Bambara Groundnut for Food Security

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Bambara groundnut is one such imperative and neglected legume crop that contributes positively to improving global food and nutrient safety. As a “complete food”, this crop has recently been treated as a new millennium crop, and furthermore, it is more adjusted to poor soil and climatic conditions than other dominant crops. Bambara groundnut is a repository of vital nutrients that provides carbohydrates, crucial amino acids, proteins, and energy as well as minerals and vitamins to developed and low-income countries where animal proteins are not readily available.

Keywords: Bambara groundnut ; new millennium crop ; food and nutritional security

1. Introduction

Eradicating poverty and malnutrition involves the copious consumption of a balanced diet, confirming that daily uptake of nutritional elements is essential. Despite a greater diversification of agri-based food on the planet, people are used to a monoculture of limited crops for nourishment in their daily diets [1]. However, this may not ensure nutrient security and does not ensure nutrient affectability, accessibility, or availability. In the current era, measures such as poverty, infant weight, and adult obesity have gained increasing attention [2]. With a continuation of the present food production and diet patterns, unfortunately, we will be unable to reach the UN’s Sustainable Development Goal (SDG) of eliminating poverty by 2030. Several issues, such as industrialization, urban expansion, rapid birth rate, insect/pest and disease epidemics, provincial battles, unpredictable weather, and asset reduction, hasten the need for extra food consumption and production [3]. To eliminate poverty and malnutrition and to achieve the UN Sustainable Development Goal by 2030, it is necessary to produce quality foods, especially for low-income countries. To retain food quality and nutritional safety while also attaining the UN’s second Sustainable Development Goals [4], efforts must be directed towards agri-based diets such as minor cereal crops and legumes, neglected crops, underutilized crops, root vegetables, agro-ecology-specified crops, fruits, and whole grains.

About ten thousand years ago, humans invented agriculture for the domestication of wild plants for human use. Globally, population growth rate trends are increasing at an alarming pace, and modern techniques must be introduced to increase production; to upgrade nutrient availability; and to produce disease-, pest-, and insect-resistant crops. Since ancient times, humans have attempted to implement techniques and approaches to heighten production and to protect crops from various diseases by applying conventional methods. Unfortunately, conventional methods are no longer serviceable for current demands. It is advised that the global food stock must be increased by 70% by 2050 to satisfy the requirements of the increasing world population [5].

Global food and nutritional safety has become an important issue owing to over-dependence on, primarily, cereal crops as the principal basis of diets and nutrition [6]. Hence, current production from dominant crops might be inadequate to provide for the predicted population [7]. Furthermore, the dangers that environmental change poses to food safety have become an obvious effect of the temperature variations, prolonged droughts, soil degradation, salinity, flooding, and increases in insect pest and disease severity that significantly impede the development and production of principal food crops. Now, it is important to discover resources to address the genetic inconsistency of crops to accelerate crop production and to produce stock that consequently reduce extreme dependence on an inadequate quantity of food crops as well as to attain world food security [8][9]. Only diversified farming practices can offer a resolution to these obstacles in terms of the establishment, integration, and application of underutilized crops as a strong basis of nutrition to overcome food security challenges [10][11]. Research has shown that concentrated efforts and attention to a limited number of crops with a lack of genetic diversity can have injurious effects on the human diet, leading to malnutrition and/or a food crisis [12].

The Bambara groundnut (*Vigna subterranea* L. Verdc.; Syn: *Voandzeia subterranean* L. Thouars.) is an underutilized legume species widely produced in Africa [13]. This crop is a legume that is cultivated well in Africa and Asia. It is ordinarily regarded as a “poor man’s” crop, and mostly known as a “women’s crop” grown only to achieve family food security [13]. It was also recently declared one of the “crops for the new millennium” [14]. Oyugi et al. [15] reported that the main production activities analyzed in terms of gender involvement, including land preparation activities, planting, weeding, pest control, harvesting, drying activities, threshing, and winnowing, were performed by women. This is the main reason for indicating that this crop is a "women's crop". The Bambara groundnut is considered the third most common major legume after groundnuts (*Arachis hypogea*) and cowpeas (*Vigna unguiculata*) on the African continent. This crop is efficient at promoting nourishment, boosting food assurance, fostering pastoral improvement, and supporting sustainable land uses.

Underutilized Bambara groundnut crops are not classified as commodities in the global trading scheme, and researchers have paid little attention to them because of their low production rank [16]. The cultivation of such crops has a significant effect on food and nutritional protection by providing income to marginal farmers; by reducing the over-reliance on limited crop plants as sources of diet, fuel, and food; and by requiring low input in comparison to conventional agriculture systems [17][18]. Due to its high yield under drought stress conditions, local and marginal farmers still grow Bambara groundnut [19].

As a nutrient-rich legume, Bambara nut is often termed as a "complete balanced diet". Dried Bambara seeds possess carbohydrates (64.4%), protein (23.6%), fat (6.5%), and fiber (5.5%) as well as are rich in micronutrients such as K (11.44–19.35 mg/100 g), Fe (4.9–48 mg/100 g), Na (2.9–12.0 mg/100 g), and Ca (95.8–99 mg/100 g), as reported by Paliwal et al. [20] and Lin Tan et al. [21]. It is underutilized in comparison to other major lucrative crops and is frequently grown on marginal land and in survival farming, and in the majority of cases, women are the primary contributors in the production and processing of these crops [21]. The Bambara groundnut on the other hand, is drought-tolerant, has a healthynutritional composition, and can trap nitrogen from the atmosphere. Bambara groundnut has the potential to help protect our future food and dietary needs in the face of climate change as part of more diverse and resilient agricultural farming due to its intrinsic resistance to stressful conditions and its capacity to generate yield in soils that are too poor for the cultivation of drought-prone species such as peanuts. In the field of agriculture, current technologies and biotechnology have afforded improved genotypes that can persist in a changing world. Knowledge about genetic relatedness among prospective parents is needed for the production of new cultivars. Prior to beginning breeding, morphological and molecular methods must be used to discover information about the genetic gap in parents [22]. Several methods are used in crop advancement to adopt better agronomic characteristics, including mutation, mutagenesis, genome editing, and proteomics profiling. For a plant breeder, the primary intention is to create new, enriched varieties in order to generate genetic differences in the traits of a breeding program. Following the development of such types of variety, it is necessary to identify and then to choose the preferred types among those that provide a greater description of the trait and/or combination of traits. If the targeted desirable traits are established, they must be stabilized and popularized for applications and understanding. However, the influence of the environment on traits, either alone or in combination with the genotype, provide better evidence of the genotype than phenotype inspection alone. Plant breeders must conduct a G × E interaction analysis to validate the stable and superior plant before releasing a commercially improved variety [23].

2. Botanical Description of Bambara Groundnut

Bambara groundnut is a legume that is cultivated in soil-cover situations. Bamshaiye et al. [24] explained that it is an intermediate form, the herbaceous, of the year-round plant, with crawling stems at the earth's surface. The Bambara groundnut plant grows to a height of 30 to 35 cm with a well-developed taproot system and numerous small sidelong stems of one petiole with three leaflets. According to Linneman and Azam-Ali, [25], the roots appear rounded and as rarely lobed nodules due to the symbiotic relationship with atmospheric nitrogen-trapping bacteria such as *Rhizobium, Cholestridium,* and *Azotobacter*. A special A unique feature of Bambara groundnut, according to Toungos et al. [26], is that pod formation begins with a fertilized flower above the soil surface, whereas pods and seeds develop and mature only beneath the earth's surface. Following pollination and fertilization, light yellow flower buds appear on the freely branching stems, which then spread downwardly into the soil, bearing a developing embryo that becomes a seed in the future. [27]. When dry, pods are round, wrinkled, and over half an inch long, bearing one or two oval or round seeds, smooth and multicolor testa, and hard seeds per pod. The typical pod length vs. width and the seed length vs. width of some accessions such as (a) Maikai, (b) Cancaraki, and (c) Giiwa are displayed in Figure 1a–c. When young, Bambara pods are greenish-yellow, turning brownish-yellow or purple when they mature. This plant's stems can be hairy or hairless, and its leaves can be round, lanceolate, or elliptical [27]. The color of the testa varies depending on the seed's ripeness, varying from pale yellow to black, purple, cream, and other shades [28], and the seed's color differs from black, red, or brown to mottled or black-eyed, with or without hilum coloration. Seed color and texture of some accessions such as (a) Duna, (b) Roko, (c) Katawa, (d) Ex-Sokoto, (e) Maikai, (f) Maibergo, (g) Karu, (h) Cancaraki, (i) Bidillali, (j) Jatau, and (k) Giiwa are shown in Figure 2. The hundred-seed weight of Bambara groundnut ranges between 280 g and 320 g [29]. In the roots of Bambara groundnut, the plants produce nodules that trap atmospheric nitrogen (28.4 kg N/ha) in phosphorous (P)-deficient soils but this increased to around 41 kg/ha when P fertilizer was applied, according to Yakubu et al. [30].

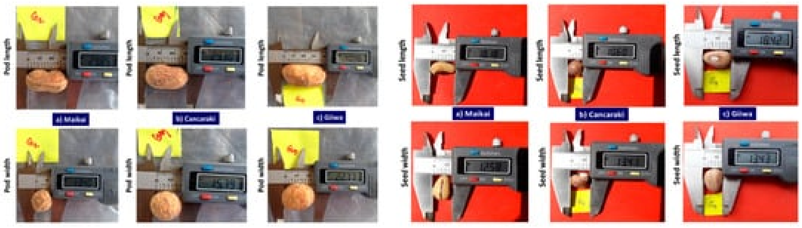

Figure 1. Pod length vs. width and seed length vs. width of some accessions. Legend: (**a**) Maikai, (**b**) Cancaraki, and (**c**) Giiwa (pictured taken from author research (unpublished)).

Figure 2. Seed color and texture of some accessions. Legend: (**a**) Duna, (**b**) Roko, (**c**) Katawa, (**d**) Ex-sokoto, (**e**) Maikai, (**f**) Maibergo, (**g**) Karu, (**h**) Cancaraki, (**i**) Bidillali, (**j**) Jatau, and (**k**) Giiwa (pictured taken from author research (unpublished)).

2.1. Agronomic Attributes of Bambara Groundnut

Typically, Bambara groundnut is a year-round growing plant and its incorporation into an established cropping pattern can improve soil physical conditions [31]. The yield of Bambara groundnut is greatly influenced by sowing date; the optimal time is in early November, recording high yield, rather than late sowing in late December to January [31]. Due to numerous advantages such as high tolerance to drought, the capability to grow in poor fertile soil, and high nutritive features, Bambara groundnut is regarded as a hardy and robust plant [24][32]. Bambara groundnut is a fast-growing plant that does not tolerate freezing temperatures at any stage of its development. Warm temperatures are also ideal for optimal growth [32].

The optimal temperature for Bambara groundnut seed germination is 30–50 °C while the ideal daytime temperature for normal crop growth and development is 20 °C to 28 °C [33]. The regular growth of Bambara groundnut is influenced by the duration of daytime or the photoperiod, which mainly affects the pod set and filling. It is a short-day plant that needs at least 3–5 months of frost-free growth [33]. Due to high temperatures that cause the leaves to die, the biomass yield of this crop is decreased. Bamshaiye et al. [24] reported that this crop can be grown successfully, where the annual rainfall should be less than 500 mm, and that its best growth reaches between 900 and 1000 mm. The plant grows fine in well-drained rainforests and cool moist highlands and can tolerate heavy rainfall, except at the time of maturity. After sowing, seed emergence takes 5–21 days. The plant starts flowering from 30 to 55 days after planting and may continue until the plant dies [34]. Linnemann and Azam-Ali [25] reported that, after fertilization, pods take 30 days to reach their full size and seeds take the following ten days to grow large enough to reach maturity. However, in damp conditions, it may be susceptible to various fungal diseases [35]. Seeds that have been stored for more than a year have reduced viability [31]. Limited irrigation induces early flowering, though pod and grain formation start 30–40 days after fertilization. Fifty percent of flowering starts 86–88 days after planting in well-irrigated situations but while 64–66 days after planting in a rain-fed situation [36]. Loosening and earthing up the soil had a positive effect on pod formation and pod growth under and above the soil surface after successful fertilization and the peg goes into the soil. The pod is usually 17.96–53.54 nm long and contains one or two seeds, 7.54–22.48 nm long [37]. Plant population density should be held between 6 and 29 plants·m^{-2} for optimal growth and development, and it requires mild temperatures, bright sunlight, and evenly distributed precipitation. The best soil for Bambara groundnut production is well-drained sandy-loam soil with a pH of 5.0–6.5, and the seed should be sown 2.5–7.5 cm soil deep [31]. The typical growth and development stages of Bambara groundnut are illustrated in Figure 3.

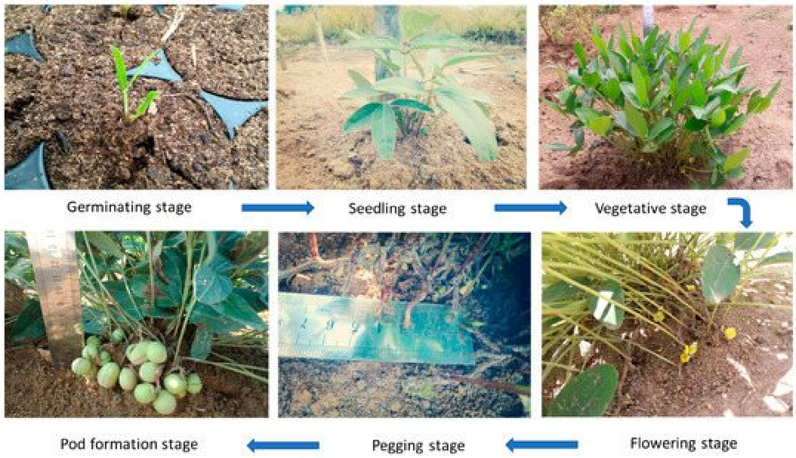

Figure 3. A typical growth and developing stage of Bambara groundnut (picture captured from the author's research field (unpublished)).

3. Potential Uses of Bambara Groundnut for Food Security

Bambara groundnut is used in a variety of ways by local consumers in different countries. A great deal of effort has gone into promoting the use of this crop in various manners. The biggest drawback to using it is that it takes a long time to boil or prepare. Dried Bambara beans take 3 to 4 hours to cook, while green fresh beans take 45–60 min to boil and green nuts can be boiled with salt and pepper and then eaten as a snack by West Africans. [38]. Mazahib et al. [39] reported that shortening the cooking time is the foremost challenge for researchers and farmers. A large number of reports on the use of Bambara groundnut show that grains are very nutritious, which makes them ideal for people who cannot afford to buy the valuable protein in animal products [40]. Green pods and dry nuts as well as grains are processed and refine into a variety of foods. Figure 4 shows some processed and confectionary food items manufactured by the center for the future crop (CFCF) and in different regions of the world such as Indonesia, India, Mexico, and Malaysia [11][41][42][43].

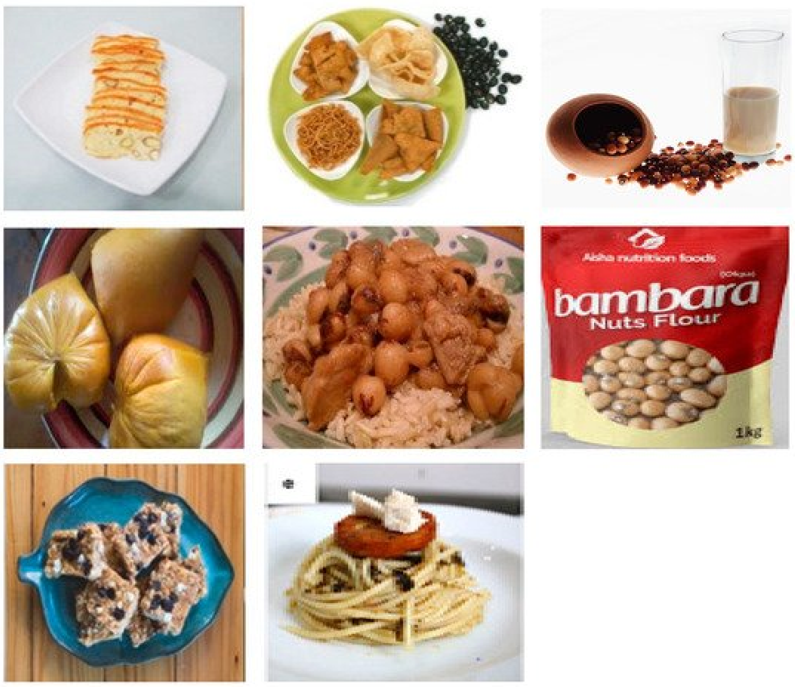

Figure 4. Bambara groundnuts using various processing methods and confectionary food products. Some of the product were made at the center for the crop for future crop, while others were produced from other parts of the world, such as Indonesia, India, Mexico, and Malaysia. All sources of the adopted images are duly acknowledged as follows. Adapted with permition from [11][41][42][43]. Copyright Springer 2019, Science and Education Publishing 2018, Springer 2018, Gregory et al. 2019.

Freshgreen nuts are steamed or grilled and served as titbits [16][32]. Its seeds are very caloric, and flour can be used to make a thick and tiny porridge [8]. Due to their toughness, dehydrated seeds are difficult to crush into powder, but when crushed into powder, delicious bread and flat cakes can be made [18]. The flour of Bambara seeds is used to prepare soup and can also serve as a coffee substitute, as noted by Hillocks et al. [38]. According to Mazahib et al. [39], the Bambara nut can be used as a cooking ingredient by mixing its flour with other components to prepare diverse food items. According to FAO [44], it is used to prepare dumplings. In a formulation stated by Akpalu et al. [45], the seeds are milled into flour and mixed with corn to enhance the conventional diet. Bamshaiye et al. [24] mentioned that different types of porridge and bean cakes (Akara) can be made using Bambara flour solely or by mixing with other cereal flour. The seeds are baked or roasted and consumed with palm kernels in southeastern Nigeria. A brewed gel made from the slurry of Bambara beans is known as Okpa or Ukpa (by the northern cross river) or Moi-Moi (by the Igbos) in Nigeria [46]. Various forms of traditional or indigenous foods were listed by Lin Tan et al. [21] using green young pods, harvested mature pods, and dried seeds of Bambara groundnut (Figure 5). Traditional/indigenous food product(s) in a given community are acquired and processed from bio-diverse plant sources available in their ecology. Most agri-based native foods are low in sugar and fat but are wholesome (whole grains, with dietary fibers) and have high potential for diet diversification. The documentation provided helps to create awareness for the preservation of traditional foods/dishes and beverage culture and as baseline information for further studies for those nutrients and bioactive compounds in which data are not available.

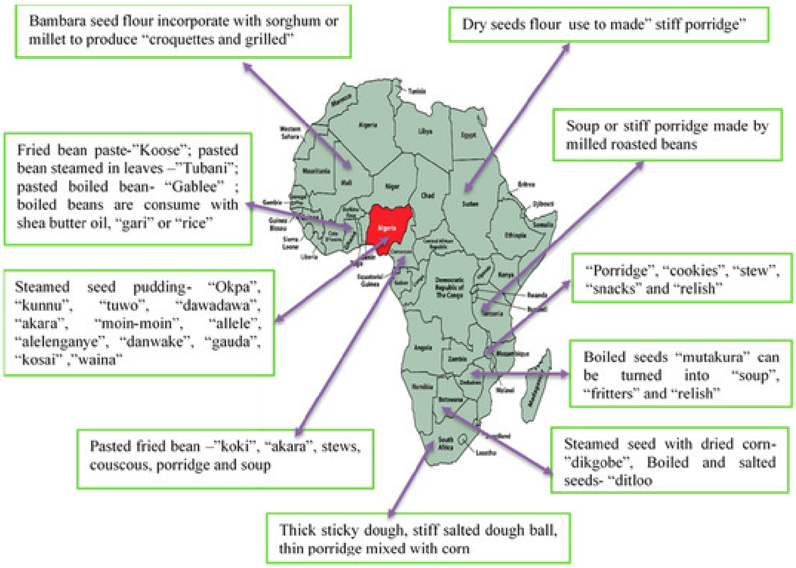

Figure 5. Some traditional or indigenous food or dishes using Bambara groundnut in the different region of Africa (adopted with permition from Lin Tan et al. [21]). Copyright Lin Tan et al. 2020.

According to a study by Bamshaiye et al. [24], milk made from Bambara nuts is identical to soybean milk and is frequently used as supplemental milk for babies in several African countries. Bambara nut milk has a higher acceptance rate than soybean and cowpea milk [47]. Adebanke et al. [48] stated that milk made from soybean, cowpea, and pigeon pea had less appealing flavors than milk made from Bambara groundnut. Supermarkets in Indonesia make a lot of money selling deep-fried snacks made from young Bambara seeds known as "Kacang Bogor" or "Bogor nut", which are in high demand and can also be found in high-end grocery stores in European markets. Mayes et al. [49] suggested that snacks prepared from the Bambara groundnut mixed with the roasted groundnut (*Arachis hypogaea*) are less sticky and are highly delicious. Cooked bananas can be serves as a weaning diet for children, and their nutritional value can be improved by adding Bambara flour [50]. Recent studies on various food processing enterprises have shown that Bambara groundnut can be incorporated into their commodities [48][51]. The Center for Feature Crop (CFC) disclosed strategies for substituting other ingredients into Bambara groundnut recipes [11]. The protein from leaves and Bambara nuts were used as an animal meal, such as to increase the growth of tilapia fish, as reported by Adeparusi and Agbede [52]. The weaning diet is made up of 70% cooking banana and 30% Bambara flour, according to Ijarotimi [53], and is nutritionally sufficient to help children grow and develop. According to a study released by the OECD-FAO-UN [54], protein and energy shortage is a major challenge for public health in developing countries; however, plant protein plays a potential role in global food safety, providing 65% of the world's supply of proteins, with up to 15% of that coming from legumes and with Bambara groundnut contributing 25% of the total protein. Doku and Karikari [55] stated that, in rural areas, Bambara nut has the potential to improve marginal people's food security; however, since Bambara seeds contain a relatively limited amount of oil, though, some people in Congo have been discovered to extract oil from Bambara seeds.

3.1. Health and Medicinal Significance of Bambara Groundnut

Atoyebi et al. [41] stated that, besides the nutritional significance of Bambara groundnut, it also has different physical and medicinal benefits; for example, the water from steamed seeds of Bambara groundnut is used to remedy diarrhea by Lio Kenya's tribe. Lin Tan et al. [21] stated that the macro-nutrient, micro-nutrient, and anti-nutrient components possessed by Bambara groundnut are listed in Table 1. Nutraceuticals, a form of medication used to prevent high blood pressure and oxidative stress, may be derived from Bambara groundnut diets [56]. Bambara groundnut leaves can be used specifically to heal untreated wounds, inflammations, and abscesses, and the sap from leaves can be used to treat epilepsy when applied to the eyes. Raw seeds are chewed and swallowed to control nausea and vomiting in pregnant women [57] in South Africa. In Senegal roots of Bambara, plants are used as an aphrodisiac or herbal remedy and pulverized seeds are incorporated with water to cure cataracts. Hillocks et al. [38] noted that the Igbo tribe in Nigeria applied the Bambara plant in nursing venereal diseases.

Table 1. Major nutritional and anti-nutritional profile of Bambara groundnut seeds.

Macronutrient Depending on Genetic and Environmental Factors, Stage of Maturation, and Method of Analysis	
Carbohydrate	64.4% of total dry seed weight
Polysaccharides and oligosaccharides complex	22 to 49.5% of total dry seed weight
Amylose	19.6–35.1%
Amylopectin	1–2%
Protein	9.6–40% (average 23.6%) Vicilin (7s) and Legumin (11S) reported as major elements of protein
Bambara groundnut protein isolate (BGPI)	Varied from 81.4 to 92.8%
Invitro protein digestibility (IVPD)	70–81% raw BG 82–87.5% cooked BG
Lipids	1.4–9.7%
Fatty acids	Major: oleic and linoleic acid (omega 6); third most: palmitic acid and linolenic acid exist in small amounts
Micronutrients	
K, Ca, Mg, Fe, P, and Zn	Abundant: the handiness of micronutrients was poorly affected by anti-nutritional factors in seeds. The density amount and availability of K, Ca, Mg, Fe, P, and Zn in Bambara grains were affected by a storage system, duration, approach of processing, and the position of trace nutrients (seed coat, hilum, testa, seed leaf, or cotyledon). A red-coated seed contains more Fe than cream- and black-coated seeds.

Macronutrient Depending on Genetic and Environmental Factors, Stage of Maturation, and Method of Analysis	
Phytochemicals	Flavonoids and tannins (generally in seed coat; majorly in dark or red-colored seeds)
Flavonoids	Epicatechin major: in raw red seed Catechin major: in cooked red seed
Proanthocyanins	Polymers of epicatechin and catechin also have neuroprotective, antitumor, cardioprotective, and antioxidant properties (abundant in brown and red seeds)
Fiber	1.4 to 10.3%
Anti-nutrient factors	
Tannins condensed	0.0011–18.61 mg/g
Phytic acid	1.10–15.11 mg/g
Inhibitor trypsin	0.06–73.40 TI mg/g
Pectin	Bind the micronutrients (Ca, Zn, and Fe)
Raffinose and stachyose, flatus causing–alphaoilgosacharides, Saponins, Oxalate, Hydrogen cyanide	Trace amount present in Bambara groundnut

3.2. Role of Bambara Groundnut to Overcome Malnutrition and Nutritional Gap

In previous decades, the Bambara groundnut played a minor role because little to no effort was put into its improvement, nourishment, and exploration of its nutritional values. Since they had not discovered its nutritional profiles, people were blind to and uninterested in this crop development. [24]. Later on, some researchers explored its nutritional content: CHO—63%, protein—19%, oil—6.5%, fiber—4.8 g, ash—3.4 g, and water—10.35 g. Moreover, it contains 367–414 calories per 100 g, which is more than other legumes such as cowpea, lentil, and pigeon pea [31]. Despite the limited oil content, tribes of the DR of Congo extracted considerable amounts of oil from Bambara groundnut seeds locally [58]. Recent biochemical research by Dansi et al. [59] noted that it contains a significant amount of macro-elements (mg/100 g dry weight) such as calcium, 37–128 mg; potassium, 1545–2000 mg; magnesium, 159–335 mg; sodium, 16–25 mg; and phosphorus, 313–563 mg and micro-elements such as copper, 3.0–13.2 mg; iron, 23.0–150 mg; zinc, 13.9–77.0 mg; beta-carotin, 10 µg; thiamin, 0.47 mg; riboflavin, 0.14 mg; niacin, 1.8 mg; and ascorbic acid traces. The essential amino acids per 100 g are tryptophan, 192 mg; lysine, 114 mg; methionine, 312 mg; phenylamine, 991 mg; threonine, 617 mg; valine, 937 mg; leucine, 1385 mg; and isoleucine, 776 mg [59]. A pilot-feeding project was introduced to eliminate infant malnutrition by preparing agri-based milk, such as soybean milk, peanut milk, cowpea milk, and Bambara milk, while researchers and consumers ranked Bambara milk first for its odor, color, and nutrient profile [31]. Due to its high protein content, this crop has the potential to challenge global food shortages and malnutrition in the future. Recently, people have veered away from animal protein due to its high cholesterol content and high prices; thus, Bambara groundnut has the potentiality to contribute up to 25% protein and to be a substitute for animal sources. People must consume 60 to 100 g at least 3–4 times per week to obtain the necessary amount of protein from plant sources [31]. Bambara groundnut is unique in its potential to minimize the nutrition gap, to reduce food insecurity, to alleviate hunger, and to ensure agricultural productivity and food production as well as to ensure agricultural sustainability in developing countries.

3.3. Anti-Nutritional Ingredients in Bambara Groundnut

Generally, legumes possess a considerable number of anti-nutritional components such as phytate, tannic acid, phenolics, and additional complexes that can reduce the nutritional value by rendering some elements unable to be metabolized entirely or partially. During famine [60], anti-nutrient factors such as the amino-acid β-N-oxalyl-α, ODAP (β di-amino propionic acid), in pulse crops (grass pea; *Lathyrus sativus*) may cause paralysis when eaten as the only staple food source. Easy and simple strategies such as fermentation, germination, soaking, drenched, cooking, and dehulling can effectively decrease anti-nutrient factors and can improve food safety [41][61]. Ijarotimi and Esho [62] stated that fermentation improved the mineral structure but had a small effect on amino acid content and reduced non-nutrient components such as tannin, trypsin, oxalate acid, and phytic acid, According to Ndidi et al. [40], anti-nutrient factors such as phytate, oxalate, hydrogen cyanide, and trypsin inhibitors exist in more than the allowable limit in raw Bambara groundnut, which can be greatly reduced to a tolerable limit through steaming and roasting. The processing of Bambara nut flour with 60% alcohol may reduce the anti-nutrient components while also lowering flatulence-inducing sugars, as stated by Alain et al. [63].

3.4. Processing of Bambara Groundnut

After harvesting, sun-drying is an effective way for long-term preservation of seed. Before cooking or eating, the dried seed may be rehydrated by water or pulverized into flour. Most of the traditional pretreatment methods increase or decrease the nutritional quality of Bambara groundnut seeds. According to the discussion by Lin Tan et al. [21], here, some of the approaches for Bambara groundnut processing are stated. Dehusking is a tedious operation among the post-harvest activities due to its very hard nature; for convenience, mechanical defusing is effective. Dehulling is a separation of the testa, seed coat, or hilum from the seed cotyledon. A significant number of antinutrients exist in testa; removing them can increase nutrient content and digestibility. Milling is the process of grinding the Bambara seeds into a powder, but in the household condition, it is extremely tedious due to its “hard to mill” phenomenon. Milling can incorporate micronutrients and anti-nutrients, resulting in a reduction in mineral obtainability. Soaking is the typically dried seed of Bambara being saturated in water for 12–24 h as a pre-cooking treatment. Soaking at 60 °C enhances the water absorption rate and increases the dehulling potentiality without physical losses in the soaked seeds. Sprouting is a pretreatment keeping the seed at low temperatures or saturating it in water for up to 3 days. During sprouting, the CHO and lipid content are degraded while the amino acid and protein profiles are upgraded. Sprouting ensures the reduction in anti-nutrients such as saponin, oxalate, oligosaccharides, tannins, and trypsin and, at the same time, helps dehulling by splitting the seed coat during germination or malting. Boiling is the process of cooking Bambara nuts in excessive water for various durations of time. Usually, the cooking period depends on the measures followed during harvesting to storage. Cooking with boiled water ultimately breaks down the cell skeleton; denatures the proteins, carbohydrates, and water-soluble minerals; and drains the anti-nutritional factors with increasing nutrient solubility, availability, and digestibility. Fermentation is a low-cost approach in Bambara groundnut processing consisting of 96 h of soaking in water, followed by dehulling, cooking, and covering with banana leaves before the fermentation process. It helps in the conversion of flatus, causing oligosaccharides and polysaccharides to become digestible monosaccharides with the depletion of phenols and anti-nutritional factors. Yogurt from Bambara milk was also prepared by the fermentation process, which improves the protein quality and digestibility with a lower phytate profile. However, the application of several approaches of Bambara nut processing harmful and beneficial impacts on diet and nutrient safety. Additionally, besides old-style processing of Bambara groundnut, there are some advanced approaches such as irradiation, autoclaving, pressure cooking, and infrared heating that can be implemented to process the Bambara nuts but need skilled personnel and sophisticated tools, usually convenient only in a large-scale commercial manner.

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