Medicinal Uses, Nutraceutical Potentials and Traditional Farm Production of Bambara Beans and Pigeon Pea

Oluwatoyin B. Oluwole[1,*], Viola A. Nwachukwu Nicholas-Okpara[1], Gloria Elemo[2], Olubamike Adeyoju[3] , Deborah Ibekwe[1] and Maryam Olanshile Adegboyega[1,4]

[1]Department of Food Technology, Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria, [2]Department of Chemical Sciences, Faculty of Natural Sciences, Ajayi Crowther University, Oyo State, Nigeria, [3]Production Analytical and Laboratory Management Department, Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria and [4]Animal Science Department, University of Benin, Edo State, Nigeria

Abstract: Bambara groundnut (BGN) [Vigna subterranean (L) Verdc] and Pigeon pea [Cajanus cajan (L.) Millspaugh] are grain legume species grown in tropical and subtropical parts of the world. Both legume grains are highly nutritious and have been used as food and medicine for both humans and animals. However, Bambara groundnut and pigeon pea are still highly underutilized and produced in low quantities despite their nutritional benefits. This review examines nutritional properties, medicinal uses, nutraceutical potential and the limitations in the utilization of bambara groundnut and pigeon pea. Scholarly articles and organization white papers were searched for using various word combinations of traditional farm practices, modern agricultural practices, traditional medicinal uses, nutritional composition, biochemical composition, Bambara groundnut and pigeon pea. Bambara groundnut and pigeon pea are popularly used as medicine in many parts of Africa. Both species are rich sources of bioactive compounds and several studies have documented their efficacy against several diseases. Bambara groundnut has been used to treat polymenorrhea, venereal diseases, cataracts, and morning sickness. The stem, leaves, seeds, and roots of pigeon pea plant has been used to treat many diseases in many parts of the world. Bambara groundnut has been found to be a potential dietary probiotic, antioxidant, antibiotic and anticancer. Hypocholesterolemic, anticancer, hepatoprotective, antidiabetic and antimicrobial activities have been documented for pigeon pea as well. However, low yield, unfavourable land tenure systems, unimproved varieties, diseases, and pests are the major constraints of the traditional production of bambara groundnut and pigeon pea. Both legume grain species are important sources of nutrients and they both possess strong potentials to be nutraceutical agents against many diseases including malnutrition. However, advanced and intensive research on pest management, improvement of the traditional landrace cultivars for improved yield and palatability as well as formulation of favourable land tenure policies are recommended for better adoption, utilization and commercialization of bambara groundnut and pigeon pea.

Keywords: Medicinal Uses, Nutraceutical Potentials, Crop Production, Bambara Groundnut, Pigeon Pea.

INTRODUCTION

Pulses or grain legumes represent a significant component of human diets especially in economically developing nations [1]. In Sub-Saharan Africa, pulses serve as food and feed of important dietary value, fuel, source of income, source of soil fertility and even used as medicine [2, 3, 4]. Grain legumes are a major source of dietary protein in a typical African diet. Moreso, Africa also has a great diversity of grain legume species but many of them are still understudied and underutilized. Two of such species are Bambara groundnut and pigeon pea.

Bambara groundnut (BGN) [Vigna subterranean (L) Verdc] is a hardy legume grain which originates from Africa [5]. It is the third most important pulse grown in Semi-arid Africa after cowpea (Vigna unguiculata) and peanut (Arachis hypogea) [6]. BGN is adaptable to marginal land with little nutrient requirement and it is mainly produced by subsistence farmers [5, 7]. The plant is grown majorly for its edible seeds which are highly nutritious and are considered complete food [8, 9]. The seeds contains of 49%-63.5% carbohydrate, 15-25% protein, 4.5%-7.4% fat, 5.2%-6.4% fiber, 3.2%-4.4% ash as compared to cow milk with 4.8% carbohydrate, 3.2% protein, 3.4% fat, and 0.7% ash [9]. The seeds are often salted and boiled or grilled as snack [9]. In the Eastern parts of Nigeria, the seeds are pounded to flour, mixed with oil and seasoning, and boiled to make a popular delicacy known as Okpa [10]. Milk extracted from soaked and homogenized BGN seeds ranked higher in acceptability compared to other legumes such as soy milk and cowpea milk [9]. BGN have also been used for its therapeutic properties. The seeds have been reported to possess remedial effects on typhoid, diarrhea, sexually transmitted diseases, menstrual disorders, morning sickness and inflammatory diseases in different parts of Africa [11]. Due to the remarkably high soluble fiber content, Kone et al., [11] mentioned that that BGN is believed to prevent colorectal cancer and coronary heart diseases.

Pigeon pea [Cajanus cajan (L.) Millspaugh] is a protein rich legume grain popularly cultivated in the tropical and subtropical parts of the world [12]. The pigeon pea plant is a multipurpose plant [13]. It is cultivated for its edible and nutritious seeds which are popularly used in the Indian cuisine [13]. According to FAO [14], Pigeon pea seed is nutritionally composed of 68% carbohydrate, 20-22% protein, 1.2% fat and 3.8% ash content. The seeds and leaves are excellent feed with high nutritional quality for poultry, cattle, pigs, and fishes [13, 15]. Its woody stalk serves as fuel, used in basket weaving and thatching [16]. Pigeon pea contains stilbenes, flavonoids and other organic compounds that are used as important medicines. The pulse has been reported to possess antibiotic, hypocholesterolemic, antiplasmodial, antioxidant, anticancer, glycemic, antidiabetic and hepatoprotective effects [17]. Also known as red gram or dhal, Pigeon pea originates from India, where the largest production of the pulse takes place [16]. In Sub-Saharan Africa, Malawi, Tanzania, Kenya, and Uganda are the major producers of Pigeon pea [16]. Pigeon pea is a negligible pulse in West Africa but plays an important role for low income farmers in Benin, Ghana, and Nigeria [18].

Department of Food Technology, Federal Institute of Industrial Research, Oshodi, Lagos, Nigeria; Email: oluwatoyinoluwole575@yahoo.com

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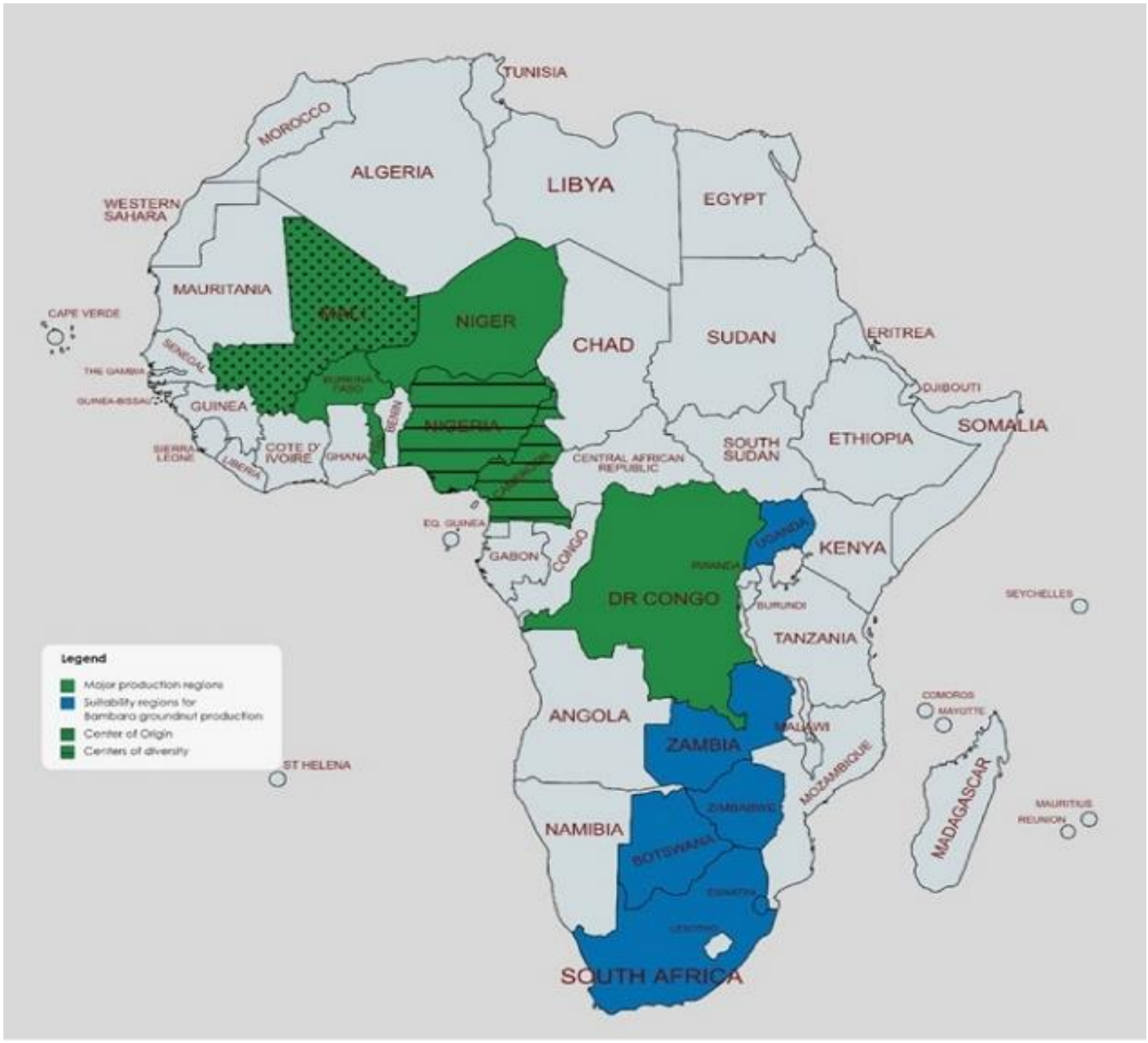
Despite the numerous benefits of these crops, Bambara groundnut and pigeon pea remain neglected, highly underutilized, multipurpose grain legumes among many others in Africa [19]. Based on various existing evidence, the medicinal uses, nutritional composition and nutraceutical potentials and constraints in the utilization of Bambara groundnut and pigeon pea are discussed.



Green- Major production regions
Blue- Suitability regions for Bambara groundnut production
Dotted green- Center of origin
Striped green- Centers of diversity

Figure 1: Distribution of Bambara groundnut production in Africa [20].

Figure 2: Split pigeon peas [21].

METHOD

Web search engines such as google and google scholar and databases such as Scopus and science direct were used for literature search using various word combinations of 'traditional farm practices', 'modern agricultural practices', 'traditional medicinal uses', 'nutritional composition', 'biochemical composition', 'Bambara groundnut' and 'pigeon pea'. Review articles, original studies and organization white papers focused on the traditional and modern agricultural practices, traditional medicinal uses, nutritional and biochemical composition of Bambara groundnut and pigeon pea were collected and reviewed. Relevant articles cited in reviewed studies were collected and reviewed as well.

RESULTS AND DISCUSSION

Bambara Groundnut

Traditional farm Production of Bambara Groundnut

Bambara groundnut is a prostate creeping plant with its pods found buried in the soil. Depending on the variety. They are three known varieties of BGN. They are spreading, bunched and semi-bunched varieties.

Bambara groundnut is cultivated in Botswana, Togo, Burkina Faso, Cameroun, DR Congo, Mali, Zimbabwe, Zambia, Ghana, Niger, Chad, and Cote d'ivoire [22]. Nigeria is the center of origin of BGN but its production falls behind cowpea (Vigna unguiculata), peanut (Arachis hypogea) and soybean (Glycine max) since it is majorly grown in low quantities by subsistence farmers [23]. Adamawa, Yobe, Bauchi, Borno and Taraba are the major producers of BGN in Nigeria [22]. Smallholder farmers in Kogi state of the North central have also been reported to grow BGN as a cash crop [23].

Figure 3: Bambara groundnuts [24]

BGN is propagated with seeds. A qualitative review [25] revealed that local farmers in Ghana acquire their first seed stock through inheritance, from other farmers or in the local markets. In Nigeria, several varieties exist, and farmers can tell them apart by their appearances and a preferred strain has been chosen and maintained by the community over a long period [22]. BGN is predominantly intercropped with yam, cassava, peanut, maize, millet, and cowpea in Nigeria [22]. Ibrahim et al. [26] reported that only 1% of BGN farmers in Western Niger practiced mixed cropping system. Monocropping of BGN was also reported to be common in the Wa district of Ghana [25].

BGN landraces are grown in different colours ranging from black to purple to brown to red to yellow, cream then white [27]. In many parts of Sub-Saharan Africa, both farmers and consumers have shown stronger preference for lighter coloured seed coats in Bambara groundnuts. Berchie et al., [28] found that both farmers and consumers preferred BGN with white seed coats. This is on par with studies that farmers in Ghana [29], Niger [30], Nigeria [31] and Cameroon preferred the white, yellow, cream, and Ivory white landraces respectively.

BGN grow well on acidic laterite soils, commonly found in Africa [32]. In Nigeria, BGN is mainly grown on flat grounds but in some cases on mounds and ridges. In Ghana, Anchirinah et al., [25] reported that planting on flat beds and mounds or ridges were predominant in the Nadowli and Wa district, respectively. One grain is planted per hole on a row with plant spacing usually at farmer's discretion [23]. Farm sizes used for cultivation of BGN ranges between 0.25-1.0 hectare in the North east and about 0.5 hectare in the north central part of Nigeria under mixed cropping system [23, 22]. Ibrahim et al., [26] documented that BGN farm sizes ranged from 0.2-2.0 hectares with an average of 0.8 hectares while Berchie et al., [33] documented an average of 1.1 acres of farmland for the cultivation of BGN. Planting companion crops a little before BGN were documented in Ghana, Niger, and Nigeria [22, 26, 25]. In many parts, fertilizers and manure are not used because they are costly and not accessible to remote farms [32]. Harvesting of ripe, underground BGN pods is reported to be 4 months after planting [22]. Harvesting is by uprooting stands and detaching pods from roots and Ogwu et al., [32] recommended harvesting before full foliage drying.

Yield is mostly dependent on photoperiod response, time of planting and cultivar. Ogwu et al., [32] stated that BGN is a short-day crop and longer photoperiod affected the development and flowering of BGN. Mkandawire [34] and Ogwu et al., [32] reported yields in Semi-arid Africa to be between 500-800kg per hectare. Touré et al., [35] documented yield of 79 - 495 kg per hectare from 10 landrace cultivars in Ivory Coast. Low yields of BGN used in studies were justified with high humidity from heavy rainfall during planting season. On contrary, Berchie et al., [33] documented yields as high as 4 tonnes per hectare in agro transitioning areas in Ghana. The study found that yields from certain landraces are higher in forest zone with minor rainfall and higher temperature.

Harvested pods are dried and threshed, stored, or sold in the market as pods or seeds [32]. Farmers also collect and store planting materials for the following season as pods to protect from insect infestation [33].

Table 1: Traditional treatment of some diseases with Bambara groundnut in Africa.

Disease	Country	Reference
Sexually transmitted diseases	Nigeria	[11]
Nausea	Kenya, South Africa, Zimbabwe	[36], [9]
Wounds	Senegal	[37]
Cataract	Senegal	[38]
Menorrhagia	Cote d'voire	[36]
As an aphrodisiac	Zimbabwe	[39]
Epilepsy	Senegal	[37]
Anaemia	Zimbabwe	[36]
Constipation	Zimbabwe	[39]
Ulcer	Zimbabwe	[36]

Medicinal uses of Bambara groundnut

Kone et al., [11] reported the traditional medicinal uses of Bambara groundnut in Africa. The Igbo tribe of the eastern Nigeria was mentioned to use the Bambara groundnut to treat venereal diseases. Another Luo tribe of Kenya use BGN with boiled maize water as remedy for diarrhea. The review added that consuming roasted BGN seeds will treat polymenorrhea. In Senegal, leaf preparations are used to treat abscesses and infected wounds [37]. Udeh et al., [38] reported that leaf extract is applied ocularly to treat cataract and the extracts are also used as a remedy for epilepsy. The Vhembe people of Zimbabwe were reported to use BGN as an aphrodisiac, weaning food for toddlers, used to prevent constipation, children diseases, morning sickness and epilepsy [37]. In northern Côte d'Ivoire, BGN seeds are predominantly used as medicine than as food [36]. It is used in treating anemia, ulcers, and menorrhagia during pregnancy. BGN is also used as an insecticide for livestock. Mkandawire [34] reported that BGN leaves are pounded with Lantana Trifolia, mixed with water, and applied on the coat of livestock.

Nutraceutical Potentials of Bambara Groundnut

Probiotics are live microbes that possess healthful benefits when consumed. These benefits are reported to be therapeutic, suppress infectious diarrhea, irritable bowel syndrome and inflammatory bowel disease [9]. Murevanhema and Jideani [9] proposed fermented BGN milk in lactic acid bacteria as a source of probiotics.

Bambara groundnut against malnutrition

Bambara groundnut is termed a complete food. The edible seeds contain 49%–63.5% carbohydrate, 15%–25% protein, 4.5%–7.4% fat, 5.2%–6.4% fiber, 3.2%–4.4% ash and 2% mineral. Makanda [40] reported that the legume is used in a part of Zimbabwe to mitigate malnutrition. Many studies such as Ndidi et al., [41] and Murevanhema and Jideani [9] supports the potential of Bambara groundnut in alleviating protein-energy malnutrition in Africa as it is a cheap and an excellent source of carbohydrate and protein.

Free radical scavenging effect

There is an upsurge in the research on legumes because of their potential medicinal properties for human health [42]. A study aimed to discover the antioxidant potential of Bambara groundnuts in in vitro assays with employed 1,1-diphenyl-2- picrylhydrazyl (DPPH) and Ferric Reducing Antioxidant Power (FRAP) [42]. The study found that BGN is a potential antioxidant agent. Chinnapaun [43] also found that steamed BGN seeds caused a significant reduction of ferric-reducing antioxidant power (FRAP), metal chelating activity, DPPH• and ABTS•+ radical scavenging activity.

Antimicrobial activity

Bambara groundnut has been used as an antimicrobial agent in traditional medicine. Some studies have been done to support these practices. Klompong and Benjakul [44] found that BGN seed coat extract showed antimicrobial activities against Staphylococcus aureus, Escherichia coli, Bacillus cereus), yeast (Candida albicans) and mold (Aspergillus niger) when administered in a dose dependent manner without any cytotoxic effect. The study suggested that BGN seed extract could be an antimicrobial agent without cytoxic effects. In addition, BGN seed extracts also showed antimicrobial effect on Klebsiella pneumonia, Pseudomonas aerugonisa and Bacillus cereus, Candida albicans and Aspergillus niger [38].

Anticancer activity

There is much evidence that high fiber foods may reduce the risk of colon cancer. BGN has a high amount of fiber and can serve as a functional food that can reduce the incidence of colon cancer when consumed [11].

Constraints in adoption of Bamabara groundnut

BGN is highly underutilized and produced in low quantities all over the world [45]. This is due to the hard-to-cook (HTC) property of Bambara groundnut [46]. Cooking time of BGN reaches 3-4 hours due to the cell morphological alterations and chemical reactions which take place in the cotyledon and seed coat during cooking [47]. This phenomenon can be rectified with modern techniques and technology which are often not accessible to Bambara groundnut farmers [47]. In addition, BGN is understudied and has received little attention from both national and international bodies in comparison with soybean which is vastly studied and supported for production [45].

Pigeon Pea

Traditional farm Production of Pigeon pea

Pigeon peas Cajanus Cajan (L) Millsp. are globulated, red, brown, black, purple, or speckled coloured with or without hilum, enclosed in pods [48].

Several survey studies have documented the various systems of C. cajan production in Africa. Studies from Benin, Nigeria, Ghana, Tanzania, and Kenya indicated that pure hectarage of C. cajan stands were rare and it is commonly intercropped with yam, cassava, maize, sorghum, and millet [48, 49, 50, 51]. These studies also reported a good number of varieties of species as well, but landraces are most cultivated by the farmers.

C. cajan is propagated through its seed which are usually obtained from previous harvest, relatives or friends or sold at local markets. In Nigeria, C. cajan are grown in the North central, North Eastern and Southern parts in small farmlands, in homestead gardens or even as borders [52, 23]. Tabo et al., [52] described the farm production of C. cajan in Nigeria in a detailed review. C. cajan is hand-sewn in manually prepared farmlands around May-July depending on the region. Spacing between the stands between locations and the seeds may be sown before or after the cultivation of the companion crop. No fertilizer is usually applied as this may be due to the soil revitalizing properties of the plant. In Tanzania, C. cajan is planted at the onset or late period of the raining season [48]. C. cajan mature in 7-8 months and are harvested in January or February [52]. Harvesting of ripe pods is by handpicking when about 75% of the pods have turned brown [53]. Harvesting spans for a long period depending on the size of farmland [53]. Yields of C. cajan vary among varieties and location. In the harsh conditions of Senegal, Algeria and Niger, yields are as low as 0.65 tonnes are produced primarily for human consumption [54] while in Kenya, yields about to 1 tonne per hectare of C. cajan [53]. Whereas, up to 3-5 tonnes per hectare can be produced in pure stands as seen in C. cajan farms of India and Indonesia [53]. Harvested seeds are dried, threshed and stored in ambient conditions.

Figure 4: Pigeon pea farming [55].

Constraints of traditional farm production of pigeon peas

They are several barriers hindering the full utilization and adoption of C. cajan in Africa. In Ghana, a qualitative research by Adjei-Nsiah [56] discovered that land tenure, unavailability of early maturing varieties and low market demand of C. cajan discouraged farmers from cultivating the pulse in large scale. Another detailed review by Saxena et al., [57] stated that factors such as post-harvest diseases and insect infestation can be a problem in C. cajan production areas. This coincides with Silim et al., [48] which mentioned Fusarium wilt (Fusariun udum), pod borers (Helicoverpa armigera), pod suckers (Clavigralla sp.) and bruchids (Callobruchus spp.) as destructive biotic factors of relevance to Tanzanian C. cajan farmers.

Traditional medicinal uses of C. cajan

Seeds, stem, leaves and roots of the C. cajan plant have been used in various parts of the world as therapies for gastrointestinal disorders, respiratory tract diseases, menstrual problems, toothache, sores, wounds, and diabetes [58].

Seeds: Saxena et al., [59] reported that scorched C. cajan seeds taken with coffee beans are used as a remedy for headache and dizziness. In Africa, the seeds are used as sedatives [49], therapy for diabetes and measles [58]. In traditional Chinese Medicine (TCM), pigeon seeds are used as a styptic, analgesic, wormicide, expectorant and sedative [58]. Mula and Saxena [49] reported in a detailed review that C. cajan seeds blended to a fine paste is used to reverse baldness and C. cajan flour can be applied as poultice to relieve inflammation or soreness. paste made from C. cajan seeds is warmed with leaves to induce breastmilk secretion when applied all over the nursing mother as poultice [59].

Stem: Mula and Saxena [49] reported that C. cajan stem burnt to ash is applied to treat wounds. Ganesan [61] documented that the young stem of C. cajan is used as a therapy against gingivitis, stomatitis and used as toothbrush.

Leaves: The leaves of C. cajans have been used the most in traditional folk medicine. It contains certain active compounds which are effective as remedies to some human diseases [59]. In Argentina, the leaves are infused as therapy against bronchitis, genital and skin inflammations (58). In Nigeria, the leaves have been used to treat malaria [62]. Pal et al., [22] reported that boiled leaves are used as laxatives and leaves paste can be used to treat oral inflammations and ulcers.

Roots: Saxena et al., [59] mentioned that root decoction is used to treat syphilis, cough, and stomach problems. The root can also be chewed with the stalk for toothache. In TCM, roots are dried and sold as worm expeller, expectorant, poison antidotes and alexiterics.

Table 2: Traditional medicinal use of Pigeon pea.

Medicinal use	Plant part	Reference
Gastrointestinal disorders	Seeds	[59]
Menstrual problems	Seeds	[49]
Toothache	Stem	[58]
As sedatives	Seeds	[49]
Wounds	Stem	[61]
Diabetes	Seeds	[58]
As laxative	Leaves	[22]
Dizziness	Seeds	[59]
As poultice	Seeds	[60]
As wormicide	seeds, roots	[59]
Baldness	Seeds	[60]
Stomatitis	Stem	[61]
Genital inflammations	Leaves	[59]
Malaria	Leaves	[62]
Ulcers	Leaves	[22]
Syphillis	Roots	[59]
Cough	Roots	[59]
Measles	Seeds	[58]

Nutraceutical Potentials of C. cajan

Antimicrobial activity

Okigbo et al., [63] studied the effect of C. cajan leaf extract in aqueous and organic solvent on Escherichia coli, Staphylococcus aureus, and Salmonella typhi. Leaf extract in organic solvent showed significant reduction in microbial load on three pathogens while leaf extract in aqueous solvent inhibited S. aureus and E.coli. Cajanus lactone and two phytoalexins, pinostrobin and cajaninstilbene acid were isolated during the CHCl3 extraction from C. cajan leaves [57]. These natural coumarin exhibited inhibitory effects on Gram-positive microorganisms. The study concluded that the C. cajan leaves are excellent potential against Gram-positive microbes.

Hypocholesterolemic effects

In an in-vivo experiment with C. cajan leaves methanol extract in HepG2 cells, Chang et al., [65] identified a main bioactive compound, cajaninstilbene which downregulated the LDLR and PCK9 expression in the HepG2 cells. The study opined that the C. cajan leaves hyocholesterolemic is a potential and cajaninstilbene acid contained in the leaves may have played a role in the cholesterol-lowering activity. This agrees with an earlier study by Luo et al., [66]. Kunming mice with diet induced hypocholesterolemia were treated with 200mg/kg of stilbene-containing (sECC) extract from C. cajan for four weeks [65]. This reduced liver and serum cholesterol by 22.7% and 31.4% respectively. The atherogenic index and body weight were reduced and serum LDL cholesterol was markedly attenuated by 52.8%.

Anticancer activity

Cajanol is the most affective phytoalexin isolated from C. cajan roots [22]. Luo et al., [66] showed the cytotoxic effect of cajanol against cancer cells in an in vitro study. Cajanol stemmed the growth of MCF-7 human adenocarcinoma cells in a time and dose-dependent manner. It also induced cell death through a ROS-mediated mitochondrion-dependent pathway. The study concluded that the phytoalexin, cajanol, is a potential anti-cancer agent.

Antioxidant and hepatoprotective activity

Iweala et al., [67] administered 200mg/kg of N-nitrosodiethylamine to male Wistar rats, inducing hepatotoxicity. C. cajan was administered at 200, 400 and 800 mg/kg for 28 days and the study reported a significant improve in liver condition as a decrease in ALT and AST levels in the bloodstream was observed and ALB, GST, GSH, SOD and CAT were also shown to increase.

Anti-diabetic effects

A comparative study on anti-diabetic potential of plant extracts used extracts from C. cajan roots and Tamarindus indica seeds to treat alloxan-induced diabetic swiss albino mice at 200 and 400 mg/kg respectively via oral administration for 5 days [68]. The study reported that the trial resulted in significant decrease in fasting serum glucose level and blood glucose level in mice and that the reduction potency was higher with C. cajan roots extract than in T. indica seeds extract.

Anti-sickling activity

A study reported estimated amount of phenylalanine and hydroxybenxoic acid present in Cajanus cajan per gram weight of seed was 4.92 mg ± 0.13 mg and 21.0 mg ± 3.0 µg, respectively [69].

Positive result was observed in which there was sickling inhibition with the sample containing mixture of phenylalanine (0.69 mg/ml) and p-hydroxybenzoic acid (10.5 µg/ml), equivalent to those found in the seed extract [69]. The therapeutic effect of C. cajan in the treatment of sickle cell anemia can be explored for the development of nutraceuticals.

CONCLUSION

Bambara groundnut and Pigeon pea are nutrient packed underutilized/neglected legume species. These legumes have been used in various forms as food as well as medicine in the traditional setting. Several studies have identified useful phytochemicals which can be harnessed into modern medicine to remediate many human ailments. However, more insights should be shed on the various uses of the plant. The improvement

of the landrace cultivars prevalent in Africa should be studied and improved as well. Then, consciousness to the properties of the species should be kindled among consumers and farmers to improve diversity of cuisine mitigating protein-energy malnutrition especially in economically challenged parts of the world.

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