Nutraceutical and antimicrobial potentials of Bambara groundnut (Vigna subterranea): A review

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ABSTRACT

Bambara groundnut (Vigna subterranea (L.) Verdc.) [BGN] is an easy-to-cultivate vegetable crop neglected over the past years. It is a drought-tolerant crop with nutritional and medicinal values and as a result, the crop is referred to as nutraceuticals. Based on this, there exist a need to review the beneficial potential (nutraceutical value) of this neglected and underutilized crop to protect and promote its cultivation for food (source of nutrients) and medicines especially among rural poor communities in sub-Saharan Africa. This review systematically examines the background information and uses of BGN. The antimicrobial properties of BGN were also considered and examined to ascertain its nutraceutical importance. BGN has been reported as a crop possessing antioxidant and antimicrobial properties. Clinically, the extracts of BGN have been reported to exhibit antimicrobial activities against bacteria such as Klebsiella pneumoniae subsp. pneumoniae ATCC 700603, Pseudomonas aeruginosa ATCC 27853, Staphylococcus aureus subsp. aureus ATCC 33591, Escherichia coli, Bacillus cereus, yeast (Candida albicans) and mold (Aspergillus niger). This review outlines the uses of BGN as a functional food crop as well as its nutraceutical and antimicrobial potentials. However, there exist paucity of knowledge and literature on the crop's antimicrobial activities especially against plant pathogens of economic importance. Hence, this review proposes that more research be geared towards assessing the nutraceutical value and antimicrobial potentials of this crop against plant pathogens of economic importance and the promotion of the crop's cultivation.

1. Introduction

Leguminous plants are known for their nutritional value and economic significance in the world [1]. Even though legumes are regarded as the poor man's meat, they play a crucial function in the diets and wellbeing of humans especially in poor rural African communities in sub-Saharan Africa because of the high protein and carbohydrates content and assorted phenolic compounds being released when consumed (cooked or uncooked) [2]. Carbonaro et al. [3] reported that legume seeds contain proteins and peptides that could be grouped as nutraceuticals. According to Pandey, Verma, & Saraf, [4], nutraceuticals are synthetic substances or chemical compounds (usually concentrated in powder, capsule or pill form) that can provide therapeutic or wellbeing benefits to humans, including the promotion of disease prevention and treatment. Sasi [5] refers nutraceuticals as any functional food extract with health and medical benefits especially to humans. Also, López-Gutiérrez et al. [6] reported phytochemicals as non-nutritive compounds in plants with disease-preventive properties. Plant-based nutraceuticals have drawn the attention of most researchers in recent years due to the presence of a vast variety of phytochemicals (some undiscovered) with health benefits and disease-preventive properties.

One of the major causes of premature death killing about 50000 people daily in the world is infectious diseases [7]. Due to the resistance of human pathogenic microbes to drugs, a subsequent rise in the infectious diseases has been reported leading to increase in mortality rates [7]. This has resulted in an increased pursuit for plants phytochemicals with the potency to inhibit the proliferation of microbes that have shown or developed resistance to conventional drugs or antibiotics. Plants with one or more of their organs containing bioactive compounds that can be used to synthesize drugs are referred to as medicinal plants according to the World Health Organisation [8]. Vats et al. [9] reported that plants are used traditionally as antimicrobials. Hence, plants could be regarded as alternatives to the cure of infectious diseases as the incidence of microbes resistant to antibiotics has been on the increasing side.

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Bambara groundnut [BGN] is mainly cultivated for its seed in most rural areas in sub-Saharan Africa [10]. Mayes et al. [11] reported BGN as a crop that researchers have ignored despite its nutritional value. This could be attributed to less knowledge of the plant's phytochemical composition and their associated nutraceutical properties including its antimicrobial and antioxidant potentials. In sub-Saharan Africa, BGN is grown locally to sustain families by providing a source of protein, carbohydrates and nutrients (functional food) and income for households especially in rural communities [12]. Bambara groundnut has been a research focus as a functional food alternative as well as characterisation of its phytochemical properties since the identification of its nutritional and nutraceutical values. For example, Bambara groundnut cultivars from Zambia were reported to exhibit antioxidant potency similar to lentils, common beans and chickpeas [13]. Furthermore, the presence of flavonoids, tannins and alkaloids in BGN cultivars were found in Nigeria and the alkaloids were reported to possess analgesic properties [14]. In addition, work done by many other researchers has shown that BGN possess antioxidant and antimicrobial properties and are used to treat many ailments [15, 16, 17, 18, 19]. However, literature is scant on the uses and potential nutraceutical and antimicrobial properties of BGN especially against plant pathogens of economic importance. Therefore, this review examined the background information on the cultivation and uses of BGN. The nutraceutical and antimicrobial properties of BGN were also considered and examined to ascertain the medicinal uses of the plant especially its antimicrobial potentials for control and management of both human and plant pathogens.

2. Bambara groundnut description and cultivation

Bambara groundnut (BGN) is a native crop widely cultivated in most countries in sub-Saharan Africa. In sub-Saharan Africa, the countries where BGN is widely grown cut across different agro-ecological regions in the continent including the west, central, east and southern sub-regions [20, 21, 22, 23]. The crop is an indigenous African legume that belongs to the family and sub-family of Fabaceae and Faboidea respectively. The common names of BGN vary across the continent. In Nigeria, it is called Okpa (Igbo speaking part) and Gurujua (Hausa speaking part), Njugo in South Africa, Nzama in Malawi, Ntoyo in Ci Bemba or Katoyo in Zambia [24]. Stephens [25] also indicated that BGN is also known as voandzou nzama (in Malawi), baffin pea, indhlubu, and underground bean.

Bambara groundnut is an annual leguminous plant [26, 27] with strong taproot and trifoliate leaves that have long and green petiole [27]. Massawe et al. [28] pointed out that the flowers are borne on long, hairy peduncles arising from the stem nodes. The plant has oval or spherical pods that are about 3.0–3.7 cm long [29]. Bambara groundnut landraces comprise of many genotypes with diverse strength to endure environmental pressure [27, 29, 30]. The developmental period of the plant ranges from 110-150 days under a mean temperature of 20–28 °C, well-drained soil and sandy loams with 5.0–6.5 pH values [27]. Bambara groundnut seed colouration varies from black, brown or red and sometimes stippled with numerous colours [22, 31]. The hulls are often removed before they are consumed. The removed hulls are regarded as a waste product. However, the work done by Klompong and Benjakul [18] has shown the hulls to be a source of nutraceuticals and functional ingredients. BGN is free from complete crop failure because of its ability to thrive well under harsh environmental stress conditions like low and uncertain rainfall and nitrogen-deficient soils [30, 32, 33].

The plant is capable of surviving in wet climates, and poor-nutrient soil conditions that most non-leguminous plant may not survive [31]. Tibe et al. [34] indicated BGN as a pest, disease, and drought-resistant crop capable of reducing pest in the field. The ability of BGN to fix atmospheric nitrogen through the process of biological nitrogen fixation reduces the necessity to apply manures or expensive environmentally unfriendly synthetic fertilizers especially in nutrient-poor soils in Africa, where the crop is cultivated by resource-poor farmers. This nitrogen-fixing ability of BGN was supported by work done by Mohale et al. [35] on the symbiotic nitrogen (N) nutrition efficiency of BGN grown in the Lowveld region (Mpumalanga Province) in South Africa. The authors found that BGN was significantly dependent on symbiotic fixation (4–200 kg N-fixed ha⁻¹) for its N nutrition and contributed N (33–98%) to the nutrient-poor soils in the region [35]. In the dry savannah regions in sub-Saharan Africa, BGN is a point of interest for utilization and cultivation. In Botswana, 90% of farmers (majority are women) cultivate BGN and 63% of the farmers grew the crop for consumption, 12% of them grew the plant for making a profit and 25% for both feeding and making a profit [36]. Based on the crop's ability to thrive well in harsh conditions such as poor-nutrient soils and drought under future climate change scenarios, the crop is seen as a poverty and poor nutrition remediation crop that can enhance food and nutrition security especially in poor rural communities in sub-Saharan Africa.

3. Bambara groundnut nutrition and uses

Bambara groundnut serves as a source of protein to the consumers and is grown locally by the rural population to provide food for their immediate families especially in most countries in sub-Saharan Africa. The works done by researchers have shown that seeds of BGN per 100 g dry weight may contain carbohydrates (49–63.5%), protein (15–25%), fat (4.5–7.4%), fibre (3.2–4.4%), ash (0.7%), and cholesterol (0.01%) [24, 31, 37]. Mwale et al. [12] pointed out that the protein content of BGN is comparable to other legumes and as a result, it is regarded as a worthy supplement for cereal-based diets. Sesay [38] further pointed out that BGN is a source of protein, and carbohydrates to consumers (thus servings as a functional food), and additional income to subsistence farmers in rural areas in most West African countries. The fruits of BGN are produced underground and the pods containing at least one or two seeds are noticeably hard and wrinkled when dried. The dried seeds can be boiled and consumed as a functional food. Further, the food crop can be consumed matured as porridge [22] or immature form as a snack after roasting with a tincture of salt [25]. The seeds’ chemical content makes them nutritious and a complete food [32, 39, 40].

Biochemical composition of the seed has been reported by many researchers [39, 40, 41, 42, 43, 44]. Although the seed is reported to have little fat, some parts in Congo still extract oil from the seed [45]. Bambara groundnut is roasted, crushed and used in food making without condiments in East Africa [45, 46]. Some of the Zambia bread is made from BGN flour [47]. In Botswana, the nuts are used in making cakes and stiff porridge [43, 45]. Goli et al. [45] also reported the use of BGN flour in making steamed products like “okpa” in Nigeria. Murevanhema and Jideani [48] clarified “okpa” as a cooked mixture like gel produced using BGN paste enveloped by banana leaves and bubbled till prepared for utilization. Further, Heller et al. [26] revealed the application of matured black landraces seed for medicinal purposes. Vegetable milk produced from BGN was ranked first in flavour and composition; and the lighter colour of the milk was more preferred than cowpea, pigeon pea, and soybean milk [32].

Generally, most legumes are noted to possess antioxidants [48]. White and Xing [49] reported antioxidants as ingredients with the potential of protecting the quality of food by impeding the oxidative breakdown of lipids. Furthermore, Adelakun et al. [50] referred to antioxidants as ingredients that protect the cells and tissues of human against free radicals (reactive oxygen/nitrogen species (ROS/RNS)). The seed coats of most leguminous nuts are rich in antioxidants, and differences in amounts of antioxidants in the dark-seeded and light-seeded landraces of BGN have been reported [49]. Onyilagha et al. [51] reported that the red and black seed coat of BGN contains antioxidants whose antioxidative mechanisms were different from other legumes and were noted to contain more nutrient and mineral content than the light-seeded landraces. In Botswana, the light-seed landrace is preferred for consumption because of less time to cook and superior flavour while the dark-seeded landrace is used to treat impotence [48]. Interestingly, in Africa, BGN is
used by different tribes for the treatment of different diseases. For example, some tribes used BGN to treat nausea and diarrhoea (in Kenya [16], venereal diseases (in Nigeria) [48], nausea and vomiting in pregnant women (in South Africa) [15] and cataract (in Senegal) [48]. In summary, BGN has different usages, which includes provision of functional foods (nuts and minerals) and health benefits (due to their antioxidant properties) for humans and animals, and as a commodity to generate income or financial support for people in rural communities in sub-Saharan Africa. Hence, there exists the need to preserve and promote the growth of this crop for the continuous supply of the crop’s benefits to the populace in most rural communities in Africa.

4. Bambara groundnut nutraceuticals

The progressive increase in the resistance of microorganisms to recently available antibiotics has prompted the quest for effective and novel antimicrobial compounds. This quest for effective antimicrobial compounds has directed researchers to focus on plant-based medicine because of their historical use for curing infectious and non-infectious diseases especially in developing and under developed countries [52]. Rojas et al. [53] pointed out that these medicinal plants are consumed as elixirs, teas, or juice preparations for respiratory infection treatments. Works done by many researchers [53, 54, 55, 56] have shown these medicinal plants as major sources of antimicrobial, antioxidant and anticancer compounds that can be used to produce new antibiotics that pathogenic microbes are not resistant to. For example, Kumar et al. [57] examined five leguminous plants (Kingiodendron pinnatum, Humboldtia brunonis, Indigofera cassioides, Derris scandens and Ceasalpinia mimosoides) for anti-tubercular activity and observed that the legumes contained saponins, steroids, anthroquinones, terpinoids, flavonoids and phlabonoids that showed potential for anti-tubercular activity.

The findings of some researchers [8, 45, 58] have shown that Gram-positive bacteria were more susceptible to extracts from plants than the Gram-negative bacteria. Gao et al. [45] reported that the ability of Gram-negative bacteria to resist plant extracts is an attribute of the bacterial agent’s mechanism of action is through the penetration of the cytoplasmic membrane, disruption of the permeability of the membrane leading to the destruction of the membrane [63]. Consequently, cytoplasm leakage and coagulation occur causing the deformation, lysis and death of the cell [64]. In fungi, this agent prevents mycelial growth and spore germination [65]. The hydrophilicity and hydrophobicity of BGN phytochemicals enhance its accumulation in cell membranes leading to the change in permeability of the membrane, seepage of intracellular components, weakening enzyme systems of microbes and consequently, their death [64]. Clearly, the antimicrobial activities of BGN depend on the concentration of the extract and nature of tested organisms. However, no study has so far quantified the dosage of BGN extracts for treatment of any human disease in sub-Saharan Africa.

The use of BGN traditionally to treat many human diseases is prominent across sub-Saharan Africa countries (South Africa, Botswana, Kenya, Nigeria and Senegal) and therefore provides many opportunities for more study on the therapeutic importance and application of the crop [17]. Several authors [59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72] have reported the presence of phytochemicals with antioxidant properties in legumes, and in particular, higher amounts of phenolic compounds including nutraceutical and functional ingredients have been found in the hull of BGN compared to other parts of the plant [67]. Table 1 summarises the nutraceuticals reported to be present in BGN and their functions. It is noted that the pre-processing techniques and

Table 1. Summary of the nutraceuticals in BGN and their functions.

| Nutraceuticals                      | Functions                              | References                  |
|-------------------------------------|----------------------------------------|-----------------------------|
| Alkaloid compounds (e.g. 9-Octadecenamide, Zα), ethanol 1- methoxy-benzoxate, 1-Monolinoleoylglycerol trimethylsilyl and ether butylated hydroxytoluene) | Antimicrobial and antioxidants activity | Taahir [59] |
| Flavonoid compounds (e.g. rutin and myricetin), Tannin compounds (e.g. chlorogenic acid and elagic acid) | Anti-inflammatory activity, oestrogenic activity, enzyme inhibition, antimicrobial activity antiallergic activity, antioxidant activity, vascular activity and cytotoxic antitumour activity | Cushnie and Lamb [66] Taahir et al. [67] |
| Sphingolipids                       | Involved in protein sorting, apoptosis and calcium regulation | Spassieva and Hille [68] Tsamo et al. [69] |
| Fatty acids                         | Anti-inflammatory, antimicrobial and cytotoxic Activities | Tsamo et al. [69] Farag et al. [70] |
| α-Ferulic acid                      | Exhibits a wide variety of biological activities such as antioxidant, anti-inflammatory, antimicrobial, antiallergic, hepatoprotective, anticarcinogenic, antithrombotic, increase sperm viability, antiviral and vasodilatory actions, metal chelation, modulation of enzyme activity, activation of transcriptional factors, gene expression and signal transduction | Nyau et al. [71] Kumar and Pruthi [72] |
| p-Coumaric acid                     | High free radical scavenging, anti-inflammatory, antineoplastic, and antimicrobial activities | Nyau et al. [71] Ferreira et al. [74] |
| Catechin and Epicatechin             | Involved in antioxidant activities | Nyau et al. [71] Bernatoniene and Kopustinskiene [75] Schwarz et al. [76] |
| Salicylic acid                      | Performs anti-inflammatory functions through suppression of transcription of genes for cyclooxygenase | Nyau et al. [71] Randjelovic et al. [77] |
extraction methods can affect the concentration and type of polyphenols in BGN [73]. For example, boiling dry beans have been reported to reduce the polyphenolic content (protease inhibitors) by 80–90% and treatment with 60% ethanol improved the nutritional quality of BGN flour and dehulling was reported to reduce the tannins content by up to 92% [67].

Cooking red BGN was reported to enhance its nutraceutical properties, and limited works have been done on the nutraceutical value of the crop and its potential to discover more novel phytochemical components of BGN. Therefore, there is need for more research geared towards assessing the nutraceutical value and antimicrobial potentials of this crop.

5. Conclusion

There is an increasing knowledge of the benefits of nutraceuticals which have attracted the interest of researchers globally. Although limited works have been done on BGN, some works done on BGN have demonstrated their potentials as a source of nutraceuticals. This review examined the uses of BGN and found that the crop has varieties of uses which cut across medical and nutritional uses. However, it was noted that limited works have been done on the nutraceutical value of the crop and the effect of pre-processing techniques and extraction methods of optimisation to fully utilise the nutraceutical potential of BGN. Therefore, there is need for more research geared towards assessing the nutraceutical value and antimicrobial potentials of BGN.

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Author Contribution statement

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The authors declare no conflict of interest.

Additional information

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