*International Journal of Development and Sustainability*
*ISSN: 2186-8662 – www.isdsnet.com/ijds*
*Volume 6 Number 12 (2017): Pages 1919-1930*
*ISDS Article ID: IJDS17080807*

# Food security potentials of Bambara groundnut (Vigna subterranea (L.) Verdc.)

Emmanuel Bassey Effa *, Aniefiok Effiong Uko

*Department of Crop Science, Faculty of Agriculture, F&WRM, University of Calabar, PMB 1115, Calabar, Nigeria*

## Abstract

Food security can eventually be achieved, whereas the larger paradigm that must not be overlooked is nutrient and nutritional security. Until both paradigms are achieved; and side by side, efforts to maintain a healthy global population could best be described as dismal. Beyond the concept of satisfying hunger by mere calorific consumption; carbohydrates being the main stay for many families, there is the need to satisfy hidden hunger through balanced feeding and appropriate nutrition, which is often overlooked. Most times the damage caused by hidden hunger is realized when the costs of amelioration have become out of reach and the damage has been done. Animal proteins are not readily available in Sub - Sahara Africa (SSA) hence there is an ever increasing need to exploit non animal protein sources. Legumes or pulses remain a highly untapped storehouse of essential nutrients, providing carbohydrate and protein energy as well as minerals and vitamins, and especially essential amino acids. One such undermined pulse is Bambara nut which is described as a complete food because of its rich nutrient profile, but nonetheless has been relegated to third place of importance among legumes. With the resurgence of interest in development of pulses for nutrient security, there is hope that once relegated pulse crops will re-emerge as champions and veritable store houses of required nutrients in the fight for food and nutrient security in SSA. This review examines the food and nutrient security potentials of Bambara groundnut, its characteristics, production, utilization, constraints as well as improvement efforts. Finally, it posits that there is a need for a wider inclusion of researchers in work bothering on Bambara groundnut, with respect to equal opportunities for training and funding.

***Keywords:*** Bambara Groundnut; Food Security; Nutrient Security; Legumes



***Cite this article as:*** Effa, E.B. and Uko, A.E. (2017), "Food security potentials of Bambara groundnut (Vigna subterranea (L.) Verdc.)", *International Journal of Development and Sustainability*, Vol. 6 No. 12, pp. 1919-1930.

* Corresponding author. *E-mail address:* emmaeffa@unical.edu.ng

## 1. Introduction

As Africa attempts to achieve food security, there must be an end to contemplations of food shortages; and rather emphases on hitherto neglected and underutilized indigenous African crop species that have not only food security but also nutrient security potential for the sub-region. According to Doku (1996), it is a paradox that an indigenous African crop which produces almost completely balanced food, easy to cultivate and also makes little demand on the soil, should be relegated in its own countries. Interestingly, indigenous crops have a comparative advantage of resilience in their local environment, compared to exotic species that have assumed more popularity over time. With little attention given to their improvement, production, utilization and value chain addition by scientific research, these indigenous crops have not been fully exploited and have remained primordial in their development and integration.

Several international fora and engagements on meeting the food sufficiency and nutrition needs of a fast growing population have prompted the food and Agriculture Organization to rediscover the lost food crops of the world and reinvigorate research around their production and utilization as a means of curbing hunger; rediscovery in the sense of giving a new prominence to such crops beyond the local use. The celebration of the international year of pulses is therefore a welcome development for "reinventing" the potentials of non-animal protein sources of which Bambara nut is notable.

Bambara groundnut or Bambara nut (*Vigna subterranea* (L) Verdc), synonym (*Voindzea substerranea* (L.) thours), belong to the family Fabaceae and sub family Faboidea (Bamshaiye *et al*., 2011). It is severally known in different parlances by many names. In Nigeria, most popular names are 'Okpa' by the Ibos, 'Ekpa-Roro' by Yoruba tribes and 'Gurjiya or Kwaruru' by the Hausas, while the Obudu and Ogoja people in Northern Cross River State, Nigeria refer to it as 'Ukpa'. It is also known as Izindlubu by the Zulus and Jugo beans in South Africa, Ntoyo Cibemba (Zambia) and Nyimo beans (Zimbabwe) Bamshaiye *et al.,* 2011, Mahboudhi *et al.,* 2013 and FAO, 2017).

### 1.1. Origin of Bambara groundnut (BG)

Several workers have reported differently regarding the centre of origin of BG. It is largely believed that BG was first found in West Africa (Hillocks *et al.,* 2012), where it has since spread through sub - Saharan Africa. Swanvelder (1998) reported that BG originated from North Africa, and moved as far as Kwazulu – Natal through migration of indigenous people. It is confined to the Northern province of Swaziland and Kwazulu.-Natal. According to FAO (2017), the centre of origin is most likely North – Eastern Nigeria and Northern Cameroon in West Africa. Similarly, Goli (1997) reported that the cultivation of wild BG extends from Jos Plateau and Yola in Nigeria, to Garoua in Cameroon. Harper (1970) also placed the probable centre of origin in Nigeria, and this is supported by the existence of extensive BG genetic resources (Tanimu & Aliyu, 1997).

According to Linneman (1987), the common English name appears to be derived from Bambara, an agriculturalist tribe who live mainly in the Bambara district, near Timbuctoo in Mali. However, Swanvelder (1998) argued that because it is widely cultivated throughout tropical Africa, the Bambara district has no pre-eminent claim to the plant. It is most probable that BG originated in the Nigerian – Cameroon corridor where abundant genetic resources exist but was eventually moved due to transhumance by the Hausa – Fulani tradesmen to the Bambara district where it earned its common English name, having been a part of their food stores or trade items.

## 1.2. Plant morphology

Bambara nut is a low growing legume. Bamshaiye *et al*. (2011) described it as an herbaceous, intermediate annual plant with creeping stems at ground level. It grows to a height of 30 – 35cm has a well developed tap root with many short lateral stems on which compound leaves of three leaflets are borne. In association with rhizobium, the roots form rounded and sometimes lobed nodules (Linneman and Azam – Ali, 1993). A special feature of Bambara groundnut is that the fruit begin as a fertilized flower above the ground, while pods and seeds mature just below the soil (Toungos *et al.,* 2009). After fertilization, pale yellow flowers are borne on the freely branching stems; which then grow downwards into the soil, taking the developing seed with it (Bamnetwork, 2014). Bambara nut pods are round, wrinkled and over half an inch long, containing one or two round, smooth and very hard seeds, when dried. Unripe pods have a yellowish-green colouration which turns to yellow or purple on maturity. According to Swanvelder (1998), the testa color varies according to ripeness from light yellow to black, cream, purple and other shades. Seed color ranges from cream, brown and red to mottled, with or without hilum colouration.

## 1.3. Qualities and characteristics of Bambara groundnut

Although it is referred to as a groundnut, BG is actually a bean. Some of its characteristics include drought tolerance, low input requirements, Nitrogen fixing – soil nutrient restoring capability, photoperiod control and it is regarded as a complete food.

I. *Low Input Requirement:* Bambara groundnut is a low input requirement crop that performs commendably on marginal soil conditions, due to its hardy resilient nature. It is therefore quite suitable for incorporation into resource poor, low input sustainable farming systems.

II. *Drought tolerance:* According to Thottapilly and Rossel (1997), BG yields well under conditions which are too arid for groundnut, maize, and even sorghum. Perhaps its effectiveness in low humidity climes resulted in the report of low pest and diseases incidence on the crop. Under high relative humidity conditions of the South-Eastern rainforest, Effa *et al.* (2016) reported severe viral leaf curl disease incidence that resulted in drastic yield reductions. However, its low input requirement and drought tolerance status gives it advantage as a choice crop for incorporation into climate smart agriculture.

III. *Nitrogen fixing ability:* BG has a high $N_2$ fixing ability; therefore it is an important component crop for small holder farmers in sub - Saharan Africa. To combat low level of resilience and dependence on unpredictable weather conditions, and climate variability, farming systems research is advancing along the lines of utilizing resilient crops in agricultural systems. BG synthesizes $N_2$ not for its immediate use, but leaves a net deposit for following crops in a rotation and also benefits intercrop situations. Therefore it is a plus on low inputs systems, and might even benefit organic crop production. It can therefore be ploughed into soil as a residual or live mulch material for land use intensification. Yakubu *et al*. (2010) reported that BG fixed 28.42 kg N $ha^{-1}$ in the Sudano – Sahelian Zone of Nigeria.

IV. *Photoperiod control:* considerable differences exist between land races under long-day photoperiod exposure (Kendabie *et al*., 2012). Photoperiod affects pod set and seed filling. According to Bamnetwork (2014), four distinct classes of landraces have been identified with regards to photoperiod and these are;

   a. Qualitative short-day landraces e.g. Ankpa 4.
   b. Quantitative short-day landraces e.g. TN, Gresik, LunT.
   c. Quantitative long-day e.g. IITA – 686, DodR.
   d. Photoperiod insensitive/day neutral landraces e.g. 519 – 3, Uniswa – Red, Dip C.

V. Bambara nut is also known as a 'complete food', because the seeds contain an average of 63 % carbohydrates, 19 % protein and 6.5 % fat. It is a healthy meal and an important source of dietary protein and energy.

## 1.4. Nutritional value

The nutritional value derivable from BG is very high. It contains 63 - 65 % carbohydrates, 18 - 19 % protein and 6.5 % fat (Goli, 1997 and Mahazib *et al*., 2015), thus it is referred as a complete meal. Kari-kari *et al*. (1997) analysed BG for micronutrient content and reported that per 100 g it contains: Ca (95.5 – 99.0 mg), Fe (5.1 – 9.0 mg), K (11.45 – 14.36 mg) and Na (2.9 – 10.6 mg). Its Zinc content is as high as 20.98 ± 1.07 mg/100 g, far above the 15 mg/100 g adult recommended daily allowance of the USDA (Ndidi *et al*., 2014), which might hold positive implications for prostrate health in men.

According to Massawe *et al*., (2002), its high protein content confers advantage in alleviating nutritional disorders in both humans and animals. While food consumption may ordinarily satisfy hunger (food security), the larger issue of hidden hunger bordering on nutrient security is often overlooked. As a complete food, the nutritional value of BG therefore portrays it as having the ability to satisfy both requirements. The reports of Ihekoronye and Ngoddy, (1985) and Bamshaiye *et al*. (2011), indicate that Bambara nut seeds are richer than peanuts in essential amino acids such as Isoleucine, Lysine, Methionine, Phenylalanine, Threonine and valine. Because of these traits, BG has high potential for use to complement foods lacking the above listed essential amino acids. Predominantly, the fatty acid content is made up of fractions such as linolenic, palmitic and linoleic acids (Minka and Bruneteau, 2000).

Bambara nut flour can be used in composite flour preparation and should particularly be incorporated into noodles. Indeed Effa *et al*. (2016) have suggested that proteinisation of foods can easily be accomplished through Bambara flour fortification. The authors suggested that addition of Bambara nut flour to noodles could offset any nutrient imbalances that might occur in children who are fed large portions of noodles as a whole meal without additional proteins whatsoever. Perhaps a presidential initiative on BG incorporation into foods, much like the presidential initiatives on cassava in many Sub - Sahara African countries which led to the resurgence of cassava production in Africa, might be helpful in drawing more attention to Bambara groundnut research, improvement, production and utilization in sub - Sahara Africa.

## 2. Utilization of Bambara groundnut

Inspite of its high and balanced nutrient profile, BG remains underutilized compared to peanuts, cowpea and other legumes. A major drawback to its utilization is that it takes a long time to cook and contains some anti-nutritional factors such as tannins and trypsin inhibitor, which can be denatured by fermentation as well as appropriately long cooking time. Ndidi *et al.* (2004) reported that the levels of oxalate, phytate hydrogen cyanide, and trypsin inhibitor activities which are above permissible levels in raw Bambara groundnuts, were reduced significantly ($p<0.05$) to permissible levels by both boiling and roasting, with boiling causing more significant reduction than roasting. Moist heat treatment is therefore a means of reducing anti-nutritional factors in legumes (through dilution and volatilization). Mune *et al*. (2007) reported that treatment of Bambara nut flour with 60% alcohol, decreases anti-nutritional factors and eliminates flatulence inducing sugars.

Barimalaa and Anoghalu (1997) reported that BG has poor milling characteristics and does not dehull easily. According to Hillocks *et al*. (2012), fresh beans could be boiled for as long as 45 – 60 minutes to cook, while dried beans could cook for as much as to 3 - 4 hours. This is time consuming and utilizes much fuel and water. However pressure cooking can reduce the length of time as well as fuel resources needed for cooking to tenderness and should therefore be explored.

There are numerous traditional recipes in different communities across sub -Saharan Africa. Generally, both mature and immature seeds are consumed, with most consumers preferring boiled seeds. This is advantageous as it reduces anti-nutritional factors. To this end, short cooking time has become a required trait amongst breeders and farmers (Berchie *et al*., 2010 and Mahazib *et al*., 2013). According to Mahazib *et al*. (2013), BG can be used as an ingredient for cooking, flour milling or just eaten as a snack. It can also be used to make Bambara nut dumplings (FAO, 2017).

In some West African Countries, fresh pods are boiled with salt and pepper as a snack (Hillocks *et al*., 2012). In Cote d'lvoire, the seeds are milled into flour, which increases digestibility. In East Africa, roasted beans are pulverized and used to make a kind of soup, or just crushed and eaten as a relish. In Nigeria and Ghana, the seeds are pounded into flour, which is usually added to maize to enrich traditional foods (Akpalu *et al*., 2013). A variety of cakes can be made from Bambara nut flour or it can be mixed with cereal to prepare several types of porridge (Bamshaiye *et al*., 2011). In South Eastern Nigeria according to Uvere *et al*. (1999), BG seeds are roasted and chewed with palm kernels, and sometimes milled into flour for making bean cakes (Akara). Most popular is the steamed gel, prepared from slurry of the beans, also known as 'Okpa moi-moi' by the Igbos or 'Ukpa' by Northern Cross River, a particular delicacy consumed at all times and is not lacking in important traditional occasions.

Bambara nut milk can be prepared in a way similar to soybean milk, and is often used as weaning milk in many SSA countries (Brough *et al*., 1993 and Bamshaiye *et al*., 2011). According to Murevanhema and Jideani (2013), Bambara nut milk has been rated higher in acceptability compared to other legume based milk such as soybean and cowpea. As an animal feed, Adeparusi & Agbede (2002) reported improved fish growth in tilapia fish fed on Bambara nut and leaf protein from *Leucaena leucocephala* or *Gliricidia sepium* diets. In addition Bambara groundnut seeds have been successfully used for feeding chicks, while the leaves are suitable for grazing due to their Nitrogen and Phosphorus rich status (Bamshaiye *et al*., 2011).

Research into use has resulted in several outcomes. *Hillocks et al*. (2012) reported that the nutritional composition of cooking bananas as a weaning food can be enhanced through BG flour supplementation. According to Ijarotimi (2008), the composition of the weaning food containing 70 % cooking banana and 30 % BG flour is nutritionally adequate to support child growth and development, and a good replacement for more expensive commercial products. Uvere *et al*. (1999) reported that flour yield can be improved by malting, which reduces the energy required for flour production. However the end product was not acceptable to consumers due to the reduction in the characteristic beany flavor popular with 'okpa' steamed gel. With an oil content of only around 6 percent, Bambara bean would seem to make for an unlikely oilseed, but reportedly some people in Congo pound the roasted nuts and separate the liquid for cooking.

## 2.1. Production of Bambara groundnut

Bambara groundnut is third in importance amongst cultivated legumes after peanuts and cowpea. Perhaps the ease of processing peanuts, a Brazilian native which reached Africa only 400 years ago can be implicated as the main reason for the relegation of BG. Increasingly however and although it is still considered as a snack crop, Bambara groundnut is now widely cultivated in many semi arid sub-Sahara African countries such as Ghana, Nigeria, Cameroon, Togo, Mali etc. In Southern Africa, Zimbabwe is the major production hub. Secondary areas of cultivation are South East Asia, especially Thailand, Indonesia and Malaysia. Cultivation of Bambara groundnut on a large scale and in pure stands is not very common. The crop is mostly grown by women, intercropped with major commodities such as maize, millet, sorghum, cassava, yam, peanut and cowpea. Grown in rotation, Bambara groundnut improves the nitrogen status of the soil

According to Mabhaudi *et al.* (2013), it was traditionally cultivated in extreme tropical environments by small-scale farmers with no access to irrigation and/or fertilizers, who had little or no guidance on improved production practices. Azam-Ali *et al*. (2001) reported that there is potential for cultivation of BG in many countries with a Mediterranean climate such as Italy, Greece, Spain and Portugal. The authors concluded that BG yields can be significantly increased when factors such as seasonal distribution of rainfall, day length and temperature ranges during the growing season are accounted for.

BG's adaptability to poor soils and tolerance to drought have been reported. It yields well under marginal environmental conditions, which according to Thottapilly and Rossell (1997) are too arid for groundnut, maize and even sorghum. Under optimal environmental conditions with adequate moisture, BG could have better yield potential. In two year study conducted during the late planting seasons of 2013 and 2014, Effa *et* *al*. (2016) obtained highest combined seed yield of 1.68 t ha $^{-1}$ at 111, 111 plants ha$^{-1}$. In the second year however, there was drastic yield reduction occasioned by viral leaf curl disease (Table 1).

Table 1 findings might underscore the need for adequate plant protection, when planting in wetter periods. Using organic fertilizers, Shiyam *et al*. (2016) reported the highest yields of 1.95 t ha $^{-1}$ with the application of 2.5 t ha $^{-1}$ of organo-mineral fertilizer in Calabar. Toungos *et al.* (2009) reported yields of 432.5 kg ha$^{-1}$ following the application of 60 kg ha$^{-1}$ $P_2O_5$ in Yola, while Nweke and Emeh (2013) obtained the highest yields of 1.65 t ha$^{-1}$ after the application of 110 kg ha$^{-1}$ of $P_2O_5$ in Igbariam, South East Nigeria.

**Table 1.** Bambara groundnut performance and yield reduction occasioned by viral leaf curl disease

| Density ha$^{-1}$ | Seed yield (t ha$^{-1}$) | | Combined seed yield (t ha$^{-1}$) | Leaf curl severity (%) | % yield reduction |
|---|---|---|---|---|---|
| | 2013 | 2014 | | | |
| 111,111 | 2.55 | 0.80 | 1.68 | 38.59 | 68.63 |
| 83,333 | 2.30 | 0.47 | 1.39 | 35.43 | 79.56 |
| 69,400 | 1.45 | 0.20 | 0.82 | 20.72 | 86.21 |
| LSD | 0.89 | 0.15 | 0.52 | 3.16 | 8.31 |
| $P_2O_5$ kg ha$^{-1}$ | | | | | |
| 0 | 2.30 | 0.26 | 1.28 | 32.34 | 88.70 |
| 45 | 2.26 | 0.40 | 1.33 | 33.57 | 82.30 |
| 60 | 1.89 | 0.41 | 0.65 | 23.10 | 78.31 |
| 75 | 1.97 | 0.43 | 1.2 | 36.42 | 78.17 |
| LSD | NS | NS | NS | NS | NS |
| Interaction | | | | | |
| LSD | NS | NS | NS | NS | NS |

*NS indicates means that are non- significant.*

Relegating BG to women; hence the name "women's crop" is also a factor militating against its expansion. Because the production coincides with the cassava and tuber crops season in most countries, crops which require much energy, men are often reluctant to participate in Bambara nut planting and processing. Rather production activities are left in the hands of women and children. On the other hand, incorporating BG into the regular cropping patterns is a sure way of boosting its production.

There are no recent and reliable yield data for BG due to disinterest in research and commercialization of the crop. Hillocks *et al*. (2012) reported on the production of BG in Africa with Nigeria leading its production at 100,000 metric tonnes per annum (Table 2).

## 2.2. Improvement of Bambara groundnut

Other constraints limiting the development of BG include the lack of genetic improvement, inadequate knowledge on the taxonomy, reproduction biology and the genetics of agronomic and quality traits, management of disease and pests infestation (Lacroix *et al*., 2003).

**Table 2.** Bambara groundnut production in Africa

| Country | Estimated Bambara groundnut production (metric tonnes) |
|---|---|
| Nigeria | 100,000 |
| Botswana | 6,000 |
| Togo | 4,400 |
| Burkina Faso | 44,712 |
| Cameroun | 24,000 |
| DR Congo | 10,000 |
| Mali | 25,165 |
| Zambia | 18,750 |
| Zimbabwe | 750 |
| Ghana | 20,000 |
| Niger | 30,000 |
| Cote d'ivoire | 7,000 |
| Chad | 20,000 |

*Source: Hillocks et al. (2012)*

**Table 3.** Accessions of Bambara groundnut by Country of origin at IITA

| **Country** | **No of accessions** |
|---|---|
| Benin | 27 |
| Botswana | 5 |
| Burkina Faso | 27 |
| Cameroon | 207 |
| CAR | 103 |
| Chad | 70 |
| Congo | 42 |
| Cote d'Ivoire | 4 |
| Ethiopia | 1 |
| Gambia | 11 |
| Ghana | 120 |
| Kenya | 2 |
| Madagascar | 49 |
| Malawi | 59 |
| Mali | 28 |
| Niger | 33 |
| Nigeria | 310 |
| Senegal | 36 |
| South Africa | 1 |
| Sudan | 7 |
| Swaziland | 11 |
| Tanzania | 28 |
| Togo | 139 |
| Zimbabwe | 245 |
| Zambia | 284 |
| Unidentified accessions | 101 |
| Total | 2008 |

*Source: Goli (1997) and Mkandawire, (2007)* In recent times efforts are ongoing to improve the productivity of Bambara groundnut. There are however no known varieties in existence yet. All germ plasm currently being used in cultivation and research are at the level of accessions of which they are thousands. The widest database of BG accessions is housed by the IITA, from where detailed investigations of the potentials of BG and other studies are being coordinated (Table 3). There are several attempts on-going at improving BG to meet sufficiency, and these are based on several aspects of its improvement. From the table below, Nigeria has by far the largest assortment of accessions followed by Zambia and Zimbabwe. This further strengthens the fact of its origin in the Nigerian area due to largest number of wild accessions available.

## 3. Summary and conclusion

Bambara groundnut has great potential for achieving food and nutrient security for sub Saharan Africa. Present research efforts into production, improvement and utilization should not be left in the hands of struggling scientists and researchers. This review has examined contributions and reports from several workers on the crop and also cited results from actual field research to buttress the arguments set forth. There is need for a wide spread base of resources to assist targeted studies to achieve meaningful contribution to the eventual body of knowledge surrounding BG and its production practices to enable it attain its food security potential.

## References

Adeparusi E.O. and Agbede, J.O. (2009), "Evaluation of Leucaena and Gliricidia Leaf Protein Cconcentrate as Supplements to Bambara Grundnut (*Vigna subterranea* (L.) Verdc) in the Digestive tract of *Oreochromis niloticus*", *Aquaculture Nutrition,* Vol. 12 No. 2, pp. 335-342.

Akpalu, M.M., Atubilla, I.A. and Oppong-Sekyere, D. (2013), "Assesing the level of cultivation and utilization of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) in the Sumbrungu Community of Bolgatanga, Upper East Region, Ghana", *IJPAES,* Vol. 3 No. 3, pp. 68–75.

Azam – Ali, S. N., Aguilar-Manjarrez, J., and Bannayan-Avval, M. (2001). *A Global Mapping System for Bambara Groundnut Production. FAO Agricultural Information Management Series No. 1.* (Accessed 13th January, 2017).

Bamnetwork (2014), Bambara Groundnut. Crops. URL: http://www. Bambaragroundnut.org. (Accessed 5th January, 2017).

Bamshaiye, O.M., Adegbola, J.A. and Bamishaiye, E.I. (2011), "Bambara groundnut: an Under-Utilized Nut in Africa", *Advances in Agricultural Biotechnology,* No. 1, pp. 60-72.

Barimalaa, I.S. and Anoghalu, S.E. (1997), "Effect of processing on certain antinutrients of bambara groundnuts (*Vigna subterranea*) cotyledons", *Journal of the Science of Food and Agriculture,* No. 73, pp. 186–188.

Berchie, J.N., Sarkodie-Addoo, J., Adu-Dapaah, H., Opoku. M., Addy, S., Asare, E. and Donkor, J. (2010), "Yield evaluation of three early maturing Bambara groundnut (*Vigna subterranea* L. Verdc.) Landraces at the CSIR-Crops Research Institute, Fumesua-Kumasi, Ghana", *Journal of Agronomy,* Vol. 9 No. 4, pp. 175–179.

Brough, S.H., Azam-Ali, S.N. and Taylor, A.J. (1993), "The potential of Bambara groundnut (*Vigna subterranea*) in vegetable milk production and basic protein functionality systems", *Food Chem*., No. 47, pp. 277-283.

Doku, E.V. (1996), *Problems and prospects for the improvement of bambara groundnut*. Proceedings of the International Bambara Groundnut Symposium, July 23-25, University of Nottingham, UK, pp. 19-27.

Effa, E.B. Nwagwu, F.A. Osai, E.O. and Shiyam, J.O. (2016), "Growth and Yield Response of Bambara Groundnut (Vigna subterranea (L.) Verdc) to Varying Densities and Phosphate Fertilizer Rates in Calabar, South Eastern Nigeria", *Journal of Biology, Agriculture and Healthcare*, Vol. 6 No. 16, pp. 14-20.

FAO (2017), Http://www.fao.org/traditional-crops/bambaragroundnut/en/. (Accessed 13th January, 2017).

Goli, A.E. (1997), "Bibliographical review of Bambara groundnut (*Vigna subterranea* (L.) Verdc.)", in Heller, J., Begeman, F. and Mushonga, J. (Eds.). *Conservation and improvement of Bambara groundnut (Vigna subterranea [L.] Verdc.).* Proceedings of an International Workshop held at Harare, Zimbarbwe, 1998, IPK/IPGRI, pp. 11–19.

Harper, F.N. (1970), "Bambara groundnut (*Vigna subterranea (L) verdc.)*: Review article", *Field Crop Abstracts*, Vol. 23 No. 1, pp. 1-6.

Ihekoronye, A.I. and Ngoddy, P.O. (1985), *Integrated Food Science and Technology for the Tropics*. University of Ibadan Press, Ibadan, 283.

Ijarotimi, O.S. (2008), "Nutritional composition, microbial status, functional and sensory properties of infant diets formulated from cooking banana fruits (*Musa* spp. ABB genome) and fermented bambara groundnut (*Vigna subterranea L. Verdc.*) seeds", *Nutrition and Food Science,* No. 38, pp. 325–340.

Karikari, S.K., Wigglesworth, D.J., Kwerepe, B.C., Balole, T.V., Sebolai, B. and Munthali, D.C. (1997), "Country Reports: Botwana", in Heller, J., Begeman, F. and Mushonga, J. (Eds.). *Conservation and improvement of Bambara groundnut (Vigna subterranea [L.] Verdc.).* Proceedings of an International Workshop held at Harare, Zimbarbwe, 1998, IPK/IPGRI, pp. 11–19.

Kendabie, P., Holdsworth, M. and Mayes, S. (2012), Understanding photoperiod requirements for reproductive development in bambara groundnut (Vigna subterranea). *Poster presentation 2012 World Food Congress.* (Accessed 13th January, 2017).

Lacroix, B., Assoumou, N.Y. and Sangwan, R.S. (2003), "Efficient in vitro direct shoot regeneration systems in bambara groundnut (*Vigna subterranea* (L.) Verdc.)", *Plant Cell Rep*., No. 21, pp. 1153-1158.

Linnemann, A.R. (1987), "Bambara groundnut (*Vigna subterranea* (L.) Verdc.): A review", *Abstracts on Tropical Agriculture,* Vol. 12 No. 7, pp. 15-18.

Linnemann, A.R. (1990), *Cultivation of bambara groundnut in Western Province, Zambia*. Report of a Field Study. Trop. Crops Comm. No. 16, Wageningen Agricultural University. (Accessed 13th January, 2017).

Linnemann, A.R. and Azam-Ali, S.N. (1993), “Bambara groundnut (*Vigna subterranea* (L.) Verdc.)”, in *Underutilized Crops Series 2, Vegetables and Pulses.* Williams, J.T. (Ed.), Chapman & Hall, London, UK, pp. 13–58.

Mabhaudhi, T., Modi, A.T. and Beletse, Y.G. (2013), “Growth, phenological and yield responses of a bambara groundnut (*Vigna subterranea* (L.) Verdc) landrace to imposed water stress: II and Rain shelter conditions”, *Water SA,* Vol. 39 No. 2, pp. 45-52.

Mahazib, A.M., Nuha, M.O., Salawa I.S. and Babiker, E.E. (2013), “Some nutritional attributes of bambara groundnut as influenced by domestic processing”, *International Food Research Journal,* Vol. 20 No. 3, pp. 1165-1171.

Massawe, F.J., Dickson, M., Roberts, J.A. and Azam – Ali, S.N. (2002), Genetic diversity in Bambara groundnut (*Vigna subterranean [L.] Verdc.*), landraces revealed by AFLP markers. Published on NRC Research Press. Website http//:www.genome.nrc.ca, Canada. (Accessed 5th January, 2017).

Minka, S.R. and Bruneteau, M. (2000), “Partial chemical composition of Bambara pea (*Vigna subterranea* (L.) verdc), *Food Chem.,* No. 68, pp. 273-276.

Mkandawire, C.H. (2007), “Review of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) production in Sub – Sahara Africa”, *Agricultural Journal*, Vol. 2 No. 4, pp. 464–470.

Mune, M.A., Mbome Lape, I. and Minka, S.R. (2007), “Improving the Nutritional Quality of Cowpea and Bambara Bean Flours for Use in Infant Feeding”, *Pakistan Journal of Nutrition,* No. 6, pp. 660-664.

Murevanhema, Y.Y. and Jideani, V.A. (2013), “Potential of Bambara groundnut (Vigna subterranea (L.) Verdc) milk as a probiotic beverage”, *Critical Reviews in Food Science and Nutrition,* Vol. 53 No. 9, pp. 67-72.

Ndidi, U.S., Ndidi, C.U., Aimola, I.A., Bassa, O.Y., Mankilik, M. and Adamu, Z. (2014), “Effects of Processing (Boiling and Roasting) on the Nutritional and Antinutritional Properties of Bambara Groundnuts (*Vigna subterranea* [L.] Verdc.) from Southern Kaduna, Nigeria”, *Journal of Food Processing*, Vol. 2 No. 14, pp. 1-10.

Nweke, I.A. and Emeh, H.O. (2013), “The Response of Bambara Groundnut (*Vigna Subterranea* (L.) Verdc.) to Phosphate Fertilizer Levels in Igbariam, South East Nigeria”, *Journal of Agriculture and Veterinary Science,* Vol. 2 No. 1, pp. 28-34.

Shiyam, J.O., Nkor, N.N., Binang, W.B. and Effa, E.B. (2016), “Yield response of Bambara groundnut (*Voandzeia subterranea* (L.) Thours.) varieties to organomineral fertilizer in the Coastal Forest of SouthEastern Nigeria”, *SCIREA Journal of Agriculture,* Vol. 1 No. 1, pp. 91-106.

Swanevelder, C.J. (1998)*, Bambara - Food for Africa*. www.daff.gov.za (accessed 5th January, 2017).

Thottappilly, G. and Rossel, H.W. (1997), “Identification and characterisation of viruses infecting bambara groundnut (Vigna subterranean) in Nigeria”, *International Journal of Pest Management,* No. 43, pp. 177–185.

Toungos, D.T., Sajo, A.A. and Gungula, D.T. (2009), “Effect of P2O5 on the yield and yield components of Bambara groundnut (*Vigna subterranea [L.] Verdc.*) in Yola Adamawa State, Nigeria”, *World Journal of Fungal and Plant Biology*, Vol. 1 No. 1, pp. 1–7.

Uvere, P.O., Uwaegbute, A.C. and Adedji, E.M. (1999), "Effects of malting on the milling performance and acceptability of bambara groundnut (*Voandzeia subterranea* Thouars) seeds and products", *Plant Foods for Human Nutrition,* No. 54, pp. 49–57.

Yakubu, H., Kwari, J.D. and Sandabe, M.K. (2010), "Effect of Phosphorus Fertilizer on Nitrogen Fixation by Some Grain Legume Varieties in Sudano – Sahelian Zone of North Eastern Nigeria", *Nigerian Journal of Basic and Applied Science,* Vol. 18 No. 1, pp. 19-26.