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Bambara Groundnut (*Vigna subterranea* (L.) Verd.): A Review of Its Past, Present and Future Role in Human Nutrition

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ABSTRACT

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is an indigenous African legume with a wide adaptation in a range of environments. It is popular among subsistence farmers in sub-Saharan Africa. However, research on the crop still lags behind compared with the other established legumes; in most places landraces are being used for cultivation, with no locally improved varieties available. This paper was aimed to review the past, present and future role of Bambara groundnut in human nutrition. In the past, Bambara groundnut played a little role in human nutrition due to the fact that it was considered as "poor man's crop," with little economic value; it was also regarded as a pulse of African origin which was neglected by the European farmers. Recently, people have started consuming it, thereby increasing its market value. Reports indicate that it is a good source of Ca, K, Mg and Fe; 100 g of dry seeds of Bambara groundnut contains water (10.3 g), energy (367 Kcal), protein (18.8 g), fat (6.2. g) carbohydrate (61.3 g), fiber (4.8 g) and ash (2.4 g). The macro-element values (in g/100 g dry matter) of Bambara Groundnut are Ca (37-128), K (1545-2000), Mg (159-335), Na (16-25) and P. (3.13-563). The micro-minerals include Cu (3.0-13.2), Fe (23.0-150) and Zn (139-720). Beta-carotene, thiamin, riboflavin and ascorbic acid are also present. It also contains some essential amino acids such as tryptophan, lysine, methane, phylachen, valine and lenure. In the future, Bambara groundnut intake will increase due to the current research on its medicinal value and the high protein content which can compete with animal protein. Bambara groundnut will gradually replace animal protein, which has high cholesterol.

Keywords: Bambara groundnut, Human nutrition, Cultivation, Micro-minerals, Subsistence farmers

INTRODUCTION

Bambara groundnut (Vigna subterranea (L.) Verd.), a self-pollinating annual legume, is one of the most favoured legumes by resource-limited farmers living in rural areas. It has a somatic chromosome number of 2n=22 [1]. It is the third most important legume after peanut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*) [2]. The crop is believed to be tolerant to drought [3] and pests [4]. It produces a reasonable yield when grown under poor soil conditions. Azam-Ali et al. [1] demonstrated that Bambara groundnut is resilient to adverse environmental conditions as it tolerates low fertility soil and low rainfall. Ocran et al. [5] also reported that Bambara groundnut could successfully grow in areas with less than 500 mm of annual rainfall. Studies by Mabhaudhi and Modi [6] and Mabhaudhi et al. [7] have also shown that local landraces of Bambara groundnut are drought-tolerant, suggesting that it may be a suitable crop for cultivation in marginal areas with low rainfall.

In addition to drought-tolerance, the Bambara *groundnut* seeds also make a complete feed for both humans and animals. The above-ground material and by-product of Bambara groundnut can be used as ingredients to be incorporated in the formation of animal feed. Bambara groundnut can easily be converted to 'meat', which may meet human needs for animal protein. Nutritional analyses undertaken by various researchers revealed that on the average the seeds contain 63% carbohydrate, 19% protein and 6.5% fat in the form of oil [1,8]. From human nutrition

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perspective, the protein is of high quality with a good balance of essential amino acids and relatively high lysine (6.8%) and methionine (1.3%) [9]. The gross energy content has been reported to be higher than that of other more popular legumes such as cowpea, lentils and pigeon pea. The nutritional value of Bambara groundnut provides a cheap source of good quality protein to poor resource farmers in semi-arid areas [10]. This makes it a good supplement for both human and animal diets. The dual purpose of Bambara groundnut makes it an important future crop.

Legumes have received much attention for utilization in a variety of food systems due to their wide distribution throughout the world and potentially high protein content [11]. They have been a basic source of food security in a number of developing countries [12]. In addition, legumes can be exploited for both human and animal use. However, very little efforts have been made to exploit the less popular legumes in the fight against poverty and malnutrition. There is fear that the current subsistence farming systems cannot support the nutritional needs of population. Bambara groundnut is one of the legumes that have not been thoroughly studied. For example, it has a great potential in addressing the problem of protein deficiency in the sub-Saharan Africa. Furthermore, with daily increase in the price of animal protein, such legumes could prove to be a cheaper source of dietary protein.

Agriculture is mainly carried out to produce food for human and animal consumption as well as for raw materials for industries. In most African countries, farming is practised by smallholder farmers for their own subsistence, using traditional methods. These methods of production are evidently not efficient enough to meet the increasing demands for food, arising from the ever- increasing population [13]. In 1900, the world population size was estimated at 1.5 billion. Today, it is over 7 billion and is expected to increase to 9 billion by 2050 [14]. The highest rate of population growth will be in the zone which already suffers from poverty and food shortage; most of these zones are in Africa [13]. South Africa's current population has surpassed the 50 million people mark [15]. This suggests that South African agriculture will have to increase output in order to meet the growing demand from an increasing population.

However, there are limitations to achieving this; land and water are limited resources with water set to become even more scarce in the near future [16,17]. This suggests that there is a need for innovative and sustainable agricultural interventions in order to broaden the food base and to ensure food security. One approach that has recently emerged is to evaluate and characterize underutilized indigenous and traditional food crops with a view to re-introducing them in rural areas [18]. One of such crops of interest is the bambara groundnut (*Vigna subterranea* (L.) Verdc.), an indigenous African legume [7].

ORIGIN AND TAXONOMY

The origin of the Bambara groundnut is Africa and the region of cultivation is Sub-Saharan Africa's warm tropics. In South Africa, Bambara groundnut production occurs in Kwazulu-Natal, Eastern Cape, Mpumalanga, Limpopo and the Northern Province [19]. The Venda and the Bolabadu people claim to have brought bambara groundnut to south Africa [20]. The Venda people's claim is sounder as the name 'Ndluhu-mvenda, meaning groundnut of Venda land, is commonly used around the Venda region. Farmers in Mpumalanga province claim that the introduction of the crop came about during the winter season when major crops such as maize were not produced to their potential yields around Mpumalanga; it was, therefore, called the poor man's crop, as it was an alternative source of food protein for the small-scale farmers. It also provided a means of survival during the time of drought-induced famine. Bambara groundnut is also known as "ntoyocin" (Bemba, Republic of Zambia), "Jugo beans" (South Africa), "Izindlubu" (Zulu, South Africa), "Indlubu" (Xhosa, South Africa), "Gujiya" (Hausa, Nigeria), "Okpa" (Igbo, Nigeria), "Epa-roro" (Yoruba, Nigeria) and "Myimo" (Shona, Zimbabwe) [20].

Early researchers interested in the origin of Bambara groundnut believed that the crop originated from Africa. The Bambara groundnut belongs to the family Leguminosae (now Fabaceae) and sub-family Papilionoideae [21]. The genus Vigna comprises a wide range of species types (*V. subterranea* var. *spontanea* is the cultivated species). Bambara groundnut is derived from the name of a tribe, Bambara people, in central Mali near Timbuktu [21]. The crop spread throughout Africa by means of migration of indigenous people. The crop is also found in other continents like Asia and North America. However, despite its being an indigenous African legume, its popularity has now been overshadowed by groundnut (*Arachis hypogaea*) [21].

GENETIC RESOURCES AND BREEDING

The genetic diversity needed to improve Bambara bean is available. Collections have been made across Africa and the resulting seeds remain securely stored in facilities across Africa [22].

Therefore, following the NRC report on the long process of improving this crop, one of the largest collections is held by IITA in Nigeria while a small collection is held at the Crop Research Institute in Ghana, along with several other locations in Africa [22].

The collections differ markedly in general morphology, particularly size and colour of seeds, number of pods per plant and colour of leaves. Specialists have declared that the existing germplasm collections hold insufficient population samples from Chad, Ethiopia and Niger. Having come from different parts of the continent, these seeds should demonstrate the genetic treasures within this species.

The plant's flowers make cross-pollination difficult, but attempts are being made to breed for desirable characters, particularly high and stable yield, early maturation and photo-insensitivity. These are important actions, but more are still needed to ensure that the crop moves forward with a broad-base and reliable genetic underpinning. The plants are self-compatible and largely self-pollinated (though ants may help increase the level of cross-pollination); once a variety is found, it should stay reasonably stable.

In part, parallel crop breeding activities are necessary because Bambara bean occurs throughout Africa and occupies a vast array of different sites. Though this suggests a highly adaptable plant, there are indications that individual cultivars are site-specific. Tanzanian cultivars, for example, have been demonstrated to yield in Zambia. Indeed, some from northwestern Tanzania failed in the drier climes and different soils of central Tanzania. For starters, the most effective research on improving this crop may be to concentrate on local landraces [23].

It is also important to separately sort out the photoperiod effects, and to create day-neutral types that will grow in different latitudes and seasons. Breeding could be the key to long-term success, as it was with the wheat that resulted in Green Revolution in Asia and Latin America. Moving seeds sequentially from location to location and discarding all but the best producers at each site quickly distinguishes the most resilient and adaptable types.

In part, too, parallel crop breeding activities are needed to produce different plants for different farming systems. Types suitable for large-scale mechanized farming are needed on the one hand and types for small-scale cultivation by subsistence farmers on the other. It has been suggested that the targets should be a bunch ideotype for large-scale mechanized farming and a spreading ideotype for smallholders dependent on cereal-based subsistence systems where the plants are more scattered [23].

Although it has been noted that adequate genetic diversity is on hand, more collections are needed on farms in Burkina Faso, Togo and Nigeria's middle belt—a zone believed to contain the greatest variation. Furthermore, there is a need to collect the ancestral, pre-domestication wild form that is distributed in natural areas from the Jos Plateau and Yola in Nigeria, to Garoua in Cameroon, and probably beyond.

BOTANY OF THE CROP

Bambara groundnut is an herbaceous, intermediate, annual plant, with creeping stems at ground level [20]. This legume is a small plant that grows to a height of 0.30-0.35 m with compound leaves of three leaflets. The plant generally looks like bunched leaves arising from branched stems which form a crown on the soil surface. After fertilization, pale-yellow flowers are borne on the freely branching stems; these stems then grow downwards into the soil, taking the developing seeds with it. The crop forms pods encasing seeds just below the ground in a similar fashion to the peanut. Bambara groundnut pods are round, wrinkled and over 1.25 cm long. Each pod contains one or two seeds that are round, smooth and very hard when dry.

CULTIVATION

In most African countries, Bambara groundnut is intercropped with maize, cowpea, peanut and other major crops. It is also grown in rotation as it improves the nitrogen status of the soil [24,25]. Bambara groundnut can be planted from October through November to early December after good rains. Sinefu [26] evaluated planting dates as a tool for managing water stress in Bambara groundnut in the Kwazulu-Natal area of South Africa. The study showed that Bambara groundnut planted at optimum planting date (November) had the best yields compared with late planting date (January). Bambara groundnut has been reported to take 7-15 days to emerge [19]. However, recent studies using local South African landraces showed slow emergence of up to 35 days after planting [6,7,18]. Seeds stored for 12 months germinate well, but longer storage resulted in loss of viability [27]. Vegetative growth takes place in spring and early summer and pods form only in late summer and autumn [26]. In Plateau State of Nigeria, Bambara groundnut is planted in June-July and it takes 3 months to mature. The pods are ready for harvest when the leaves have started drying up.

Bambara groundnut is a typical short-day plant. Flowering starts 30-35 days after sowing and may continue until the end of the plant's life. Mabhaudhi and Modi [7] observed that it took 86-88 days after planting for 50% flowering to occur in Bambara groundnut under irrigation while it took 64-66 days after planting under rain-fed condition [7]. However, flowering may occur much earlier when water is limiting. Pods and seeds develop approximately 30 to 40 days after fertilization. The fruit of Bambara groundnut develops above or below the soil surface, although in practice few varieties are surface-bearers. The Bambara groundnut pod is small, about 1-5 cm long, round or slightly oval-shaped with wrinkled mostly one and sometimes two seeds. The seeds develop during a further 10 days. Seeds are more matured when the parenchymatous layer surrounding the embryo has disappeared. The seeds are round, 1 to 5 cm in diameter, smooth and very hard when dry. The crop has a growth period of about 130 to 174 days [18].

Bambara groundnut needs bright sunshine, high temperature and evenly distributed rainfall during the rainy season to achieve best growth potentials. Average temperatures of between 20°C and 28°C are most suitable. It requires a frost-free period of at least 3 to 5 months. It has also been reported that very low yield and crop failure occurred in Bambara groundnut planted during May in Kwazulu-Natal; this is typically onset of winter in the province and the crop's growth cycle may have coincided with frost occurrence [18]. The plant is highly adaptable and tolerates

harsh conditions better than most leguminous crops. It requires moderate rainfall from sowing until flowering. An annual rainfall of 500-600 mm is required. The plant does not tolerate heavy rainfall except at maturity.

Bambara groundnut grows well in a well-drained soil. It requires a soil pH of 5.0-6.5. Best yields are obtained in a deeply ploughed field with fine seedbeds. The established planting density ranges from 6 to 29 plants per m^2 or 6,000-29,000 plants per hectare [28]. The Bambara seed varies in size and, therefore, planting density can vary from 25-75 kg/ha. The recommended spacing is 10-15 cm in a single row of 45-90 cm apart. Planting density is usually low especially when crops are not in rows. Under conditions of high moisture levels and heavy soils, seeds can be planted 2.5-3.0 cm deep or 5.0-7.5 cm deep in sandy soil [28].

PRODUCTION

Bambara groundnut is cultivated in many semi-arid African countries such as Ghana, Nigeria and South Africa with a secondary cultivation centre in South-East Asia namely Thailand, Indonesia and parts of Malaysia. Traditionally, it was cultivated in extreme, tropical environments by small-scale farmers without access to irrigation and/or fertilizers and with little guidance on improved practices [18]. In 2001, FAO published a global mapping report for bambara groundnut in which crop modelling was for the first time used to predict potential areas of production as well as potential yields. Azam-Ali et al. [1] reported that beyond its two current cultivation centres there is a potential for cultivating Bambara groundnut in many countries with a Mediterranean climate such as Lebanon and Israel as well as European countries such as Italy, Portugal, Spain and Greece. The report also concluded that when factors such as the seasonal distribution of rainfall, day length and range of temperatures during the growing season are considered, the potential yields of Bambara groundnut within its current areas of cultivation can be significantly increased without high levels of agronomic input.

NUTRITIONAL VALUE

According to some research, high carbohydrate (65%) and relatively high protein (18%) content as well as sufficient quantities of fat (6.5%) make the bambara groundnut a complete food. Others reported that Bambara groundnut seeds have been found to be richer than peanuts (groundnuts) in essential amino acids such as isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine. There is, therefore, a potential for Bambara groundnut to be used to supplement foods lacking in these essential amino acids. The fatty acid content is predominantly linoleic, palmitic and linolenic acids [29].

A recent study on the evaluation of the nutritional quality of complementary foods from popcorn, African locust bean and Bambara groundnut concluded that germinated popcorn-Bambara groundnut blend was the most suitable for infant diets [30].

ECONOMIC IMPORTANCE

Bambara groundnut is considered to be an underutilized crop. The low yields associated with its production may be attributed to the fact that production and crop improvement have been neglected by researchers over the past years. This neglect has occurred despite the fact that the crop is important for small-scale farmers due to its drought-tolerance and commercial potential. The waning popularity of Bambara groundnut in traditional African communities can be attributed to the fact that it takes a long time to cook, has poor milling characteristics and contains anti-nutritional factors such as tannins and trypsin inhibitors [31]. However, it still plays an important role and is widely utilized in traditional dishes in several African countries such as Cote d'Ivoire [32], Zimbabwe and Nigeria [33] and Cameroon [34].

Bambara groundnut is primarily used for human consumption. The seeds are consumed at different developmental stages, either immature or fully ripe. The immature seeds can be consumed fresh, boiled, grilled, as a meal or mixed with immature groundnut or green maize [20]. Matured seeds are very hard; hence boiling becomes a pre-requisite before any further preparation. Ripe seeds are milled to produce flour which can be used to make biscuits and/or mixed with cereals and boiled to make porridge [20]. Ripe dry seeds are also roasted, broken into pieces, boiled, crushed and eaten as a relish in Zimbabwe; a peanut-like snack is also produced through roasting of Bambara groundnut. The seeds can also be dried and stored for later use [35].

The commercial canning of Bambara groundnut has been practised in Ghana; the nuts were canned in gravy by a government factory and over 40,000 cans were produced annually [36]. In Zimbabwe, canned Bambara beans were commercially produced for the market as 'Tulimara Nyimo Beans' and recommended for addition to soup, stew and salads. However, the successful commercialization of Bambara groundnut in Zimbabwe was hampered by problems such as transport difficulties as roads were not suitable for trucks to deliver to the farms. Other militating factors include storage facilities (the beans needed to be fumigated and stored in cold rooms) and marketing strategies (lack of awareness of Bambara groundnut as a commercial product both locally and internationally as well as limited funds for marketing activities). It is relatively expensive compared with other legumes, and its distribution to local supermarkets with large populations is not wide. It is commonly available in the villages [35].

Despite Zimbabwe's production constraints, it has been successful in exporting more than 3,000 tons of Bambara groundnuts to South Africa and Switzerland [37].

In Ghana, Bambara groundnut is also used for medicinal purposes. According to Akpalu et al. [38], white seeds are mixed with guinea fowl meat as a treatment for diarrhoea while black seeds are mixed with water to treat sick children. The ground seed is used to treat skin rashes or is chewed to alleviate swollen jaw diseases. There is a preference for white and cream landraces with large seed size in Africa [38,39] whilst in south-east Asia black and red landraces are preferred. In Ghana, majority of farmers (>60%) cultivate white-seeded landraces and only 10-15% cultivate black, cream and red-seeded landraces [38]. Most farmers within the community as well as the market women prefer the white landraces because they are early-maturing, with good market price and are high in demand. Darker seed color such as black and red are not favoured due to the higher tannin.

ROLE OF BAMBARA GROUNDNUT IN HUMAN NUTRITION: PAST, PRESENT AND FUTURE

Past role of bambara groundnut in human nutrition

Bambara groundnut played a little role in human nutrition in the past because little or no attention was given to its nutritional potentials, apart from the exploratory work done in the 1920s [20].

Later on, a group of researchers examined the biochemical composition of the seed. On the average, the seeds contain 63% carbohydrate, 19% protein and 6.5% oil. Despite the relatively low oil content, some tribes in Congo reportedly produced the seeds for oil extraction [40].

The seed has the reputation of being very filling. Its nutritional energy (per 100 g) has been estimated at 367-414 calories, an amount higher than that of common pulses such as cowpea, lentil and pigeon pea [41].

THE PRESENT ROLE OF BAMBARA GROUNDNUT IN HUMAN NUTRITION

With the current discoveries on the essential mineral elements, people's awareness about the crop is being raised. Studies on the value of this crop have resulted in increased consumption and market values of the crop, which hitherto has remained under-utilized.

Angeot et al. [42] reported Bambara groundnut as a good source of Ca, K, Mg, P and Fe with concentrations high enough to be useful in the diet of consumers. One hundred grams of the edible portion of dry seeds contains water (10.35 g), energy (367 Kcal), protein (18.8 g), fat (6.2 g), carbohydrate (61.3 g), fiber (4.8 g) and ash (3.4 g). The values (in g/100 g dry matter) of macro-minerals in Bambara groundnut are Ca (37-128), K (1545-2000), Mg (159-335), Na (16-25) and P (313-563).

The micro-minerals include Cu (3.0-13.2), Fe (23.0-150) and Zn (13.9-77.0), β-carotene (10 µg), thiamin (0.47 mg), riboflavin (0.14 mg), niacin (1.8 mg) and ascorbic acid traces. The content of essential amino acids per 100 g food is tryptophan (192 mg), lysine (114 mg), methionine (312 mg), phenylalanine (991 mg), theonine (617 mg), valine (937 mg), leucine (1385 mg) and isoleucine (776 mg) [43].

Bambara groundnut has the unique potential to provide solution to health and hunger challenges and to generate agricultural sustainability in developing countries in the sub-Saharan Africa. It constitutes a major source of affordable protein, complex carbohydrate, essential micronutrients, dietary fiber, vitamin B and antioxidant in nutritionally challenged diets of both rural and urban populace [42].

Bambara groundnut has lower tannin concentration compared with cowpea [44] and pigeon pea. However, in a study by Akindahusi and Salawu [45], it was observed that low levels of tannin had beneficial effect on human and animal nutrition. Denis et al. [46] also reported the presence of micro- and macro-elements in Bambara groundnut.

FUTURE ROLE OF BAMBARA GROUNDNUT IN HUMAN NUTRITION

With the current research on the medicinal values of Bambara groundnut, the intake of the legume in human diet is going to increase beyond reasonable doubt just as Moringa (*Moringa oleifera*), which was initially a wild plant, but has now become domesticated by rural dwellers and is used by the poor and the rich for nutritional and medicinal purposes.

Although formal infant-feeding studies are unreported, a trial has been conducted on "milk" prepared from Bambara bean, cowpea, pigeon pea and soya bean. Whereas all were declared acceptable, the scientists ranked Bambara-milk first in flavour, nutritional value and colour. The mothers and their babies also preferred the Bambara milk [47].

Galluzi et al. [48] in line with the volume of the UN conference in 1995 at Rio de Janeiro on Environmental and Sustainable Development projected that Bambara groundnut would contribute to the fight against malnutrition and famine in the world because of its high protein.

De Kock [35] noted that in Zimbabwe the red seeds were rated grade A in nutritional composition and in iron. Where Iron deficiency is high, the red seeds could, therefore, be used since they have twice the amount of Iron found in other varieties such as cream or cream with the black eye.

It is possible that the key to future food and nutrition security will lie in the untapped potentials of underutilized crop species. Therefore, it is imperative that we study locally available but neglected or underutilized crops and evaluate them for drought-tolerance using agronomic techniques as well as modern techniques, such as crop modeling, which allow for rapid evaluation of production scenarios [49].

There are hundreds of wild and cultivated species of leafy vegetables grown and consumed in Africa, and there is a huge potential for improved food security through the use and development of these species [49]. The nutritional value

of many underutilized, traditionally cultivated crops is high, with ample amounts of micronutrients, antioxidants and essential amino acids. Some of these crops have both medicinal and nutritive values. Underutilized crops provide opportunities to enrich diets with nutritionally healthier foods while at the same time they make food and food culture more varied and interesting. These crops could play an important role in a healthier and more diverse diet.

A lot of people are now running away from animal protein due to its high level of cholesterol. A research by FAO, United States of America (2010), showed that Bambara groundnut has the potentials to replace animal protein since it can provide up to 25% protein. Therefore, it can help to solve the protein-energy malnutrition which is a major health problem in developing countries.

According to Akpalu et al. [38], white seeds are mixed with guinea fowl meat as a treatment for diarrhoea while black seeds are mixed with water to treat sick children, ground to treat skin rashes or chewed to alleviate swollen jaw diseases. There is a preference for white and cream landraces with large seed size in Africa [39,38].

One of the objectives of the International Year of Pulses (2016) was to increase consumption of pulses by encouraging people to eat 60-100 g pulses at least three to four times per week (up to 15-25 kg/year). They observed that the per capital consumption of pulses was relatively low compared with other dietary intakes.

Denis et al. [46] described the Bambara groundnut as a dense food due to its high nutritional status and the role it plays in human diet. Adamu et al. [50] reported that pulses including Bambara groundnut have the potential to reduce the sugar level in the body using the solution of Bambara groundnut flour.

CONCLUSION

Bambara groundnut is a neglected and underutilized African legume, with huge nutritional potential, rich in essential elements, micro-elements and essential amino acids.

The crop also has medicinal value as it is used traditionally in some parts of Africa to treat some aliments and to neutralize blood sugar. It can be used where Iron (Fe) deficiency is high, especially the red variety which contains twice a higher amount of proteins than the rest of the varieties. Bambara groundnut milk is also regarded as the best for children and breast-feeding mothers in terms of nutritional content and color.

Therefore, nutritionists and food technologists should pay more attention to the underutilized crops. A huge gap in the knowledge base still remains to be bridged.

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