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Industrial Potentials of Bambara Nut

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Abstract
Nigeria is a major producer of bambara nut in Africa. The plant has outstanding traits such as drought tolerance, nitrogen fixation potentials and the ability to grow in marginal soils. It is a crop for high attainment of food security and poverty alleviation in Africa as it is highly nutritious. It is composed of 65% carbohydrate and 18% protein. The nut can be used in the food, cosmetics and pharmaceutical industries. The oil contain fatty acids which are mostly made up of Capric acid (17%), Lauric acid (9.0%), Palmitic acid (10%), Palmitoleic acid (21%) and Oleic acid (18%). The predominant availability of unsaturated fatty acids and high iodine value index indicate that oil from bambara nut from Nigeria is the unsaturated type. The high blend of protein and carbohydrate in bambara groundnut make it possible for the nut to be used as an emulsifier. It can also be used in weaning food formulation. The flour can also be used as partial replacement of wheat in cereal based confectionaries such as biscuit, cake and bread while the oil can be used in soap making.
Keywords: Food, Security, Nutritional Composition, Fatty Acid, Typsin, Bambara

1.0 Introduction

Bambara groundnut (*Vigna subterranea*) is grown for its edible seeds which are used as nutritious pulse (Purseglove, 1974). It is an indigenous, underutilised plant cultivated throughout the sub-saharan Africa. According to Coudet (1984), the annual production is about 330,000 tonnes of which Africa produces half, with Nigeria as the major producing country. Presently, improved Bambara groundnut cultivars do not exist (Linnemann and Azam-Ali, 1993). It exists as landraces which actually composed of many genotypes which are reported to result in inability to endure stresses under local agricultural systems (Zeveni, 1983). The yields are low because production and improvement of bambara groundnut have been neglected for many years by researchers, even though, the crop is important for the small scale farmers due to its considerable commercial potentials (Bamisaye *et* al., 2011). It grows extensively in the Southern Guinea belt of the country (Ogunlade, 1985; Enwere, 1998) where it is mostly grown as a mixed crop with maize, cowpea and groundnut (Thottapilly and Rossel, 1997). Among the underutilised plants of Africa, bambara groundnut has enough potential to warrant various sorts of investment towards its improvement. It has outstanding traits as drought tolerance, nitrogen fixation and an ability to produce yield in marginal soils. It is a crop with a high potential for attainment of food security and poverty alleviation in Africa as it is drought resistance and highly nutritious (Boateng *et al.,* 2013). Bambara groundnut has several production advantages. As the third most important legume after groundnut (Arachis hypogea) and Cowpea (*Virgna unguiculata*) in the semi-arid area of the Africa, its role in food security cannot be contested. It is composed of 65% carbohydrate and 18% protein which make it an important food crop for people who cannot afford expensive animal protein. The fresh seeds are eaten in an unripe state as the pulse after soaking and boiling as the dry seeds are very hard. Bambara groundnut can contribute positively and help alleviate nutritional problems, though, it is classified as an underutilised crop (Oyeleke, *et al*., 2012). The seed stores very well and it is not easily prone to attack by pests and diseases.

Despite all the advantages of the crop in food security, and its nutritional attributes, its use as an industrial raw material is still at very low ebb. While many food products have been developed from soy, peanut and cowpea (e.g. milk, low spread fat, meat replacers, emulsifiers, etc.), the same cannot be said of bambara nut. More recently however, there is growing interest by the industry in Nigeria to look inward for the sourcing of their raw materials. For instance, the food, pharmaceutical and cosmetic industries are yarning for the replacement of wheat with low cost, highly nutritive alternatives in several applications. This paper examines the industrial utilisation potentials of the plant species across relevant industries. The primary objective is to elucidate areas where the bambara nut can replace imported raw materials in the industries in view of its ease of availability, production and ubiquity.

2.0 Nutritional Composition of Bambara Nut

The nutritional composition of bambara nut has received considerable attention in recent years. Available information shows the nut to be an uncommon example of a complete food (Mohammed, 2014; Goli, 1997; Brough and Azam Ali, 1992; Poulter and Caygill, 1980; Ankroyed and Doughty, 1982; Deshpande and Domodaram, 1990).

Onjemeluke and Ayenor (1992) carried out an extensive study on the proximate composition of different varieties of bambara groundnut seeds, flour and seed coat. The result of the study is shown in Table 1. Culinary experiments indicated that there is little or no difference in the taste of all bambara cultivars. The result

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also indicated that processing does not erode the nutritional properties as the embedded properties remained intact. According to Bamisaye *et al* (2011), the red seeds could be useful in areas where iron deficiency is a problem as they contain twice as much iron as the cream seeds. Oyenuga (1968), reported that bambara nut contain high quantities of lysine and minimum amount of trypsin and chymo-trypsin.

Table 1: Proximate Composition of Different Varieties of Bambara Groundnut Seeds, Flour and Seed Coat

Cultivars	Crude Protein	Fat (%)	Moisture Content	CHO Soluble	CHO Content	Ash Content
Red	19.5	6.5	8.0	7.6	54.4	3.0
Black	21.7	8.5	9.0	4.0	52.8	3.5
Cream	19.5	6.0	9.7	6.5	56.0	2.5
Brown	19.0	6.5	10.3	12.0	54.4	3.0
	FLOUR					
Red	20.9	3.0	9.3	2.2	48.0	2.0
Black	22.6	4.0	9.0	1.4	32.0	2.0
Cream	22.3	3.0	9.0	1.6	49.6	1.5
Brown	19.4	3.5	10.0	2.9	48.0	2.0
	SEED COAT					
Red	5.7	6.5	3.0	2.6	8.4	1.0
Black	6.1	2.0	3.5	3.0	6.0	1.5
Cream	6.8	1.0	3.0	1.8	9.2	1.0
Brown	6.3	2.0	3.0	0.5	9.1	1.0

Source: (Ojimelukwe *et al*; (12)

Table 2: Proximate Analytical Result of Bambara Nut (Measured in Percentage of g/100g of Dry Sample)

Parameters	Level (%)
Ash content	4.75 ± 0.25
Moisture content	7.19 ± 0.50
Protein content	18.50 ± 0.26
Carbohydrate	46.50 ± 0.20

*Carbohydrate was estimated by difference of value i.e. 100
(sum of percentages of moisture, ash, protein and lipid)
Okonkwo and Opara (2010)

The proximate analytical result of bambara nut is shown in Table 2. According to Okonkwo and Opara (2010), the low ash content (4.75%) indicated that bambara nut contain very small amount of micro-elements. The carbohydrate level of 46.5% is an indication that the nut has very high energy content which enables it to serve as energy food. The low moisture content at 7.19% is perhaps one of the reasons why the seeds stores well.

Table 3: Chemical Data Obtained for Bambara Nut Oil

Parameters	Level
Oil* (%)	72.50*
Acid value (mg g^{-1})	90.00 ± 0.12
Saponification value (mg g^{-1})	170.66 ± 0.64
Free fatty acid (%)	1.11 ± 1.82
Peroxide value (mg g^{-1})	4.00 ± 10.21
Iodine value (mg g^{-1})	88.00 ± 0.45

Okonkwo and Opara (2010)

Table 4: Relative Levels of Fatty Acids in Bambara Nut Oil

Fatty Acids	Level (%)
Oleic acid	18
Caprylic acid	17
Capric acid	8
Lauric acid	9
Palmitic acid	10
Palmitoleic acid	21
Linoleic acid	12

Okonkwo and Opara (2010)

Table 3 presents the result of the chemical composition of bambara nut oil. The chemical properties of the oil are among the most important properties that determines the present condition of the oil (Okonkwo and Opara, 2010). Free fatty acids and peroxide values are valuable measures of oil quality and iodine value was the measure of the degree of unsaturation of oil. The percentage of the Free Fatty Acid (FFA) at 1.1% can be considered low which is an indication of the stability and low probability of it becoming rancid (Okonkwo and Opara, 2010).

The fatty acid components of bambara nut oil include caprylic acid (17%), Capric (8.0%), Lauric acid (9.0%), Palmitic acid (10.0%), Palmitoleic acid (21.0%), Oleic (18.0%) and Linoleic acid (12.0%), (Table 4). The linoleic acid, oleic acid and palmitoleic acids are unsaturated acids and are also among the essential fatty acids required by the body. Linoleic acid is one of the most important polyunsaturated fatty acids in human food in view of its ability to prevent distinct heart vascular disease (Boelhouwer, 1983). Table 4 also shows that bambara nut oil is predominantly made of the unsaturated palmitoleic acid, oleic acid, linoleic acid and caprylic acid. The predominance of the unsaturated fatty acids and high iodine value index indicate that oil from bambara nut from Nigeria is of unsaturated type (Okonkwo and Opara, 2010).

Oyeleke *et al* (2012) reported that bambara nut contain a number of beneficial minerals that are required in food products (Table 5). The predominant minerals found in the plant are potassium, calcium, sodium, iron and manganese. Despite these however, Ijarotimi and Esho (2009) reported three inhibitors in the plant (Table 6). These are tannin, phytic acid and trypsin inhibitors in mg/100g. According to Prohp *et al* (2006), phytic acid affects the bioavailability of composite nutrients as they have the ability to complex bivalent ions which can make them unavailable in monogastric animals. According to Ijarotimi and Esho (2009), fermentation improves the mineral composition but had little effect on amino acid content and decreases the anti-nutritional factors as shown in Table 6.

Table 5: Mineral Composition of the Bambara Groundnut (mg/100g)

Parameter	Mean $\pm$ S.D
K	1702.10 $\pm$ 0.50
Na	135.30 $\pm$ 0.05
Mg	347.15 $\pm$ 0.01
P	738.0.4 $\pm$ 0.15
Fe	18.51 $\pm$ 0.10
Ca	256.56 $\pm$ 0.05
Mn	10.46 $\pm$ 0.05

n = 2

Oyeleke *et al* (2012)

Table 6: Anti-nutritional (mg $100g^{-1}$) factors in Raw Bambara Nut and Its Fermented Flour

	Oxalate	Tannic Acid	Phytic Acid	Phytin Phosphorus	Trypsin
Raw nut	2.7	0.39	46.4	13.1	6.7
Fermented flour	2.3	0.29	28.1	7.6	4.2

Source: Ijarotimi and Esho (2009)

In comparison with other nuts, available information show that the gross energy value of Bambara nut is higher than that of common pulses such as cowpea, lentil (Lens esculenta) and pigeon pea (Cajanus cajan) (FAO, 1982). De Kock (undated) indicated bambara groundnut to have general nutritional breakdown carbohydrate 54.5 – 69.3%, protein 17 – 24% and fat 5.3 – 7:8%, thus making it a potential raw material for the food security.

3.0 Potentials of Bambara Groundnut as an Industrial Raw Material

A number of reviews on bambara groundnut have been published. Some of them elucidated the contributions of research towards developing the potential of bambara nut as an industrial raw material. While some success have been recorded in the areas of food formulation from bambara, efforts to commercialise the crop still remain largely unsuccessful; primarily due to barriers to the establishment of functional value chain (Hillocks *et al*., 2011). One of the major problems militating against the successful industrial application of the nut is the long time it takes to cook and the anti-nutritional factors such as tannins and trypsin – inhibitors coupled with its poor milling characteristics due to its poor dehulling potentials (Barimalaa and Anoghalu, 1997). The long cooking time consumes more fuel and water than that might be required for cowpea and phaseolus bean. According to Hillocks *et al* (2011), boiling fresh seeds may take 45 – 60 minutes while dried bean may take 3 – 4 hours. Other factors limiting increased utilisation of the crop include lack of awareness of the best agronomic practices and its potentials as a cash crop; availability and access to markets, lack of government support, urbanisation and inadequate funding (DFID, 2012).

Current local utilisation patterns in Africa denotes that bambara groundnut is eaten in various forms. In Nigeria, there are a number of traditional recipes made from the beans. The freshly harvested pods may be cooked, shelled and eaten as a vegetable snack while the dry seed are either roasted and eaten as a snack in a manner similar to boiled peanuts (Kay, 1979; Alobo, 1999). In the Southwest States of Nigeria, bambara groundnut are roasted and chewed with palm kernel as a snack item or may be milled into flour and used to prepare bean balls after frying the paste in vegetable oil (Hillocks, *et al*, 2012). Alternatively, the slurry may be used to prepare a steamed gel also known as okpa (Uvere *et al*., 1999). In Nigeria and parts of Africa, Bambara nut has also for long been used as part of animal feed (Linnemann, 1991) and the seeds have been successfully used to feed chicks (Oluyemi *et al*., 1976). The stem or stalk are also used for livestock feed (Linnemann, 1988).

More recently however, there have been renewed efforts to ascertain the industrial potentials to enable its processing and increased industrial utilisation. Research efforts have shown that the high blend of protein and carbohydrate in bambara groundnut suggests its potential as an emulsifier. Bambara groundnut also has a high starch yield and carboxymethylantin of the starch improved the physical properties (water absorption, gelatinisation, swelling, power and reduced crystalinity) of the starch (Afolabi, 2012). As a result, the native starch from bambara groundnut could find wide application in the food, cosmetics and pharmaceutical industries. Afolabi (2012) also postulated on the possibility of using the starch as a biodegrade polymer in the production of hydrogels and agricultural mulch. The current desire in most industries is to replace synthetic emulsifiers with natural ones. This is because natural emulsifiers are more bio-compactible and could demonstrate satisfactory amphiphilic properties (Nakauma *et al.,* 2008; Wang, *et al.,* 2010). The search for natural products has yielded results with the use of products of some leguminous plants such as soyabean and flax seed in emulsion preparations (Huck-Iriart *et al.,* 2011). The search for emulsifiers among natural plant/food products is particularly desirable due to their often nontoxic nature, affordability and their already established food and medicinal uses (Huck-Iriart *et al*., 2011).

In a study reported by Gabriel *et al* (2013) to assess the ability of bambara groundnut flour and starch to stabilize oil in water emulsions, it was observed that an emulsion containing 9% $^{w}/_{v}$ bambara groundnut flour and 39% $^{w}/_{v}$ oil provide optimal stable characteristics. For bambara groundnut starch – stabilised emulsions, 5% $^{w}/_{w}$ bambara groundnut starch and 30% $^{w}/_{v}$ oil gave optimal emulsion. In most cases, emulsions were stable till day 5. The authors concluded that bambara groundnut flour was a better emulsifier than bambara groundnut starch. Both the flour and the starch however showed emulsifying properties.

As a result of its high protein content, the nutrient composition of a number of weaning food products can be enhanced through supplementation with bambara groundnut flour (Hillocks, *et al*., 2012). According to Ijarotimi (2008), the banana/bambara mixture can be used as a substitute for expensive commercial weaning products.

While commercial canning of bambara groundnut gravy is a successful industry in Ghana (Swanerelder, 1998) and Zimbabwe (DFID, 2001), little or no industrial activity is taking place on this plant in Nigeria. However, Uvere *et al* (1999) has indicated that flour yield from bambara groundnut can be improved by malting, with the added benefit of a decrease in milling energy which will reduce the medium of repeated milling and sieving during flour extraction from unmalted seeds. Malting reduce the toxic factors, lectins and trypsin (Hillocks *et al.*, 2011). The malted bambara can be used for the production of high energy, low weaning foods given its high carbohydrate and protein contents (Hillocks *et al.*, 2011). Apart from this, the flour could also be used as partial replacement of wheat in cereal based confectionaries such as biscuit, cake, bread, etc. (Ado and Oyeleke, 1986). The Food Research Institute of the Council for Scientific and Investment Research (CSIR), Ghana also undertook a series of studies to solve the problems accompanying declining interest in the consumption of bambara foods. The result of the research was an improvement of the traditional method of processing bambara flour before its utilisation in preparing various dishes. The improved method produced a high quality nutritionally beneficial flour that can be used to prepare traditional as well as new bambara nut based foods called High Quality Bambara Flour (HQBF) (Falley *et al.,* 2004).

Emendu and Emendu (2014) used the soxhlet extraction method to obtain oil from ground bambara nut using benzene solvent. The mixture of benzene and oil were separate using distillation methods. The benzene having a low boiling point compared to oil evaporate first and the oil characterised after removing the impurities. The oil produced was used to produce soap using the saponification process, thus making it a potential industrial raw material in the manufacture of soap, cream and in confectionery.

Brough *et al* (1993) reported that bambara groundnut is already being used for break making in Zambia. In addition, the bambara groundnut milk produced in Zambia compared favourably in its flavour and composition with those milk proposed from cowpea, pigeon pea and soya bean (Brough *et al.,* 2003).

4.0 Problems and Prospects for Industrial Utilisation of Bambara

The countries where bambara groundnut grows in situ are increasingly realising its importance in food security. Although production statistics in most countries are scarce, it is evident that bambara groundnut is not taken as a priority crop in most countries. Thus the quantity produced in most countries are still low to warrant any serious industrial use. For instance, in the 1990's, Zimbabwe produced approximately 50t a year by 3,500 farmers on an area of 2,300 ha (Hillocks, *et al.,* 2011). In Kenya, the total annual production in the period 1992 – 94 from four districts was 190t with yields averaging 400 – 600kg ha^{-1} (Hillocks, 2011). In most cases, these levels of production were not able to satisfy the local demand for food, making industrial utilisation currently impossible in most countries. As a result, the need to ensure increased production has become imperative in view of its increasing utilisation as food sources and the realisation of its industrial potentials. The world is presently over-dependent on a few plant species. Diversification of production and of the current habits to include plants such as bambara nuts have become imperative. For this to be possible however, there is need for increased production of bambara nut through research and development on improved varieties. There is need to develop the current landrace cultivars the farmers depend on in order to promote increased its production and productivity.

It has also been estimated that sustainable production and processing of bambara nut will assist in employment generation, poverty alleviation and increased foreign exchange earnings, estimated at more than 2 million dollars on annual basis. Thus, efforts should be geared towards the development of the plant species. Some of the ways the plant species can be sustainably developed in Nigeria are highlighted below:

- The silviculture of the plant species should be adequately studied and improved planting materials developed.
- Farm inputs should be made available to farmers at the right time by the relevant Ministries. In Nigeria, the Ministry of Agriculture is responsible for this. The Ministry should also encourage small scale farmers to invest in Bambara cultivation.
- Access to technical assistance, farm inputs and credit facilities are critical to ensure that small holder farmers get the best price for their products.
- Supply chain for bambara groundnut should be developed to allow for competitiveness in the international market. A developed local supply chain would increase the farmers' income.
- Farm gate processing clusters for bambara groundnut should be established to enable farmers add value to their produce. Drying and storage facilities should be established at the farm gate level to handle post-harvest management and to reduce losses.
- Formation of Cooperatives among farmers of the commodity in the producing zones/States should be encouraged.
- Specially designed programme should be put in place to encourage the youths to go into the cultivation of bambara groundnut. Public Private Partnership (PPP) arrangement could be used to deliver the programme. Private sector-led support services (credit and input supply) can be made available through collaboration with farmer groups.
- African countries should build capacity for the local fabrication of process equipment. Also, SMEs should take special interest in the design and packaging of their products so as to compete favourably with imported products.
- The National Cereals Research Institute of Nigeria, Badeggi should be more vividly involved in pilot scale development of Bambara products. The Institute should bring up new Bambara products that highlight its inherent advantages. This innovation should be supported by the relevant industries in Nigeria.

5.0 Conclusion

The need for the development of bambara groundnut cannot be overemphasised. Apart from its plausible role in food security, bambara groundnut has veritable industrial uses that cut across many industries. The development of industrial potentials of bambara nut in Nigeria will save the country more than 2 billion naira on annual basis.

Thus relevant organisations in Nigeria with the necessary mandates should be supported to promote industrial utilisation of bambara groundnut in Nigeria. The International Institute of Tropical Agriculture has a large number of accessions collected from counties across sub-Saharan Africa. IITA collection has been characterised and evaluated by Goli (1997). The development of improved varieties to replace landraces that have evolved under domestication directly from their wild relatives with boost production and consequently industrial use of the plant species in Nigeria.

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