± 93 mg/100 g) (Stadlmayr et al., 2020). However, the nutritional composition of baobab fruit can vary depending on the location (Stadlmayr et al., 2020). A study by Muthai et al. (2017) found that the nutritional composition of baobab fruit pulp varies by country. The highest mean levels of potassium (22.2 mg/g), calcium (4,300 mg/kg), magnesium (2,300 mg/kg), sodium (1,000 mg/kg), and phosphorus (1,100 mg/kg) were found in the pulp from Malawi. Mali had the lowest mean pulp iron levels (13.1 µg/g) and manganese (8.6 µg/g), whereas Kenya had the highest mean iron (57.4 µg/g) and manganese (27.2 µg/g) (Muthai et al., (2017). The difference could be attributed to geographical location, plant maturity, and the ripening stage of the fruit.

In Sudan, a study by Ali et al. (2020) compared the nutritional differences between young and mature baobab fruit. The results showed that the young baobab fruit pulp had higher contents of potassium (583.88 ± 2.42 mg/100 g), calcium (546.28 ± 5.10 mg/100 g), sodium (23.07 ± 0.31 mg/100 g), magnesium (552.68 ± 0.68 mg/100 g), and vitamin C (281.00 ± 0.89 mg/100 g). However, these differences were not statistically significant. The matured fruit pulp had lower contents of potassium (565.66 ± 5.10 mg/100 g), calcium (544.53 ± 14.84 mg/100 g), sodium (22.07 ± 0.52 mg/100 g), magnesium (542.32 ± 5.25 mg/100 g), and vitamin C (216.37 ± 3.00 mg/100 g) compared to the young fruit pulp (Ali et al., 2020).

According to a study by Aluko et al. (2016), the nutrient composition of baobab fruit pulp from three locations varied in terms of fat (ranging from 0.46 to 1.98 g/100 g), ash (ranging from 4.75 to 5.21 g/100 g), fiber (ranging from 5.91 to 9.65 g/100 g), protein (ranging from 3.23 to 3.53 g/100 g), and carbohydrate (ranging from 80.49 to 85.19 g/100 g). The study also reported vitamin C levels ranging from 169.74 to 231.57 mg/100 g and beta-carotene levels ranging from 2.16–3.19 mg/100 g (Aluko et al., 2016).

Mamman et al. (2021) conducted a study on the proximate and mineral composition of baobab fruit pulp. Their findings revealed that the fruit pulp contained moisture (10.16 ± 0.46 g/100 g), ash (4.65 ± 0.55 g/100 g), fat (0.40 ± 0.01 g/100 g), crude fiber (3.85 ± 0.05 g/100 g), crude protein (4.16 ± 0.05 g/100 g), and carbohydrates (76.78 ± 0.02 g/100 g). The mineral composition of the fruit pulp included potassium (1246.80 ± 1.4 m g/100 g), calcium (99.55 ± 0.65 mg/100 g), magnesium (59.96 ± 0.16 mg/100 g), copper (1.65 ± 0.04 mg/100 g), and zinc (1.80 ± 0.00 mg/100 g).

The baobab fruit pulp studied by Ibrahim et al. (2016) has energy concentrations comparable to some legumes. The fruit pulp also contains total amino acids (98.24), essential amino acids (40.31), sulfur amino acids (2.52),

Table 1 Some nutrient contents of baobab fruit pulp

Nutrients	Composition	Reference
Vitamin C (mg/ 100 g)	263.27; 345.82–372.52; 280–300	Erwa et al., 2018; Ibraheem et al., 2020 Kumar et al., 2022
Calcium (mg/ 100 g)	555; 344.07; 292.9	Affo & Akande, 2011; Erwa et al., 2018; Kumar et al., 2022
Phosphorus (mg/ 100 g)	95.9-118	Kumar et al., 2022
Carbohydrates (g/100 g)	62.58- 72.04; 82.84; 77.47; 75.59	Gurashi et al., 2016; Erwa et al., 2018 Kumar et al., 2022
Crude fiber (g/100 g)	4.16; 5.05	Affo & Akande, 2011; Erwa et al., 2018
Potassium (mg/ 100 g)	1890; 586.01	Affo & Akande, 2011; Erwa et al., 2018
Magnesium (mg/ 100 g)	1257; 196.37	Affo & Akande, 2011; Erwa et al., 2018
Manganese (mg/ 100 g)	69	Affo & Akande, 2011
Iron (mg/ 100 g)	17.1; 4.81	Affo & Akande, 2011; Erwa et al., 2018
Zinc (mg/ 100 g)	31.2	Affo & Akande, 2011

and essential aromatic amino acids (8.91) (Ibrahim et al., 2016). In addition, the baobab fruit pulp collected from various Angolan regions (Monteiro et al., 2022) contains a high level of fiber (56.62 g/100 g), as well as calcium (2 937–3 797 g/100 g), potassium (37 528–42 368 g), and vitamin C (163.8–288.9 g).

While there is a lot of research available about the nutritional qualities of baobab fruit pulp, less is known about consumer attitudes, behaviors, and beliefs around the product. However, a Sudanese study showed favorable attitudes and beliefs about eating baobabs and their social integration and acceptability (Saeed et al., 2023). This suggests that baobab fruit pulp might help ensure family food security to some extent, but its enormous unrealized potential poses a significant challenge (Dorah, 2019).

The nutritional benefits of baobab fruit pulp as a food complement

A study affirmed that jam made from mixes of pineapple and baobab pulp has the following nutritional values: fat (0.04—0.10 g/100 g), protein (0.90—1.33 g/100 g, and carbohydrates (36.84—44.22 g/100 g) (Millicen et al., 2021). The physicochemical, microbiological, and sensory characteristics of yogurt fortified with baobab fruit pulp have been investigated. The results showed that while the contents of carbohydrates, ash, phosphorus, and potassium increased, the contents of moisture, fat, protein, calcium, and sodium decreased (Adelekan & Saleh, 2020). Additionally, a study found that adding baobab pulp to yogurt enhanced its nutritional qualities (Wairimu et al., 2022). It can provide additional nutritional value when combined with millet, soy flour, and complementary meals (Dendegh et al., 2019). Supplementing cultured bovine milk with baobab fruit pulp can enhance the overall nutritional content of the milk and make it better suited for combating micronutrient deficiencies (Mwangi et al., 2023b). Baobab-fortified cookies may offer a less costly supply of nutrients, especially for low-income individuals residing in rural areas (Mounjouenpou et al., 2018). Dossa and colleagues replaced wheat flour with varying amounts (10, 20, and 30%) of baobab flour to enhance the nutritional quality of baked foods (Dossa et al., 2023). The high concentration of nutrients in the fruit improved the micronutrient quality of the baked foods (Dossa et al., 2023). A study established that combining baobab-fruit pulp with pineapple and black-plum fruits creates an antioxidant-rich functional beverage with optimal benefits for consumers (Adedokun et al., 2022). Beverages containing baobab fruit pulp have the potential to be used as natural antioxidants, particularly for consumers with diets deficient in micronutrients (Badejo et al., 2020). It use in food fortification can improve the population's micronutrient levels and as well promotes satiety (Garvey et al., 2017). Table 2 summarizes the various studies on baobab fruit pulp as a dietary supplement.

In fact, fortifying food with baobab fruit pulp can provide optimal health benefits. Fermenting baobab fruit pulp, compared to the gold standard "prebiotic inulin," has shown a promising prebiotic potential for the human gut microbiome (Foltz et al., 2021). This is particularly important because the human gut microbiome has a significant impact on overall health and is attracting increasing attention (Wagner et al., 2024). Dysbiosis of the gut microbiota is linked to various human diseases, including anxiety, depression, hypertension, cardiovascular diseases, obesity, diabetes, inflammatory bowel disease, and cancer (Afzaal et al., 2022; Sadrekarimi et al., 2022).

Pharmacological attributes of baobab fruit pulp

Active compounds in baobab fruit pulp

Both conventional and contemporary medicines heavily rely on plant active metabolites, particularly the secondary metabolites (Hussein and El-Anssary, 2019). The fruit pulp contains hydroxycinnamic acid, iridoid glycosides, and phenylethanoid glycosides as its primary constituents (Li et al., 2017). Table 3 displays some of the active ingredients found in baobab fruit pulp. These and numerous other metabolites in baobab fruit pulp are believed to be responsible for its various properties, including antioxidant, anti-inflammatory, antibacterial, antihelminthic, anticoagulant, anticancer, antihypertensive, antidiabetic, and hypolipidemic effects. Due to these qualities, baobab fruit pulp could be a viable option for managing or reducing the risk of human diseases, especially for individuals with lower incomes (Teoh, 2015). Other metabolites such asmalic acid, pyrogallol, protocatechuic acid, hexopyranosyl-deoxypyranoside, O-caffeoyl quinic acid, chlorogenic acid, caffeoyl–O-hexoside, coumaric acid, khellin, visnagin, cinnamaldehyde, and decursin have also been identified in the pulp of baobab fruit (Baky et al., 2021).

Antioxidant properties of baobab fruit pulp

Baobab fruit pulp is well-known for its natural antioxidant properties (Tembo et al., 2017). It may be particularly beneficial for individuals living in food-insecure regions, especially those with low calcium and potassium diets (Badejo et al., 2020). Studies suggest that consuming baobab fruit pulp may reduce the risk of chronic diseases associated with oxidative stress (Ibraheem et al., 2020; Ndiaye et al., 2021; Talari et al., 2017). Various factors, including a high-fat diet, contribute to oxidative stress (Amiya, 2016; Aparisi et al., 2022; Masenga et al., 2023; Vona et al., 2021). Low doses of baobab fruit have been reported to mitigate oxidative stress in albino rats fed a high fat diet (Abushal, 2021; Althwab et al., 2019).

Table 2 Nutritional advantages of the baobab fruit pulp as food complement

Studies	Findings	Reference
Fortification of African-type wholegrain maize-based porridges with baobab fruit pulp and moringa leaves	Compared to moringa, the pulp from baobab increased the bioavailability of iron and zinc, particularly when used with traditional iron fortification	Adetola et al., 2022
Addition of the baobab fruit pulp of different concentrations (3, 6, and 10%) to produce functional dark chocolate	The inclusion of baobab fruit pulp improves the nutritional quality of the chocolate	Monteiro et al., 2023
Impact of incorporating baobab fruit pulp on the delivery of carotenoids from composite cereal porridge	Inclusion of 25% baobab decreased (13.3%) the bio-accessibility of carotenoids, although the uptake efficiency of provitamin A carotenoids by Caco-2 human intestinal cells was not significantly altered	Debelo et al., 2020
Assessment of iron and Zinc bio-accessibility through food-to-food fortification of pearl millet with moringa leaf powder, roselle calyces and baobab fruit pulp	Combining these plant foodstuffs could contribute up to 28% and 41% of the women's absolute iron and zinc requirements, respectively, from a single meal, especially in those at-risk communities in the semi-arid tropics	van der Merwe et al., 2019
Quality attributes of *Kisra* prepared from sorghum flour fermented with baobab fruit pulp flour	The Kisra's ascorbic acid, in vitro protein, and starch digestibility increased, but its phytate and tannin contents decreased concurrently	Makawi et al., 2019a
Physicochemical, nutritional, functional, rheological, and microbiological properties of sorghum flour fermented with baobab fruit pulp flour	Improves the nutritional profile with a concomitant decrease in pH, phytate, and tannin contents	Makawi et al., 2019b
Effect of replacing skim milk powder with baobab fruit pulp on the physicochemical, nutritional, rheological, microstructure, and organoleptic properties of ice creams	Incorporating baobab fruit pulp into ice cream improved dietary values regarding macro- and micronutrients	Sakr et al., 2023
In vitro bio-accessibility and bioavailability of iron from fenugreek, baobab and moringa	Though moringa leaves exhibited iron bioaccessibility (9.88% ± 0.45 and 8.44 ± 0.01 mg/100 g), the highest percentage bioavailability was from baobab fruit pulp (99.7% ± 0.13 and 1.74 ± 0.01 mg/100 g). Both fenugreek and moringa, except for baobab, significantly inhibited iron uptake	Khoja et al., 2021
Partially substitution of Wheat flour with baobab fruit pulp to prepare composite flour	The substitution of baobab fruit pulp increased the levels of microelements like zinc, iron, and copper. Likewise, there was a favorable improvement in biological value, essential amino acid need index, protein efficiency ratio, and essential amino acid index	Barakat, 2021

Table 3 Some active principles in fruit pulp of baobab

Active principles	Composition	Reference
Total phenolic (mg GAE/100 g)	1550 – 9966; 972	Ibraheem et al., 2020; Monteiro et al., 2022
Flavonoids	1.03 to 21.53 mg of catechin (CA/g); 5.66 ± 0.18 µg EQ/mg of extract	Ibraheem et al., 2020; Ndiaye et al., 2021
Terpenoids; Glycosides; Saponins; Flavonoids; and Alkaloids (g/100 g)	1.12; 0.19; 1.79; 3.59; and 0.89	Kumar et al., 2022
Condensed Tannin contents (un-sieved; sieved (> 100 µm); sieved (100-50 µm); sieved (50 µm); mg CE/g	4.51 ± 0.30; 3.82 ± 0.02; 4.35 ± 0.07; 5.44 ± 0.10	Josiane et al., 2020
Chlorogenic acid; Epicatechin; Procyanidin B_2; and Rutin (µg/g) d.w	1.8 ± 0.09; 514 ± 1; 506.5 ± 5.7; and 80.3 ± 0.9	Chiacchio et al., 2022
Campesterol (g/100 g), Tocopherol (g/100 g), Stigmasterol (g/100 g), β-Sitosterol/gamma-Sitosterol (g/100 g)	3.74, 4.58, 5.56, 13.54/9.47	Fagbemi et al., 2022
Procyanidin trime; Quercetin; Gallic acid; and Caffeic acid (µg/g) d.w	60 ± 1.4; 39.5 ± 1.4; 33.9 ± 1.1, 25.9 ± 0.8	Chiacchio et al., 2022
1,2-Bis(trimethylsilyl)benzene; 2-Methyl-7-phenylindole; 2-Ethylacridine; and 2,8-Dimethyl-2,3-dihydro-1,5-benzoxazepine-4(5H)-thione	13.17; 11.75; 10.11; and 10.11%	Wasihun et al., 2023

GAE Gallic Acid Equivalent, *CE* Catechin Equivalent

Oral administration of an aqueous extract of baobab fruit pulp has been shown to reduce oxidative stress and histopathological alterations in lead-intoxicated rats (Otong et al., 2022), as well as oxidative stress caused by *Trypanosoma brucei brucei* (Ogunleye et al., 2020). *Trypanosoma brucei* infection can damage the host's tissues and organs by disrupting membrane integrity and generating free radicals (Ogunleye et al., 2020). Figure 2 provides a graphic representation of some of the health benefits of baobab fruit pulp.

Anti-diabetic activities of baobab fruit pulp

Diabetes is recognized as a serious global health concern. It is characterized by elevated blood sugar levels due to insufficient insulin production or insulin resistance. These metabolic errors increase the risk of developing diabetic complications if blood sugar levels remain high, making it crucial to have effective and safe treatment approaches to lower blood glucose levels.

A study conducted by Gwarzo and Bak (2013) examined the effects of methanol extract from baobab fruit pulp on blood sugar levels in albino rats with alloxan-induced diabetes. The results demonstrated a significant reduction in blood sugar levels in rats that received the extract compared to those that did not, suggesting that the fruit pulp extract may be a promising hypoglycemic option. Another study by Braca et al. (2018) found that baobab fruit extracts had higher α-glucosidase inhibition than acarbose, a medication used to treat type-2 diabetes. This indicates that the fruit pulp could potentially be used as an alternative to treat diabetes. It is important to note that acarbose, like other medications, may have adverse effects, so maximizing the therapeutic benefits of the fruit pulp is crucial. Human research has shown that consuming baobab fruit pulp significantly lowers blood sugar levels in healthy individuals (Rita et al., 2022), further supporting its potential use in diabetes treatment.

Evidence from experimental rats with streptozotocin-induced diabetes showed that the butanolic extract of baobab fruit pulp significantly improved glucose and lipid metabolism, protecting the rats against diabetic alterations (Mohammed et al., 2021). Additionally, adding baobab fruit pulp to bread reduced the amount of fast-digesting starch in white bread samples (Shelly et al., 2013). This could be beneficial for individuals with diabetes, as fast starch digestion may lead to a blood sugar surge (Zhu et al., 2023). Natural carbohydrate digestion enzyme inhibitors have been explored as an alternative to commercially available anti-diabetic drugs (Kashtoh & Baek, 2023), which have shown unsatisfactory medical outcomes (D'Souza et al., 2021). The fruit pulp could fill this research gap. It has been observed to inhibit pancreatic lipase, angiotensin converting enzyme (ACE), and alpha-amylase activity (Cicolari et al., 2020). By implication, consumption of the fruit pulp may help regulate blood glucose levels by reducing the amount of glucose available from the metabolism of carbohydrates.

Furthermore, the influence of beverages made from baobab pulp on the postprandial blood sugar levels of 15 healthy subjects has been studied (Ibrahima et al., 2021). The results showed that subjects who consumed beverages containing baobab fruit pulp without added sugar had a low glycemic index and glycemic load, suggesting its potential expediency in the prevention and control of diabetes.

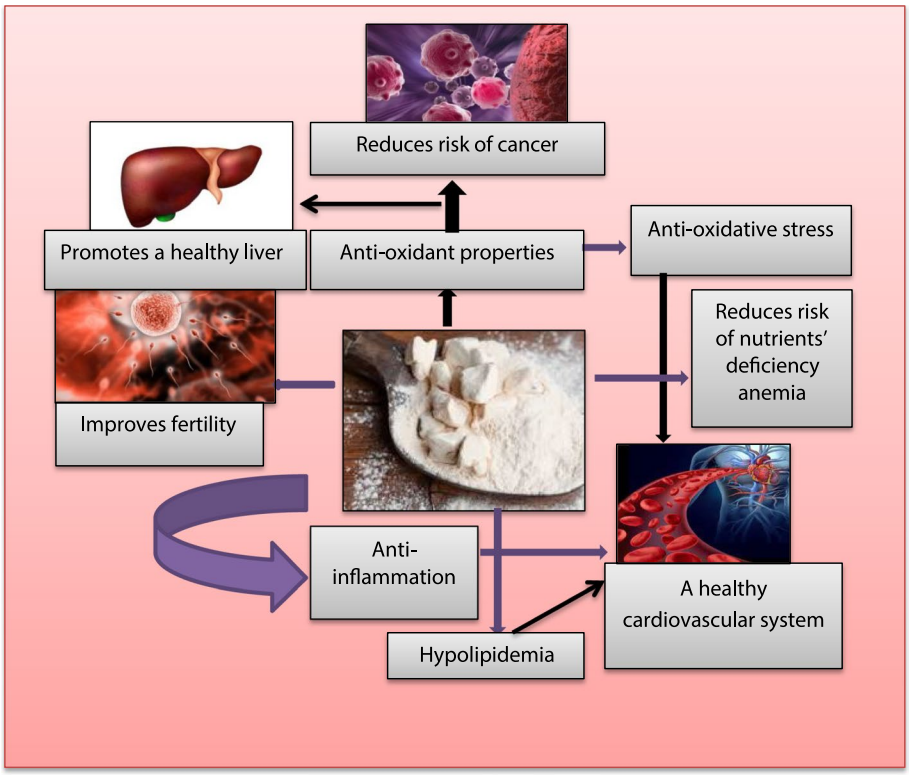


Fig. 2 A schematic representation of some health benefits of the baobab fruit pulp

Anti-cancer activities of baobab fruit pulp

Plant-based nanoparticles are becoming increasingly popular for treating various illnesses, including cancer. Researchers have studied silver nanoparticles synthesized from baobab fruit pulp for their anti-cancer properties against colon cancer cell lines. According to Almukaynizi et al. (2022), the study confirmed that silver nanoparticles made from baobab fruit extract could be a viable option for anticancer applications. The urgent need for new anticancer drugs has led to a similarity-based study. The study examined whether the bioactives found in baobabs have anticancer potential using in silico docking and similarity analysis. According to the study, bioactive chemicals such as gallic acid, malic acid, ursolic acid, betulinic acid, friedelin, catechin, alpha-amyrin, lupeol, scopoletin, genkwanin, isofucosterol etc. found in baobab pulp have activity against the hepatoblastoma cell line (HepG2) and resemble anticancer agents (Sharma & Shukla, 2023). Conversely, various extracts of baobab fruit pulp and fibers showed that only the fibers demonstrated anticancer activities against colorectal carcinoma (HCT116) and MCF-7 cells, while the ovarian cancer cells were unaffected (El-Masry et al., 2021). This suggests that a combination of baobab fruit pulp and its fiber constituents may provide a more potent medicinal solution for the prevention and treatment of cancer. Furthermore, additional research has been reported on the anticancer function of baobab fruit pulp (Elsaid, 2013; Kadam & Kondawa, 2019; Suliman & El-Hddad, 2023).

Anti-hypertensive properties of baobab fruit pulp

Hypertension (HTN), defined as systolic blood pressure (SBP) greater than 140 mmHg or diastolic blood pressure (DBP) greater than 90 mmHg, is a significant and rapidly expanding global issue. Research has demonstrated that administering methanol extract from baobab fruit pulp to hypertensive albino rats in a dose-dependent manner can prevent blood pressure from rising above normal levels (Liman et al., 2021). Another study suggests that baobab fruit pulp may be effective in treating complex metabolic issues, such as hypertension, that are associated with high-fat diets (Abushal, 2021).

Baobab fruit pulp contains active metabolites that may contribute to its ability to prevent high blood pressure. One of these metabolites is potassium, a mineral known for its anti-hypertensive effects, which is abundant in the fruit. Increasing potassium intake has been observed to lower blood pressure and reduce the risk of stroke and coronary heart disease (Palmer & Clegg, 2020; Weaver, 2013). Therefore, foods high in potassium are important

for managing hypertension, as they help counteract the effects of salt. Baobab fruit, being a major source of potassium, may play a role in slowing the progression of hypertension and cardiovascular diseases. It is important to note that potassium is just one of many compounds found in baobab fruit pulp that may help reduce the risk of hypertension and related conditions. Furthermore, the use of baobab fruit pulp as an intervention against L-NG-Nitro arginine methyl ester (L-NAME)-induced hypertension has been shown to lower blood pressure in experimental rats (Richard et al., 2021).

Lipid-lowering properties of baobab fruit pulp

Baobab fruit pulp supplementation on a high-fat diet (15 g egg yolk and 45 g beef burger) fed to albino rats showed a significant decrease in serum lipid profile (Elamin et al., 2019). Bako et al. (2014) also observed lower serum levels of triglycerides, cholesterol, and low-density lipoprotein cholesterol in alloxan-induced diabetic rats given baobab fruit pulp. Similar findings have been revealed in human studies. The results of a cohort study with 70 participants (42 men and 28 women) who consumed baobab fruit pulp and another 70 participants (44 men and 26 women) who did not, showed that the baobab fruit users had significantly lower levels of low-density lipoprotein cholesterol, triglycerides, and total cholesterol (Ahmed et al., 2022). These findings suggest that consuming baobab fruit pulp may enhance cardiovascular health by reducing the risk of hyperlipidemia (Fig. 2).

Anti-anemic properties of baobab fruit pulp

The impact of a baobab pulp drink on the iron status levels of school children has been investigated. The study took place in the Nigerian state of Enugu and involved approximately 142 schoolchildren aged six to eight. The children were given about 250 mL of baobab fruit pulp drink (BFPD), which contained 60 mg of ascorbate. The results showed notable increases in the children's mean hemoglobin levels (10.85 to 12.92 g/dl) and mean serum ferritin concentrations (11.25–19.52 µg/L) (Nnam et al., 2011).

A similar investigation was conducted in Kenya on school-age children aged six to 12 who were deemed healthy but had hemoglobin levels below 12.2 g/dL. When compared to the control groups, the children in the intervention group who consumed a drink containing baobab fruit pulp did not show any significant differences in their hemoglobin, ferritin, or soluble transferrin receptor levels. However, the intervention groups did experience a slight increase in hemoglobin (2.2%), while the control groups saw a 2.7% decrease in hemoglobin levels (Evang et al., 2021).

Furthermore, research conducted in Kenya on two groups of 16 teenage anemic girls revealed that anemia was greatly improved by consuming green leafy vegetables high in iron, supplemented with baobab pulp, which is an excellent source of ascorbic acid (Riziki, 2020). This suggests that baobab fruit pulp, when combined with iron-rich foods, may help improve anemic status, especially in rural communities where baobab plants are available. This is particularly relevant for children, older adults, and women of childbearing age who are at risk of anemia due to poor diet, intestinal disorders, and other related health conditions.

Anti-inflammatory activities of baobab fruit pulp

Inflammation is the immune system's response to harmful stimuli (Chen et al., 2017). While an inflammatory response is a natural biological reaction that protects injured tissues, it can become harmful if left unchecked. The anti-inflammatory properties of various components of baobab have been studied in relation to carrageenan-induced pedal edema in seven-day-old chicks. Baobab fruit pulp has shown anti-inflammatory qualities, providing scientific evidence for its use in treating inflammatory diseases (Quartey et al., 2021). Some of the bioactive chemicals found in the fruit pulp may be responsible for its anti-inflammatory properties (Selvarani & James, 2020). However, further research is needed to fully evaluate this claim.

Antimicrobial properties of baobab fruit pulp

The baobab fruit pulp has been studied as a folkloric treatment for urinary tract infections (Fagbemi et al., 2022). Its efficacy against *Enterococcus faecalis* ATCC29212 surpasses several medications in its antibacterial action (El Yahyaoui et al., 2023), and is more effective (at concentrations of 50 µg/mL and 25 µg/mL) against *Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Staphylococcus aureus, Fusarium oxysporium, Trichoderma harzianum, Aspergillus flavus, and Pyricularia oryzae* (Ojo & Oniyi, 2022). Dabnoun et al. (2022) also found that the methanol extract from the pulp was effective against *Staphylococcus aureus, Escherichia coli, and Klebsiella pneumonia*. Similarly, studies by Selvarani and James (2020) and Kumar et al. (2016) have demonstrated the antimicrobial properties of baobab fruit pulp.

Consuming baobab fruit pulp may help lessen or overcome drug resistance to disease-causing microbes, as many antibiotics have lost their efficacy against infectious diseases. However, Gahane and Kogje (2013) found little to no zone of inhibition of the methanol extract of baobab fruit against *Klebsiella pneumoniae, Proteus mirabilis, Escherichia coli, Pseudomonas aeruginosa, Salmonella*

typhi, Bacillus subtilis, Nocardia sp, and Staphylococcus aureus.

Antiulcer properties of baobab fruit pulp

Although baobab has long been used to treat ulcers, its effectiveness has not been extensively validated. However, a study by Malgave et al. (2019) has confirmed the antiulcer qualities of baobab fruit pulp and its ability to repair peptic ulcers. Peptic ulcer disease affects the stomach and duodenum. It is characterized by acid-induced lesions that denude the mucosa and extend into the submucosa, or muscularis propria. Common symptoms include weight loss, nausea, vomiting, abdominal pain, and serious complications such as bleeding or perforation (Narayanan et al., 2018).

Fertility booster properties of baobab fruit pulp

One in six people worldwide suffers from infertility, which is the inability of a sexually active couple to conceive after a year of continuous sexual activity without the use of birth control (Harris, 2023). Histological studies revealed that rats administered cotton seed extract without baobab fruit pulp had fewer spermatogonia and developing cells in their testes. On the other hand, the group that received cotton seed extract and fruit pulp treatments showed a notable increase in sperm count and motility (Babatunde et al., 2021). Therefore, it appears that the fruit pulp has fertility-promoting qualities. This is likely attributed to the active components of the extract, such as triterpenoids, flavonoids, and vitamin C, which may help boost energy and stabilize the male reproductive system (Babatunde et al., 2021). Anoh et al. (2017) also confirmed that baobab fruit pulp improved the shape and quality of rabbits' sperm. While further research is needed to confirm these findings, baobab fruit pulp may hold promise in combating the threat of infertility.

Bioprotective properties of baobab fruit pulp

Hepatoprotective effects of baobab fruit pulp

Protecting the integrity of the liver is crucial due to its various functions in the biological system (Sa'id et al., 2020). The hepatoprotective benefits of baobab fruit pulp in rats have been examined in relation to paracetamol-induced hepatotoxicity (Badr-Eldin et al., 2017). The baobab fruit pulp showed a significant reduction in liver dysfunction. Hence, it could be considered a strong candidate for hepatic protection (Badr-Eldin et al., 2017). Hanafy et al. (2016) have also made a similar discovery, demonstrating that the methanol extract from baobab fruit pulp provides protection against paracetamol-induced hepatotoxicity. In their study, the experimental rats intoxicated with paracetamol had hepatocyte necrosis, characterized by the apoptosis of inflammatory cells and the loss of nuclei. However, treatment with baobab fruit pulp significantly mitigated these histological alterations (Hanafy et al., 2016).

Administration of baobab fruit pulp has been shown to significantly reduce elevated levels of aspartate amino transferase (AST), alanine amino transferase (ALT), alkaline phosphatase (ALP), bilirubin, and improved histopathological liver sections in rats given carbon tetrachloride (CCl4) (Sa'id et al., 2020). Furthermore, it has been documented that fermented goat milk (FGM) and aqueous extracts of baobab fruit and desert truffle (Terfezia claveryi) have a synergistic hepatoprotective effect against CCl4-induced hepatotoxicity in albino rats (Hamad et al., 2022).

Its flavonoid component has been shown to reduce hepato-renal damage caused by mercury chloride in experimental rats (Makena et al., 2022). Similar observations against lead-acetate induced liver dysfunction have been reported (Makena et al., 2021). Another study confirmed that pre-treating rats with a baobab fruit pulp extract provides hepato-renal protection against liver toxicity caused by glyphosate, the most commonly used herbicide (Ini et al., 2022).

Cardio-protective effects of baobab fruit pulp

Isoproterenol-induced oxidative stress has been studied using experimental rats. Increased levels of cardiac marker enzymes, such as lactate dehydrogenase (LDH), collagen, and galectin-3, were observed. The activities of glutathione peroxidase (GPX) and glutathione (GSH) in the heart tissue were also reduced. However, these changes returned to nearly normal when the experimental rats were fed with baobab fruit pulp (Ghoneim et al., 2016). Their findings also reported largely normal heart structure and limited infiltration of inflammatory cells (Ghoneim et al., 2016). It's obvious that information on the role of baobab fruit pulp on cardiac performance is limited; therefore, more appraisals are needed.

Other health benefit of the baobab fruit pulp

The increasing presence of heavy metals in the food chain poses various risks to both human health and the environment. Growing children, in particular, are highly susceptible to the detrimental effects of heavy metals. Baobab fruit pulp, administered orally once a day for 42 days, has been found to improve the rats' memory index, regulate glutamate levels, and protect them from oxidative stress caused by lead-induced memory impairment (Otong et al., 2022). Lead has the ability to bind to protein kinase C (PKC) and activate it. This alteration in PKC's normal functions subsequently affects neurotransmitters like glutamate (Otong et al., 2022).

In a dose-dependent manner, the baobab fruit pulp has been shown to moderate castor oil-induced diarrhea in an experimental model (Abdelrahim et al., 2013). Diarrhea is responsible for over 90% of deaths in children under the age of five in low- and lower-middle-income countries (Demissie et al., 2021; Ugboko et al., 2020). Therefore, further evaluation of studies like this is necessary, and if confirmed in future research, particularly in humans, it could potentially save the lives of children in various parts of the world. The baobab fruit pulp has been substantiated to reduce the risk of metabolic syndrome, a risk factor for numerous metabolic diseases (Suliman et al., 2020).

Toxicity of baobab fruit pulp

The baobab fruit pulp is considered essentially harmless, with an oral lethal dose of over 5000 mg/kg body weight (Muhammad et al., 2016). In a sub-acute oral toxicity study, the baobab fruit pulp was administered at doses of 250, 500, and 1000 mg/kg body weight for 28 days. The result of the toxicity study showed no lethal effects or signs of toxicity at the tested dose, indicating that lethal doses are greater than 2000 mg/kg.

In the sub-acute study, no significant differences were observed in body weight, organ weight, liver, and kidney parameters among all treated groups compared to the control group (Adebisi et al., 2022). Additionally, the group that received 250 mg/kg/body weight showed a notable decrease in lymphocyte counts and an increase in white blood cell counts. These findings suggest that while short-term use of baobab fruit pulp methanol extract is generally safe, prolonged use may affect hematological parameters (Adebisi et al., 2022).

Future directions and research gaps

Significant research has been conducted on the nutritional profiles of baobab fruit pulp, particularly its potential for fortification and how it can be fortified with other foods to enhance its value. However, there is limited information regarding the medicinal properties of the pulp, especially regarding how diets containing the pulp can impact the treatment, prevention, or cure of diseases. Despite numerous studies demonstrating the usefulness of baobab pulp, little is known about its utilization in commercial settings and for impoverished populations. The reason could be that the marketing of baobab pulp is limited to a few actors, possibly due to a lack of awareness regarding the economic importance of the fruit pulp. People in the African region, where the plants are native, may not be aware of their economic values. This could explain why unharvested baobab fruits continue to be seen in farmlands and forests (Kaimba et al., 2021).

In contrast, developed countries have realized their economic value. For example, in 2020, the US accounted for over 27.1% of the global market size, and it is projected that by 2027, the global market for baobab fruit powder will reach an estimated USD 8.5 billion (BusinessWire, 2020). Furthermore, there are only limited empirical studies regarding the socio-economic aspect of its production (Kaimba et al., 2021).

Additionally, there is little evidence available regarding the use of food fortified with baobab fruit pulp in studies focused on cardiovascular disease, cancer, and managing diabetes. Studies on the beneficial role of baobab pulp in improving fertility and treating ulcers, in any form, are also limited. It is worthy to note that baobab fruit pulp is becoming well-known as a novel food ingredient, approved by the European Commission (EC) and the US Food and Drug Administration (FDA) (Offiah & Falade, 2023). This is due to the enormous nutrients it contains. While the nutritional characteristics of the baobab fruit pulp have been extensively studied, studies on the bioactive principles of baobab fruit have not been significantly explored. Unveiling the specific secondary metabolites in the baobab fruit pulp could potentiate its application in specific disease management. Also, its application in the management or treatment of neglected tropical diseases is lacking.

Conclusion

Finding nutritious, healthy, and medicinal therapeutics has become increasingly challenging, especially for the impoverished in emerging nations. Fortunately, there are numerous plants that possess a variety of nutritional and therapeutic benefits, but they are simply not being utilized to their full potential. The baobab is one such plant that nature has bestowed upon mankind. Therefore, based on scientific research, this study provides a summary of the nutritional and physiological advantages of baobab fruit pulp. The baobab fruit pulp has the potential to address issues of hidden hunger and energy deficits, as it is a rich source of micronutrients particularly vitamin C, and carbohydrates. Additionally, baobab fruit pulp may offer certain health benefits, including organ protection and a reduced risk of diabetes, hypertension, cancer, and infertility. To further support its role, further investigation into the health benefits of baobab fruit pulp is necessary.

Abbreviations

ACE	Angiotensin converting enzyme
ALP	Alkaline phosphatase
ALT	Alanine amino transferase
AST	Aspartate amino transferase
BFPD	Baobab fruit pulp drink
CCL4	Carbon tetrachloride
CE	Catechin equivalent
DBP	Diastolic blood pressure
EC	European Commission (EC)
FDA	Food and Drug Administration

FGM	Fermented goat milk
GAE	Glic acid equivalent
GPX	Glutathione peroxidase
GSH	Glutathione
HCT116	Human colorectal carcinoma cell line
HepG2	Hepatoblastoma cell line
HTN	Hypertension
LDH	Lactate dehydrogenase
L-NAME	L-NG-Nitro arginine methyl ester
MCF-7	Michigan Cancer Foundation-7
PCV	Packed cell volume (PCV)
PKC	Protein kinase C
SBP	Systolic blood pressure
SDGs	Sustainable Development Goals
USA	United States of America

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References

Abdelrahim, M. Y., Elamin, B. M. A., Khalil, D. J., & ElBadwi, S. M. A. (2013). Antidiarrhoeal activity of ethanolic extract of *adansonia digitata* fruit pulp in rats. *Journal of Physiology and Pharmaceutical Advances,3*(6), 172–178. https://doi.org/10.5455/jppa.20130624013026

Abdulwaliyu, I., Arekemase, S. O., Adudu, J. A., Batari, M. L., Egbule, M. N., & Okoduwa, S. I. R. (2019). Investigation of the medicinal significance of phytic acid as an indispensable anti-nutrient in diseases. *Clinical Nutrition Experimental,28*, 42–61. https://doi.org/10.1016/j.yclnex.2019.10.002

Abdulwaliyu, I., Okoduwa, SIR., Arekemase, SO., & Batari, M.L. (2023). Conceptual triple E model for sustainable food security: a solution based framework for hunger and malnutrition in Nigeria. *World Nutrition*, 56-62. https://doi.org/10.26596/wn.202314456

Abushal, S. A. (2021). Therapeutic effects of Baobab fruit pulp (*Adansonia digitata)* aqueous extract on liver and cardiovascular system of high-fat diet rat model. *Journal of the Saudi Society for Food and Nutrition (JSSFN),14*(1), 80–93.

Adebisi, I.M., Mansur, Y., Fajobi, S.J., Ugwah-Oguejiofor, C.J., & Abubakar, K. (2022). Acute and sub-acute oral toxicity of the methanol extract of *Adansonia digitata* fruit pulp. Sokoto *Journal of Medical Laboratory Science*, 7(3). https://doi.org/10.4314/sokjmls.v7i3.2

Adedokun, T. O., Matemu, A., Höglinger, O., Mlyuka, E., & Adedeji, A. (2022). Evaluation of functional attributes and storage stability of novel juice blends from baobab, pineapple, and black-plum fruits. *Heliyon,8*(5), e09340. https://doi.org/10.1016/j.heliyon.2022.e09340. PMID: 35540929; PMCID: PMC9079165.

Adelekan, A. O., & Saleh, A. A. (2020). Chemical composition and microbiological quality of baobab (*Adansonia digitata*) fruit fortified yoghurt. *Nigerian Journal of Microbiology,34*(1), 4998–5006.

Adetola, O. Y., Kruger, J., Ferruzzi, M. G., Hamaker, B. R., & Taylor, J. R. N. (2022). Potential of moringa leaf and baobab fruit food-to-food fortification of wholegrain maize porridge to improve iron and zinc bioaccessibility. *International Journal of Food Sciences and Nutrition,73*(1), 15–27. https://doi.org/10.1080/09637486.2021.1911962. Epub 2021 Apr 15 PMID: 33858271.

Affo, W., & Akande, S. S. (2011). Physico-chemical analysis of the fruit of *Adansonia digitata* (baobab) IN Ghana. *Journal of Ghana Science Association,13*(2), 115–23.

Afzaal, M., Shah, Y.A., Hussain, M., Rabail, R., Socol, C.T., Hassoun, A., Pateiro, M., Lorenzo, J.M., Rusu, A.V., & Aadil, R.M. (2022). Human gut microbiota in health and disease: Unveiling the relationship. *Frontiers in microbiology*, Sec. *Microorganisms in Vertebrate Digestive Systems,*13. https://doi.org/10.3389/fmicb.2022.999001

Ahmed, A. M., Khabour, O. F., Yousuf, A., Eweda, S. M., Mohammedsaeed, W., Daradka, H. M., Hassanein, S. F. M., & Ibrahim, A. M. (2022). The beneficial effect of *Adansonia digitata* products success to modulate lipid profiles and inhibit LDL oxidation in-vitro: an associational study. *Malawi Medical Journal,34*(1), 25–30. https://doi.org/10.4314/mmj.v34i1.5

Ali, M.A.M., Ali, H.A.M., Ebrahim, R.M.E., & Hamadnalla, H.M.Y. (2020). Comparison of biochemical composition and some mineral content between new and old fruits of *Adansonia digitata* (Tabaldi). *Archive of Organic and Inorganic Chemical Sciences*. 2020;4(4). AOICS.MS.ID.000194. https://doi.org/10.32474/AOICS.2020.04.000194

Almukaynizi, F. B., Daghestani, M. H., Awad, M. A., Althomali, A., Merghani, N. A., Bukhari, W. I., Algahtani, N. M., Al-Zuhairy, S. S., AlOthman, A. M., Alsenani, E. A., Alojayan, B. O., Al-Saif, K. S., & Bhat, R. S. (2022). Cytotoxicity of green-synthesized silver nanoparticles by *Adansonia digitata* fruit extract against HTC116 and SW480 human colon cancer cell lines. *Green Processing and Synthesis,11*, 411–422. https://doi.org/10.1515/gps-2022-0031

Althwab, S. A., Alsattame, M., Al-mundarij, T. I., Hamad, E. M., & Mousa, H. M. (2019). Protective effect of baobab fruit pulp (adansonia digitata l.) from oxidative stress induced in rats by High-Fat Diet. *Life Science Journal,16*(1), 63–71. https://doi.org/10.7537/marslsj160119.08. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online) 8.http://www.lifesciencesite.com

Aluko, A., Kinyuru, J., Chove, L.M., Kahenya, P., & Owino, W. (2016). Nutritional quality and functional properties of baobab (*Adansonia digitata*) pulp from Tanzania. *Journal of Food Research,* 5(5). https://doi.org/10.5539/jfr.v5n5p23

Amiya, E. (2016). Interaction of hyperlipidemia and reactive oxygen species: Insights from the lipid-raft platform. *World Journal of Cardiology,8*(12), 689–694. https://doi.org/10.4330/wjc.v8.i12.689. PMID: 28070236.

Anoh, K. U., Barje, P. P., Iyeghe-Erakpotobor, G. I., & Akpa, G. N. (2017). Influence of baobab (*Adansonia digitata*) fruit pulp meal on semen characteristics and morphology of rabbit buck during hot season in Nigeria. *Nigerian Journal of Animal Production,44*(3), 84–88.

Aparisi, Á., Martín-Fernández, M., Ybarra-Falcón, C., Gil, J. F., Carrasco-Moraleja, M., Martínez-Paz, P., Cusácovich, I., Gonzalo-Benito, H., Fuertes, R., & Marcos-Mangas, M. (2022). Dyslipidemia and inflammation as hallmarks

of oxidative stress in COVID-19: a follow-up study. *International Journal of Molecular Sciences,23*(23), 15350. https://doi.org/10.3390/ijms232315350

Babatunde, D. J., Tope, O. O., Fidelis, O. E., Enevwo, O. G., & Olugbenga, E. (2021). Aqueous extract of *Adansonia digitata* reversed cotton seed extract-induced testicular damage in Wistar rats. *JBRA Assisted Reproduction,25*(2), 257–265. https://doi.org/10.5935/1518-0557.20200092. PMID: 33565299; PMCID: PMC8083865.

Badejo, A. A., Duyilemi, T. I., Falarunu, A. J., & Akande, O. A. (2020). Inclusion of baobab (adansonia digitata l.) fruit powder enhances the mineral composition and antioxidative potential of processed tiger nut (cyperus esculentus) beverages. *Preventive Nutrition and Food Science,25*(4), 400–407. https://doi.org/10.3746/pnf.2020.25.4.400. pISSN 2287-1098 eISSN 2287-8602.

Badr-Eldin, S. M., Aldawsari, H. M., Hanafy, A., Abdlmoneim, M. S., Abdel-Hady, S. E., & Atif, H. (2017). Enhanced hepatoprotective effect of *adansonia digitata* extract on paracetamol-induced hepatotoxicity. *Research Journal of Pharmaceutical, Biological and Chemical Sciences,8*(6), 787–794.

Bako, H. Y., Mohammad, J. S., Waziri, P. M., Bulus, T., Gwarzo, M. Y., & Zubairu, M. M. (2014). Lipid profile of alloxan-induced diabetic Wistar rats treated with methanolic extract of *Adansonia digitata* fruit pulp. *Science World Journal,9*(2), 19–24.

Baky, M. H., Badawy, M. T., Bakr, A. F., Hegazi, N. M., Abdellatif, A., & Farag, M. A. (2021). Metabolome-based profiling of African baobab fruit (Adansonia digitata L.) using a multiplex approach of MS and NMR techniques in relation to its biological activity. *RSC Advances,11*(63), 39680–39695. https://doi.org/10.1039/d1ra08277a. PMID: 35494142; PMCID: PMC9044842.

Bamalli, Z., Mohammed, A. S., Ghazali, H. M., & Karim, R. (2014). Baobab Tree (*Adansonia digitata* L) parts: Nutrition, applications in food and uses in ethno-medicine – A Review. *Annals of Nutritional Disorders & Therapy,1*(3), 1011.

Barakat, H. (2021). Nutritional and rheological characteristics of composite flour substituted with baobab (adansonia digitata l.) pulp flour for cake manufacturing and organoleptic properties of their prepared cakes. *Foods,10*(4), 716. https://doi.org/10.3390/foods10040716. PMID: 33801774; PMCID: PMC8065946.

Braca, A., Sinisgalli, C., De Leo, M., Muscatello, B., Cioni, P. L., Milella, L., Ostuni, A., Giani, S., & Sanogo, R. (2018). Phytochemical profile, antioxidant and antidiabetic activities of Adansonia digitata L. (Baobab) from Mali, as a Source of Health-Promoting Compounds. *Molecules,23*, 3104. https://doi.org/10.3390/molecules23123104

BusinessWire - Global functional food market (2020 to 2027) - by ingredient, product, and application ResearchandMarkets.Com (2020). https://www.businesswire.com/news/home/20201009005190/en/Global-Functional-Food-Market-2020-to-2027-by-Ingredient-Product-and-Application-ResearchAndMarkets.com

Chen, L., Deng, H., Cui, H., Fang, J., Zuo, Z., Deng, J., Li, Y., Wang, X., & Zhao, L. (2017). Inflammatory responses and inflammation-associated diseases in organs. *Oncotarget,9*(6), 7204–7218. https://doi.org/10.18632/oncotarget.23208. PMID: 29467962; PMCID: PMC5805548.

Chiacchio, M. F., Tagliamonte, S., Visconti, A., Ferracane, R., Mustafa, A., & Vitaglione, P. (2022). Baobab-fruit shell and fibrous filaments are sources of antioxidant dietary fibers. *Molecules,27*(17), 5563. https://doi.org/10.3390/molecules27175563

Cicolari, S., Dacrema, M., Tsetegho Sokeng, A. J., Xiao, J., Atchan Nwakiban, A. P., Di Giovanni, C., Santarcangelo, C., Magni, P., & Daglia, M. (2020). Hydromethanolic extracts from adansonia digitata l. edible parts positively modulate pathophysiological mechanisms related to the metabolic syndrome. *Molecules,25*(12), 2858. https://doi.org/10.3390/molecules25122858. PMID: 32575811; PMCID: PMC7356617.

Dabnoun, F. M. O., Maaly, R. H. E., & Othman, S. M. A. (2022). Antibacterial activity of extracts of the baobab (seeds and pulp) against pathogenic bacteria. *London Journal of Research in Science: Natural and Formal,22*, 14. Compilation 1.0.

Debelo, H., Ndiaye, C., Kruger, J., Hamaker, B. R., & Ferruzzi, M. G. (2020). African *Adansonia digitata* fruit pulp (baobab) modifies provitamin A carotenoid bioaccessibility from composite pearl millet porridges. *Journal of Food Science and Technology,57*(4), 1382–1392. https://doi.org/10.1007/s13197-019-04173-y. PMID:32180634;PMCID:PMC7054500.

Demissie, G. D., Yeshaw, Y., Aleminew, W., & Akalu, Y. (2021). Diarrhea and associated factors among under five children in sub-Saharan Africa: evidence from demographic and health surveys of 34 sub-Saharan countries. *PLoS One,16*(9), e0257522. https://doi.org/10.1371/journal.pone.0257522. PMID: 34543347; PMCID: PMC8452002.

Dendegh, T. A., Ukeyima, M., & Dendegh, R. A. (2019). Proximate composition, functional and sensory properties of pearl millet, soy flour and baobab fruit pulp composite flour as a complementary food. *Asian Food Science Journal,8*(3), 1–11. https://doi.org/10.9734/AFSJ/2019/v8i329992

Donkor, A., Addae, D., Kpoanu, J. E., Kankam, F., Boaudi, A. N., & Abanya, E. Y. M. (2014). Antioxidant enrichment of baobab fruit pulp treated with oil extracted from the seeds. *Food and Nutrition Sciences,5*, 328–333. https://doi.org/10.4236/fns.2014.54039. http://www.scirp.org/journal/fns

Dorah, M.K., (2019). Potential role of baobab in household food security in Kilifi and Kitui counties of Kenya. A Thesis Submitted in partial fulfilment for the degree of Master of Science in Food Science and Nutrition in the Jomo Kenyatta University of Agriculture and Technology.

Dossa, S., Negrea, M., Cocan, I., Berbecea, A., Obistioiu, D., Dragomir, C., Alexa, E., & Rivis, A. (2023). Nutritional, physico-chemical, phytochemical, and rheological characteristics of composite flour substituted by baobab pulp flour (Adansonia digitata L.) for bread making. *Foods,12*, 2697. https://doi.org/10.3390/foods12142697

Dsouza, M. S., Brady, R. E., & Ray, S. D. (2021). Chapter 37 - Side effects of insulin and other antihyperglycemic drugs, Editor(s): Sidhartha D. Ray. *Side Effects of Drugs Annual,43*, 451–461. https://doi.org/10.1016/bs.seda.2021.08.007. ISSN 0378-6080. ISBN 9780128241196.

El Yahyaoui, O., Bouabid, B., Ouaaziz, N. A., El Bakkali, M., El Harche, H., Lrhorfi, L. A., Nakari, K., & Benguedour, R. (2023). The antibacterial activity and biochemical composition of *Adansonia digitata* edible parts. *Arab Gulf Journal of Scientific Research,41*(1), 91–106. https://doi.org/10.1108/AGJSR-07-2022-0101. Emerald Publishing Limited e-ISSN: 2536-0051 p-ISSN: 1985-9899.

Elamin, O. F., Atti, K. A. B., & Dalia, A. M. (2019). Effect of Baobab (*Adansonia digitata*) pulp powder on serum lipid profile of rats fed high lipid diets. *Pakistan Journal of Nutrition,18*, 1053–1057.

El-Masry, O. S., Goja, A., Rateb, M., Owaidah, A. Y., & Alsamman, K. (2021). RNA sequencing identified novel target genes for *Adansonia digitata* in breast and colon cancer cells. *Science Progress,104*(3), 1–25. https://doi.org/10.1177/00368504211032084

Elsaid, F. G. (2013). The effect of seeds and fruit pulp of *Adansonia digitata* l. (baobab) on ehrlich ascites carcinoma. *Food and Nutrition Sciences,4*, 38–46. https://doi.org/10.4236/fns.2013.48A005

Erwa, I.Y., Shinger, M.I, Ishag, O.A.I., Ali, A.M., Ahmed, R.E., & Mohamed, A.A. (2018). Proximate and elemental composition of baobab fruit (*Adansonia digitata* L) Pulp. *Journal of Chemical, Biological and Physical Sciences.*https://doi.org/10.24214/jcbps.B.9.1.04251

Evang, E. C., Habte, T., Owino, W. O., & Krawinke, M. B. (2021). Can the supplementary consumption of baobab (*Adansonia digitata* L.) fruit pulp improve the hemoglobin levels and iron status of schoolchildren in Kenya? Findings of a randomized controlled intervention trial. *European Journal of Nutrition,60*, 2617–2629. https://doi.org/10.1007/s00394-020-02447-2

Fagbemi, K. O., Aina, D. A., Coopoosamy, R. M., & Olajuyigbe, O. O. (2022). 'Gas chromatography-mass spectrometry chemical profile investigation and biological activities of ethylacetate fraction of Baobab (Adansonia digitata L.) pulp used in the treatment of urinary tract infections. *Journal of Medicinal Plants for Economic Development,6*(1), a117. https://doi.org/10.4102/jomped.v6i1.117

Foltz, M., Zahradnik, A. C., Van den Abbeele, P., Ghyselinck, J., & Marzorati, M. (2021). A Pectin-Rich, Baobab Fruit Pulp Powder Exerts Prebiotic Potential on the Human Gut Microbiome In Vitro. *Microorganisms,9*(9), 1981. https://doi.org/10.3390/microorganisms9091981. PMID: 34576876; PMCID: PMC8467054.

Gahane, R.N., & Kogje, K.K. (2013). Antibacterial, antioxidant and phytochemical analysis of edible parts of potent nutraceutical plant – *Adansonia digitata.* Proc. 2nd IS on Medicinal and Nutraceutical Plants Eds.: S.C. Mahapatra and V. Agrawal Acta Hort. 972, ISHS, Pp 55-60.

Garvey, R., Clegg, M., & Coe, S. (2017). The acute effects of baobab fruit (*Adansonia digitata*) on satiety in healthy adults. *Nutrition and*

Health.,23, 026010601770436. https://doi.org/10.1177/026010601770436

Ghoneim, M. A., Hassan, A. I., Mahmoud, M. G., & Asker, M. S. (2016). Protective effect of *Adansonia digitata* against Isoproterenol-induced myocardial injury in rats. *Animal Biotechnology,27*(2), 84–95. https://doi.org/10.1080/10495398.2015.1102147. PMID: 26913549.

Gimba, S. N., Anka, Z. M., Bulakarima, H. U., & Kachallah, F. (2020). Pharmacological activities of baobab (*Adansonia digitata*). *International Journal of Current Medical and Pharmaceutical Research,01*(A), 4906–491. https://doi.org/10.24327/23956429.ijcmpr202001830

Gurashi, N. A., Kordofani, M. A. Y., Abdelgadir, K. A., & Sali, V. A. M. (2016). Variation in chemical composition of baobab *(Adansonia digitata L). International Journal of Scientific Engineering and Applied Science,2*(11), 106–119.

Gwarzo, M. Y., & Bak, H. Y. (2013). Hypoglycemic activity of methanolic fruit pulp extract of *Adansonia digitata* on blood glucose levels of alloxan induced diabetic rats. *International Journal of Animal and Veterinary Advances,5*(3), 108–113.

Hamad, E. M., Alfheeaid, H. A., Althwab, S. A., Ashoush, I. S., & Mousa, H. M. (2022). Ameliorative effect of fermented goat's milk combined with desert truffle and baobab aqueous extract in ccl4 induced liver lesion in rats. *Journal of Microbiology, Biotechnology, and Food Sciences,12*(3), e298. https://doi.org/10.5525/jmbfs.2988

Hanafy, A., Aldawsari, H. M., Badr, J. M., Ibrahim, A. K., & Abdel-Hady, S. E. (2016). Evaluation of hepatoprotective activity of *Adansonia digitata* extract on acetaminophen-induced hepatotoxicity in Rats. *Evidence-Based Complementary and Alternative Medicine,Article ID 4579149*, 7. https://doi.org/10.1155/2016/4579149

Harris, E. (2023). Infertility Affects 1 in 6 People Globally. *JAMA,329*(17), 1443. https://doi.org/10.1001/jama.2023.6251

Heuzé, V., Tran, G., Archimède, H., & Bastianelli, D. (2016). African baobab (*Adansonia digitata*). Feedipedia, a programme by INRA, CIRAD, AFZ and FAO;17:39. http://www.feedipedia.org/node/525. Last updated on March 14, 2016.

Hussein, A.R., & El-Anssary, A.A. (2019).Plants secondary metabolites: The key drivers of the pharmacological actions of medicinal plants. *IntechOpen*-https://doi.org/10.5772/intechopen.76139

Ibraheem, S. E., Idris, Y. M. A., Mustafa, S. E., & Baraka, B. M. K. (2020). Total phenolic, flavonoids and ascorbic acid contents in baobab (adansonia digitata l) fruit pulp extracts from different locations in Sudan. *International Journal of Academic Management Science Research,4*(6), 22–26.

Ibrahim, H., Aremu, M. O., Onwuka, J. C., Atolaiye, B. O., & Muhammad, J. (2016). Amino acid composition of pulp and seed of baobab. *FUW Trends in Science & Technology Journal,1*(1), 74–79. e-ISSN: 24085162; p-ISSN: 20485170.

Ibrahima, C., Flore, A., Louise, A., & Ali, O. (2021). Influence of beverage consumption made from baobab pulp (*adansonia digitata l.*) on postprandial glycemia in Côte d'Ivoire. *Food and Nutrition Sciences,12*, 774–786. https://doi.org/10.4236/fns.2021.127058

Ini, A. T., Makena, W., Usman, I. M., Aminu, A., & Gadzama, M. N. (2022). Protective Role of *Adansonia digitata* extract against glyphosate-induced hepatorenal toxicity in adult male Wistar rats. *Iranian Journal of Toxicology,16*(2), 135–144. https://doi.org/10.32598/IJT.16.2.920.1

Josiane, N. M. T., Christian, F. G., Baudelaire, N. E., & Nicolas, N. Y. (2020). Antioxidant and antihyperlipidemic properties of different granulometric classes of *Adansonia digitata* pulp powder. *Pakistan Journal of Nutrition,19*, 393–403. https://doi.org/10.3923/pjn.2020.393.403

Kabbashi, N. A., Mirghani, M. E. S., Alam, M. Z., Qudsieh, Y., & Bello, I. A. (2017). Characterization of the baobab fruit shells as adsorption material. *International Food Research Journal,24*(Suppl), S472–S474.

Kadam, S. D., & Kondawa, M. S. (2019). Evaluation of in-vitro anticancer activity and quantitation of active ingredient of Adansonia digitata L. Fruit. *International Journal of Pharmaceutical Sciences and Drug Research,11*(6), 358–369.

Kaimba, G. K., Mithöfer, D., & Muendo, K. M. (2021). Commercialization of underutilized fruits: Baobab pulp supply response to price and non-price incentives in Kenya. *Food Policy,99*, 101980. https://doi.org/10.1016/j.foodpol.2020.101980. ISSN 0306-9192.

Kashtoh, H., & Baek, K. H. (2023). New insights into the latest advancement in α-amylase inhibitors of plant origin with anti-diabetic effects. *Plants (Basel),12*(16), 2944. https://doi.org/10.3390/plants12162944. PMID: 37631156; PMCID: PMC10458243.

Kehlenbeck, K., Padulosi, S., & Alercia, A. (2015). *Descriptors for baobab (Adansonia digitata L.)*. Rome, Italy and World Agroforestry Centre, Nairobi, Kenya: Biodiversity International. ISBN-13: 978-92-9255-000-4.

Khoja, K. K., Aslam, M. F., Sharp, P. A., & Latunde-Dada, G. O. (2021). In vitro bioaccessibility and bioavailability of iron from fenugreek, baobab and moringa. *Food Chemistry,15*(335), 127671. https://doi.org/10.1016/j.foodchem.2020.127671. PMID: 32745843.

Kumar, C. M. K., Yugandhar, P., & Savithramma, N. (2016). Biological synthesis of silver nanoparticles from Adansonia digitata L. fruit pulp extract, characterization, and its antimicrobial properties. *Journal of Intercultural Ethnopharmacology,5*(1), 79–85. https://doi.org/10.5455/jice.20160124113632

Kumar, G., Kumar, R., Gautam, G. K. G., & Rana, H. (2022). The Pharmacological and phytochemical study of *Adansonia digitata*. *Research Journal of Pharmacology and Pharmacodynamic,14*(2), 79–3. https://doi.org/10.52711/2321-5836.2022.00014

Li, X. N., Sun, J., Shi, H., Yu, L. L., Ridge, C. D., Mazzola, E. P., Okunji, C., Iwu, M. M., Michel, T. K., & Chen, P. (2017). Profiling hydroxycinnamic acid glycosides, iridoid glycosides, and phenylethanoid glycosides in baobab fruit pulp (*Adansonia digitata*). *Food Research International,99*(1), 755–761. https://doi.org/10.1016/j.foodres.2017.06.025. Epub 2017 Jun 19. PMID: 28784541; PMCID: PMC5555379.

Liman, A. A., Salihu, A., & Onyike, E. (2021). Effect of methanol extract of baobab (Adansonia digitata L.) fruit pulp on NG-Nitro-L-Arginine Methyl Ester (L-NAME) induced hypertension in rats. *High Blood Press Cardiovascular Preventio,28*(3), 291–300. https://doi.org/10.1007/s40292-021-00448-8. Epub 2021 Apr 7 PMID: 33826116.

Makawi, A. B., Mustafa, A. I., Adiamo, O. Q., & Mohamed Ahmed, I. A. (2019a). Quality attributes of *Kisra* prepared from sorghum flour fermented with baobab fruit pulp flour as starter. *Journal Food Science and Technology,56*(8), 3754–3763. https://doi.org/10.1007/s13197-019-03848-w. PMID:31413402;PMCID:PMC6675830.

Makawi, A. B., Mustafa, A. I., Adiamo, O. Q., & Mohamed Ahmed, I. A. (2019b). Physicochemical, nutritional, functional, rheological, and microbiological properties of sorghum flour fermented with baobab fruit pulp flour as starter. *Food Science and Nutrition,7*(2), 689–699. https://doi.org/10.1002/fsn3.913. PMID: 30847147; PMCID: PMC6392849.

Makena, W., Otong, E. S., Dibal, N. I., Ishaku, B., & Bazabang, S. A. (2021). Aqueous fruit pulp extract of *Adansonia digitata (L)* protects against lead-acetate-induced hepato-renal damage in rat model. *Beni-Suef University Journal of Basic and Applied Sciences,10*, 59. https://doi.org/10.1186/s43088-021-00151-6

Makena, W., Aribiyun, Y. S., Aminu, A., Ishaku, B., Yohana, A., & Inemesit, E. E. (2022). Flavonoids fractions of Adansonia digitata L. fruits protects adult Wistar rats from mercury chloride-induced hepatorenal toxicity: histopathological and biochemical studies. *Egyptian Journal of Basic and Applied Sciences,9*(1), 205–215. https://doi.org/10.1080/2314808X.2022.2059140

Malgave, K. K., Naikwade, N. S., Ladda, P. L., Shikalgar, T. S., & Patil, S. S. (2019). Peptic ulcer healing activity of fruit pulp extract and seed oil of *Adansonia digitata* Linn". *International Journal of Pharmaceutical Sciences and Drug Research,11*(5), 263–271. https://doi.org/10.25004/IJPSDR.2019.110518

Mamman, S., Shuaibu, B. S., & Yusuf, J. A. (2021). Exploring the nutritional and mineral compositions of baobab (*Adansonia digitata* l) fruit pulp and seed. *FUDMA Journal of Sciences,5*(2), 128–132. https://doi.org/10.33003/fjs-2021-0501-604

Masenga, S. K., Kabwe, L. S., Chakulya, M., & Kirabo, A. (2023). Mechanisms of oxidative stress in metabolic syndrome. *International Journal of Molecular Sciences,24*(9), 7898. https://doi.org/10.3390/ijms24097898

Millicen, O., Bigson, K., & Akwaah, V. (2021). Preparation and quality evaluation of baobab fruits pulp and pineapple blended jam. *EPRA International Journal of Agriculture and Rural Economic Research (ARER)*, 3. https://doi.org/10.36713/epra081

Mohammed, M. A., Attia, H. N., El-Gengaihi, S. E., Maklad, Y. A., Ahmed, K. A., & Kachlicki, P. (2021). Comprehensive metabolomic, lipidomic and pathological profiles of baobab (Adansonia digitata) fruit pulp extracts in diabetic rats. *Journal of Pharmaceutical and Biomedical Analysis,201*, 114139. https://doi.org/10.1016/j.jpba.2021.114139. ISSN 0731-7085.

Monteiro, S., Reboredo, F. H., Lageiro, M. M., Lourenço, V. M., Dias, J., Lidon, F., Abreu, M., Martins, A. P. L., & Alvarenga, N. (2022). Nutritional properties

of baobab pulp from different Angolan origins. *Plants,11*, 2272. https://doi.org/10.3390/plants11172272

Monteiro, S., Dias, J., Lourenço, V., Partidário, A., Lageiro, M., Lampreia, C., Fernandes, J., Lidon, F., Reboredo, F., & Alvarenga, N. (2023). Development of a functional dark chocolate with baobab pulp. *Foods,12*(8), 1711. https://doi.org/10.3390/foods12081711. PMID: 37107506; PMCID: PMC10137990.

Mounjouenpou, P., Eyenga, S. N. N., Kamsu, E. J., Kari, P. B., & Ehabe, E. E. (2018). Effect of fortification with baobab (Adansonia digitata L.) pulp flour on sensorial acceptability and nutrient composition of rice cookies. *Scientific Africa,1*, e00002. https://doi.org/10.1016/j.sciaf.2018.e00002

Muhammad, I. U., Jarumi, I. K., Alhassan, A. J., Wudil, A. M., & Dangambo, M. A. (2016). Acute toxicity and hypoglycemic activity of aqueous fruit pulp extract of Adansonia digitata l. (afpead) on alloxan induced diabetic rats. *Journal of Advances in Medical and Pharmaceutical Sciences*, *6*(3), 1–6. Article no. JAMPS.23862. ISSN: 2394-1111.

Musyoki, J. K., Kaigongi, M. M., Uchi, S. M., Kiama, S. M., Githiomi, J., Muthike, G. M., & Luvande, A. M. (2022). Distribution and population status of Adansonia digitata L. (baobab) and its contribution to livelihood in Makueni County, Kenya. *Trees, Forest and People,8*, 100270. https://doi.org/10.1016/j.tfp.2022.100270

Muthai, K. U., Karori, M. S., Muchugi, A., Indieka, A. S., Dembele, C., Mng'omba, S., & Jamnadass, R. (2017). Nutritional variation in baobab (Adansonia digitata L.) fruit pulp and seeds based on Africa geographical regions. *Food Science and Nutrition,5*(6), 1116–1129. https://doi.org/10.1002/fsn3.502

Mwangi, A. W., Kunyanga, C. N., & Onyango, C. M. (2023). Production, consumption, processing and marketing of the baobab fruit (Adansonia digitata L.) in Kenya. *African Journal of Food Science,17*(2), 35–48. https://doi.org/10.5897/AJFS2022.2237. Article Number: E5159AE70424. ISSN: 1996-0794.

Mwangi, A. W., Kunyanga, C. N., & Onyango, C. M. (2023b). Development, nutritional and microbial evaluation of cultured bovine milk supplemented with baobab fruit pulp. *CyTA - Journal of Food,21*(1), 198–208. https://doi.org/10.1080/19476337.2023.2188060

Narayanan, M., Reddy, K. M., & Marsicano, E. (2018). Peptic ulcer disease and *Helicobacter pylori* infection. *Missouri Medicine,115*(3), 219–224. PMID: 30228726; PMCID: PMC6140150.

Ndiaye, E. M., Yousra, Y. E. I., Alioune, S., Ayessou, N. C., Harhar, H., Cisse, M., & Tabyaoui, M. (2021). Secondary Metabolites and antioxidant activity of different parts of the baobab Fruit (*Adansonia digitata* L.*). Food and Nutrition Sciences,12*, 732–741. https://doi.org/10.4236/fns.2021.127055

Nnam, N.M., Madukwe, E.U., & Udenta, E.A. (2011). Effect of baobab (*Adansonia digitata* L.) fruit pulp drink on iron status of school children. *Nigerian Journal of Nutritional Sciences,* 32(2). https://doi.org/10.4314/njns.v32i2.71713

Offiah, V. O., & Falade, K. O. (2023). Potentials of baobab in food systems. *Applied Food Research,3*(1), 100299. https://doi.org/10.1016/j.afres.2023.100299. ISSN 2772-5022.

Ogunleye, O. O., Jatau, I. D., Natala, A. J., & Ola-Fadunsin, S. D. (2020). Effects of aqueous extract of fruit pulp of Adansonia digitata L. on the oxidative stress profile against Trypanosoma brucei brucei infection in albino rat. *Clinical Phytoscience,6*, 57. https://doi.org/10.1186/s40816-020-00203-x

Ojo, R. O., & Oniyi, S. O. (2022). The antimicrobial activities of crude extracts of fruits of *Andasonia digitata*. *Achievers Journal of Scientific Research,4*(1), 86–94.

Okoduwa, S. I. R., & Abdulwaliyu, I. (2023). Dietary approach for management of type-2 daibbetes: an overview of glycemic indices of commonly consumed foods in Nigeria. Diabetes and Metabolic syndrome. *Diabetes and Metabolic Syndrome: Clinical Research and Reviews,17*, 102698. https://doi.org/10.1016/j.dsx.2022.102698

Otong, E. S., Musa, S. A., Danborno, B., Sambo, S. J., & Dibal, N. I. (2022). *Adansonia digitata* ameliorates lead-induced memory impairments in rats by reducing glutamate concentration and oxidative stress. *Egyptian Journal of Basic and Applied Sciences,9*(1), 1–10. https://doi.org/10.1080/2314808X.2021.2009678

Palmer, B. F., & Clegg, D. J. (2020). Blood pressure lowering and potassium intake. *Journal of Human Hypertension,34*, 671–672. https://doi.org/10.1038/s41371-020-00396-1

Quartey, A. K., Ayensu, I., Orman, E., Mireku-Gyimah, N. A., Jibira, Y., & Goku, P. E. (2021). In-vivo anti-inflammatory activity of different parts of *Adansonia digitata*. *Journal of Medicinal Plants Research,15*(6), 252–259. https://doi.org/10.5897/JMPR2020.707

Rana, H., Kumar, R., Chopra, A., Pundir, S., Gautam, G. K., & Kumar, G. (2022). The various pharmacological activity of *Adansonia digitata*. *Research Journal of Pharmacology and Pharmacodynamics,14*(1), 53–9. https://doi.org/10.52711/2321-5836.2022.00009

Richard, E. J., Abi, I., & Adeniyi, O. S. (2021). Effect of n-hexane extract of baobab *(Adansonia digitata*) fruit on biochemical parameters of l-ng-nitro arginine methyl ester induced hypertension in rats. *Journal of Medicinal Plants Research,15*(9), 423–430. https://doi.org/10.5897/JMPR2021.7160

Rita, K., Bernardo, M. A., Silva, M. L., Brito, J., Mesquita, M. F., Pintão, A. M., & Moncada, M. (2022). Adansonia digitata L. (Baobab Fruit) effect on postprandial glycemia in healthy adults: a randomized controlled trial. *Nutrients,14*, 398. https://doi.org/10.3390/nu14020398

Riziki, D.Y. (2020). Enhancing haemoglobin status of anemic school girls using cooked vegetables enriched with baobab powder in Kilif county – Kenya. Dissertation submitted in partial fulfillments of the requirement for the degree of Masters of Science in applied human nutrition of theuniversity of Nairobi, Kenya.

Russo, M., Ronci, M. B., Vilmercati, A., Gionfriddo, M., Fanali, C., Dugo, L., Locato, V., Mondello, L., & De Gara, L. (2020). African baobab (*Adansonia digitata*) fruit as promising source of procyanidins. *European Food Research and Technology,246*, 297–306. https://doi.org/10.1007/s00217-019-03342-9

Sa'id, A. M., Musa, A. H., Mashi, J. A., Maigari, F. U., & Nuhu, M. N. (2020). Phytochemical screening and hepatoprotective potential of aqueous fruit pulp extract of *Adansonia digitata* against CCL4 induced liver damage in rats. *Asian Journal of Biochemistry, Genetics and Molecular Biology,3*(3), 12–21. Article no.AJBGMB.54697 ISSN: 2582-3698.

Sadrekarimi, H., Gardanova, Z. R., Bakhshesh, M., Ebrahimzadeh, F., Yaseri, A. F., Thangavelu, L., Hasanpoor, Z., Zadeh, F. A., & Saeed Kahrizi, M. S. (2022). Emerging role of human microbiome in cancer development and response to therapy: Special focus on intestinal microflora. *Journal of Translational Medicine,20*, 301. https://doi.org/10.1186/s12967-022-03492-7

Saeed, H.A.M., Adam, Y.O., Donkor, E., & Mithöfer, D. (2023). Consumers behavior, attitudes, and beliefs regarding baobab (*Adansonia digitata* L.) fruit and pulp consumption in Sudan. *Frontiers in Sustainable Food System*. https://doi.org/10.3389/fsufs.2023.1118714

Sakr, S. S., Mohamed, S. H. S., Ali, A. A., Ahmed, W. E., Algheshairy, R. M., Almujaydil, M. S., Al-Hassan, A. A., Barakat, H., & Hassan, M. F. Y. (2023). Nutritional, physicochemical, microstructural, rheological, and organoleptical characteristics of ice cream incorporating *adansonia digitata* pulp flour. *Foods,12*(3), 533. https://doi.org/10.3390/foods12030533

Selvarani, V., & James, H. B. (2020). Multiple inflammatory and antiviral activities in Adansonia digitata (Baobab) leaves, fruits and seeds. *International Scholars Journals,14*(8), 01–007.

Sharma, S., & Shukla, V. J. (2023). Similarity and docking analysis of bioactive compounds from Adansonia digitata L. against vascular endothelial growth factor receptor—An in silico approach. *Journal of Drug Research in Ayurvedic Sciences,8*, 55–64.

Shelly, A., Clegg, M., Armengol, M., & Ryan, L. (2013). The polyphenol-rich baobab fruit (Adansonia digitata L.) reduces starch digestion and glycemic response in humans. *Nutrition Research,33*(11), 888–896. https://doi.org/10.1016/j.nutres.2013.08.002. ISSN 0271-5317.

Stadlmayr, B., Wanangwe, J., Waruhiu, C. G., Jamnadass, R., & Kehlenbeck, K. (2020). Nutritional composition of baobab (Adansonia digitata L.) fruit pulp sampled at different geographical locations in Kenya. *Journal of Food Composition and Analysis,94*, 103617. https://doi.org/10.1016/j.jfca.2020.103617

Suliman, M. B., & El-Hddad, S. (2023). Characterization of chemical constituents of Adansonia digitata l. using gc-ms and lc-ms/qtof and their in vitro anti-cervical cancer effects. *Tropical Journal of Natural Product Research,7*(6), 3191–3197. https://doi.org/10.26538/tjnpr/v7i6.19

Suliman, H. M., Osman, B., Abdoon, I. H., Saad, A. M., & Khalid, H. (2020). Ameliorative activity of Adansonia digitata fruit on high sugar/high fat diet-simulated Metabolic Syndrome model in male Wistar rats. *Biomedicine & Pharmacotherapy,125*, 109968. https://doi.org/10.1016/j.biopha.2020.109968. ISSN 0753-3322.

Talari, S., Gundu, C., Koila, T., & Nann, R. S. (2017). In vitro free radical scavenging activity of different extracts of *Adansonia digitata L.*. *International Journal of Environment, Agriculture and Biotechnology (IJEAB),2*(3), 1169–1172.

Tembo, D. T., Holmes, M. J., & Marshall, L. J. (2017). Effects of thermal treatment and storage on bioactive compounds, organic acids and antioxidants activity of baobab fruit (*Adansonia digitata*) pulp from Malawi. *Journal of Food Composition and Analysis,58*, 40–51. https://doi.org/10.1016/j.jfca.2017.01.002

Teoh, E. S. (2015). Secondary metabolites of plants. *Medicinal Orchids of Asia,5*, 59–73. https://doi.org/10.1007/978-3-319-24274-3_5. PMCID: PMC7123774.

Ugboko, H. U., Nwinyi, O. C., Oranusi, S. U., & Oyewale, J. O. (2020). Childhood diarrhoeal diseases in developing countries. *Heliyon,6*(4), e03690. https://doi.org/10.1016/j.heliyon.2020.e03690. *Erratum in: Heliyon*, 10;6(6):e04040. PMID: 32322707; PMCID: PMC7160433.

Van der Merwe, R., Kruger, J., Ferruzzi, M. G., Duodu, K. G., & Taylor, J. R. N. (2019). Improving iron and zinc bioaccessibility through food-to-food fortification of pearl millet with tropical plant foodstuffs (moringa leaf powder, roselle calyces and baobab fruit pulp). *Journal of Food Science and Technology,56*(4), 2244–2256. https://doi.org/10.1007/s13197-019-03711-y. PMID:30996458;PMCID:PMC6443743.

Vona, R., Pallotta, L., Cappelletti, M., Severi, C., & Matarrese, P. (2021). The impact of oxidative stress in human pathology: focus on gastrointestinal disorders. *Antioxidants,10*(2), 201. https://doi.org/10.3390/antiox10020201

Wagner, A., Kapounková, K., & Struhár, I. (2024). The relationship between the gut microbiome and resistance training: A rapid review. *BMC Sports Science Medicine and Rehabilitation,16*, 4. https://doi.org/10.1186/s13102-023-00791-4

Wairimu, N., Elkana, O. E., & Koskei, K. (2022). Development and evaluation of goat milk yoghurt enriched with baobab fruit pulp. *European Journal of Agriculture and Food Sciences,4*(2), 100–106. https://doi.org/10.24018/ejfood.2022.4.2.485

Wasihun, A. A., Sbhatu, D. B., Berhe, G. G., Abay, K. H., & Gebreyohannes, G. (2023). Phytochemical constituents of adansonia digitata l. (baobab) fruit pulp from tekeze valley, tigrai, ethiopia. *International Journal of Analytical Chemistry,25*, 5591059. https://doi.org/10.1155/2023/5591059. PMID: 37920570; PMCID: PMC10620028.

Weaver, C. M. (2013). *Potassium and Health. Advances in Nutrition,4*(3), 368S-377S.

Zhu, J., Bai, Y., & Gilbert, R. G. (2023). Effects of the molecular structure of starch in foods on human health. *Foods,12*(11), 2263. https://doi.org/10.3390/foods12112263

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