Prospects for Multi-Functional Utilisation of Bamboo in Nigeria

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Abstract
The industrial utilisation of bamboo is expanding globally as a result of its role in climate change mitigation, adaptation and development. Bamboo has more than 1,500 industrial applications and the uses are expaanding. In Nigeria, the prospects for multi-functional utilisation is high and increasing as a result of the high dependence on importation of raw materials and the serious ecological and land degradation taking place in most parts of the country. Bamboo will find ready use in the wood and wood products sector of the economy as Nigeria currently depends on importation of plywood, particleboard and more recently seasoned planks. In the textile industry the low cotton production and productivity will encourage industrial textiles production from bamboo while the near total dependence on imported long fibre pulp will promote bamboo utilisation in the pulp and paper industry. Bamboo utilisation in housing construction is likely to look up as a result of the current housing problems in both urban and rural areas and the high level of development in engineered bamboo production globally. In Nigeria, bamboo utilisation will increse significantly in the chemical and pharmaceutical industries with adequate promotion of investment in these sectors. In line with the plans of international communities, thedevelopment and use of bamboo briquettes in place of firewood and wood briquettes coupled with establishment of bamboo plantations on degraded lands will significantly promote production and multifunctional utilisation of bamboo locally.

Keywords: pharmaceuticals, bamboo, textiles, charcoal, environmental conservation.

1.0 Introduction

The prospects for development and industrial utilization of bamboo in Nigeria have been subjects of intensive discussion in recent years. A number of authors including Ogunwusi and Onwualu (2011), Ogunwusi (2011, 2012a, 2012b, 2012c , 2013a, 2013b, 2013c); Ogunwusi and Jolaoso (2013); Ogunsile and Uwajeh, 2011; Onilude 2006; RMRDC, 2004) have discussed extensively, bamboo availability and its industrial potentials in Nigeria. Ogunwusi (2011) outlined the problems militating against sustainable development of bamboo, while Ogunwusi (2013b) observed that for bamboo development to be sustainable in Nigeria it should be backed up with adequate policy. In spite of these, no attempt has been made to highlight the multi-functional utilisation of the plant locally. This is important as the industrial sector in Nigeria depends mostly on imported raw materials. It is also important in view of the increasing roles of bamboo in climate change Mitigation, Adaptation and Development (MAD). According to Wooldridge (2012), bamboo is being hailed as a new super material with uses ranging from textiles to construction. With advancement in technology, nearly 4000 commercial items made out of bamboo or its products are available and in use daily around the world (Singh, 2008). Inspite of these, the consistent development of new technologies and processing techniques are promoting bamboo as a stiff competitor to a number of other industrial raw materials. Dayawansa (2012) estimated the world trade in bamboo resources in 2002 at 12 billion dollars. With an annual growth rate of 2 billion dollars, total bamboo resources trade will increase to about 20 billion dollars by 2015 (Dayawansa, 2012).

In view of the increasing popularity of bamboo in the industrial sector and its role in the MAD challenge (Schellnhuber, 2009), most countries have initiated plans to invest in bamboo production and processing in order to increase its role in industrial production processes (Pandey and Shyamasunder, 2008). In Sri Lanka, Philippine, Ghana, Kenya and Indonesia, structures are being put in place to tap the industrial potentials of bamboo across multiple industries. For instance, considering the great potentials of the bamboo industry, the Philippine government promulgated Executive Order (EO) No. 879 on 14th May, 2010, to prioritize bamboo production and processing, and to improve market access to local bamboo resources (Dayawansa, 2012). The government directed that all desks and other furniture requirements of public elementary and secondary schools, fixtures and construction works sponsored by government should contain a minimum of 25% bamboo.

The current patterns of development in the forest industry in Nigeria which rely solely on diminishing forest resources have been observed to be unsustainable (Ogunwusi and Jolaoso, 2012 and Ogunwusi, 2012a). A number of studies (Larinde 2010; Ogunsanwo, 2010 and Ogunwusi, 2012a) have reported the timber resources in the country to be dwindling in availability. Also, the consistent dependence on importation of more than half of the raw materials required in chemical, pharmaceutical, textile and food and beverages industries in Nigeria has increased the appeal for bamboo as industrial raw material in these sectors. Consequently, the need to develop bamboo as a sustainable, climate friendly alternative that has potentials for alleviating the social and environmental problems Nigeria is currently facing has become imperative. For instance, the high dependence on importation of long staple cotton in the textile industry has been a major factor limiting the development of the industry in Nigeria. As bamboo has been used in the textile industry to produce several varieties of texile materials, its utilization in the sector will greatly enhance sectoral development. Also, the use of bamboo in the pharmaceutical and chemical industries has made it an important raw material with multi-functional appeal in these sectors.

As Nigeria's industrialisation policy has been structured to hinge on development and utilisation of locally available raw materials (Aribisala, 1993), the development of bamboo coupled with its multi-functional appeal will reduce the current high rate of deforestation, improved technical capability and lead to development of local skills in several industrial sectors across the nation. This paper reviews the properties of bamboo and its utilisation potentials in the nation's manufacturing sector. The challenges militating against bamboo development are discussed and recommendations capable of promoting its sustainable development made.

2.0. Industrial properties of bamboo

The industrial utilization potentials of bamboo are hinged on its properties. The density of bamboo is reported to vary from 500 to 800kg/m^3 depending on anatomical structures such as quantity and distribution of fibres around vascular bundles (Sattar, 2005). Density increases from the centre to the periphery of the culm (Sekhar and Bhartari, 1960; Sharma and Mehra, 1970). It also increases from the base to the top of the culm. The maximum density is from about 3 years old culms (Liese 1986; Sattar et al 1990; Kabir, et al 1993; Espisloy, 1994). The physico – mechanical properties are extremely unstable. In certain respects, it is more unstable than wood. The complexity is due to uneven distribution of vascular bundles, variation in moisture content, differences in the physico – mechanical properties of the node and internode parts, most especially with age. The physico - mechanical properties of bamboo material in all the three directions are also different. Bamboo possesses high moisture content which is influenced by age, season of felling and species. Although unlike wood, bamboo starts shrinking above the fibre saturation point. Nevertheless, bamboo possesses excellent strength properties, especially, tensile strength. Most of the properties depend on species and on the climate condition of where they grow (Sekhar and Gulati 1973). Strength varies along the along culm height. Compressive strength increases with height, while bending strength has inverse trend (Liese 1986; Espiloy, 1987; Kabir et al, 1991, 1993). An increase in strength is reported to occur at 3-4 years and thereafter decreases (Espiloy, 1994). Thus, the maturity period of bamboo may be considered at 3-4 years with respect to density and strength. Maturity of culm is a prerequisite for the optimum utilisation of bamboo in construction and other structural uses. Janssen (1981) reported that the ratio between the ultimate compression and the mass per unit volume for dry bamboo is higher than that of dry wood. The reason is attributed to the higher cellulose content of about 55% in bamboo compared with about 50% in wood (Sattar, 1990).

Some studies have been conducted on the relationship between anatomical structure, physical and mechanical properties on one hand, and the technological characteristics, behaviour in processing and product quality on the other (Janssen 1981; Liese, 1992). Density of bamboo is closely related to the relative proportion of vascular bundle and ground tissue, and plays an important role in influencing the mechanical properties. This explains the variation of strength along the culm height. Permeability which is affected by anatomical characteristics, influences moisture movement and thereby treatability (Sattar, 1990). In wood, the chemical by products such as polyphenol, resin and wax influence properties such as shrinkage, durability and gluability. Nothing in this regards is known for bamboo.

3.0. Industrial utilization of bamboo.

The last fifteen years has seen a dramatic growth in the variety of bamboo products (Ogunwusi, 2011). In view of its proprieties, bamboo continues to be used for the production of new products. The multi-functional range of bamboo uses have shown that it may prove beneficial as a valuable and sustainable natural resource (Naxium, 2001). More recently, bamboo had been reported to have more than 1,500 documented industrial applications, ranging from medicine to nutrition and from toys to aircraft (Salam, 2008). Bamboo's appearance, strength and hardness combined with its rapid growth rate and capacity for sustainable harvesting makes it an attractive substitute in various industrial sectors. These have created opportunities for bamboo development. In economies such as in China, bamboo has reduced dependence on solid wood, while in less strong economies; there are emerging new opportunities for bamboo products that are targeted for rural development and poverty reduction (Ogunwusi, 2013). The emergence of near source value addition in modern supply chains increases bamboo economic impact on poor rural communities.

Generally investment in bamboo processing has been divided into three categories which include handicrafts which are characterized by manual processing and high value addition to relatively small volumes of bamboo; the bamboo shoot industry and the industrial processing of bamboo which involves semi-mechanized and mechanized processing of large volumes of bamboo culms. The handicraft industry is well developed in a number of countries. For instance in Vietnam, bamboo handicraft export generates excess of $640m annually (Sastry, 2008). The same is true for countries such as Indonesia and the Philippines, etc (Sastry, 2008). Industrial processing of bamboo has being offering opportunities for economic growth and development in many countries. For instance as a result of governments' initiatives, the economic benefits of bamboo are being exploited in most countries in Asia and Africa due to the remarkable growth and success of the Chinese bamboo sector in the past decade (Sastry, 2008). The India's Global Bamboo Mission Scheme with an outlay of $140 million plans to establish several hectares of bamboo over the next five years to improve supply side problem (Sastry, 2008).The programme is expected to help over 5 million families cross the poverty line and to increase the country's share in the global market from 4% to 27%. Currently, the Indian bamboo sector is worth $500 million annually (Kumer, 2007). In comparison, China's bamboo industry has an annual turnover production value of $5 billion from the export of a variety of processed items (Jang, 2007). Premium processing of bamboo is being envisaged to leapfrog a number of countries into the big league. In countries such as China, modern bamboo supply chains has developed to comprise of different industries producing a variety of products, with premium bamboo parts going for high value use such as flooring and laminated furniture, the mid quality parts going to medium value-added products such as blinds, mats and chopsticks. The leftovers or residue parts are used in the production of paper, charcoal or chipboard. Also, bamboo products have been classified into three major categories which include wood substitutes and composites, industrial products and construction and structural application products.

4.0. Prospects for multi-functional industrial utilisation of bamboo in Nigeria

The prospects for industrial utilization of bamboo in Nigeria are enormous. Bamboo could be used in more than five industrial sectors in the country. The industries where it can find immediate relevance, based on current level of technological development locally are subsequently discussed.

4.1. The wood products industry.

The state of the national forest estate and the status of forest industry in Nigeria will greatly enhance bamboo development and utilization in the country. For the past thirty years, as a result of resource depletion, production capacity within the sector has been on decline. FAO (2006) reported that Nigeria has about 1 million hectares of forests which is about 12% of the total land area. However, most of the resources are largely in the savanna woodland with limited potentials. With an estimated population of about 150 million, Nigeria has enormous domestic demand for construction and joinery raw materials (Blackette and Gardette, 2008).

During its boom period, the Nigeria wood and wood products sector was made up of sawmills, furniture, wood based panels, safety matches and wood treatment subsectors. However since 1980's the installed capacity of the sawmill industry has dwindled considerably. It decreased from 15,793,188m^3 in 1992 to 11,734,000m^3 in 2010 (Ogunwusi, 2012a). Plywood production has also reduced drastically as a result of reduction in the volume of economic wood species (RMRDC, 1991; Arowosoge, 2010, Ogunwusi, 2012a). In 1988, the total capacity utilization was 126,000m^3. This decreased to 106,000m^3 in 2010 (Ogunwusi, 2012a). Face veneer is in short supply as one of the major producers; the government owned African Timber and Plywood has closed operations. Currently, a considerable volume of face veneer is being imported from Ghana and various parts of Europe (GWV Consultants, 1994). Thus, Nigeria depends almost entirely on imported plywood, particle board, etc, for use in the industry. Also, wood in form of planks is being imported for use in the sector. As a result, a policy orientation directed at promoting utilisation of bamboo in the sector cannot be over emphasized. To optimize development in the forest industry, there is need for the establishment of factories producing bamboo based panels. The panels are manufactured under high temperature and pressure with the aid of adhesives. The thickness of bamboo based panels varies from 2-40 mm and the dimensions depend on the manufacturing equipment adopted. The main feature of its manufacturing technology is high temperature softening and flattening (Qisheng *et al*, 2002). It can be sawn, planed, milled, dried and used for further processing, thereby making it a comparatively ideal material for engineering structure (Qisheng et al, 2002). In Nigeria, this product can reduce the dependence on wooden planks. Ply bamboo is used in truck floors as weight of steel materials is too high. In addition ply bamboo has high friction coefficient and it does not rust. Also production of laminated bamboo board (planed) is very essential. During the production of laminated bamboo, bamboo materials are cut into square edge strips of even thickness and width. The strips are bleached or carbonized. They are arranged in one direction during assembling and pressed. The products are multilayered and of great dimension. The surface is fine grained and can be used in furniture production and in inner decoration, just as in laminated high grade wood. Other important bamboo products required in the wood industry are mat ply bamboo; curtains ply bamboo, laminated wood strips, mat curtain plywood, bamboo chipboard, floor tiles and composites (Ogunwusi, 2012a).

4.2. Construction of houses

While bamboo houses exits in different communities in Nigeria, the lack of government interest in making bamboo a recognized building material stemmed development in this sector. Bamboo houses are common in Asia where there is a serious housing problem. The government of India declared housing for all in 2010 and anticipated the building of 2 million low cost houses per year by the public sector in addition to ongoing housing construction in the private and informal sectors (Destimuka and Karpe, 2007) The National Habitat Policy of India recognized the housing sector as a medium to promote environmentally friendly and cost effective building materials where bamboo can be promoted. In view of its low cost and fast growth rate, bamboo offers an ecologically viable alternative to timber for construction. Construction grade material is available in three years of growth as opposed to ten to twenty years for timber (Satter, 1995). Unlike trees, harvesting doesn't kill the bamboo plant thereby causing erosion problems (Ogunwusi and Jolaoso, 2012). Bamboo also offers an opportunity for greater personal sovereignty as individuals can grow their own home (Janssen 1995). One of the major impediments to bamboo housing development was lack of adequate bamboo treatment methods. However bamboo treatment procedures have been perfected and structural bamboo materials can now be treated with borate to create a long lasting insect and fungus resistant building material (Edward and Doing, 1995). In Costa Rica seventeen hundred homes are built with bamboo under a government sponsored program using the borate treatment process (Janssen, 1995). The waste from the process is used to feed bamboo plantations as boron is a necessary nutrient for plant growth. In Columbia, structural bamboo is being used to create large public buildings with arches spanning 27.4metres (Janssen, 1995).

In order to promote acceptability of bamboo houses globally, efforts are being made to formulate an international building code for bamboo (Janssen 1995). According to Janssen (2000), the advantages of codified design with bamboo include engineering recognition, promotion of contractual and trade advantages coupled with increased use of bamboo as codification leads to better social acceptance and innovation. Among the types of bamboo houses that are required in Nigeria are prefabricated houses made of engineered bamboo. These can be packed and transported over long distances at reasonable costs. They are better designed and environmentally friendly. As bamboo is less durable than timber, it is important that houses are designed in such a way that the bamboo materials that are used are allowed to dry by sun and wind, if it gets wet in other to prolong its life in service (Janssen, 1995). These could be achieved by having a water tight roof with an overhanging roof to prevent bamboo from rain, plastering or a side walk of brick or cement mortar, to protect the lower part of the outside wall from splashing rain water. Bamboo weaving mats in between structural bamboo weaving columns should be fixed in such a way that they could be replaced easily (Janssen, 2000). Modern prefabricated houses made of bamboo can be built in towns in elegant manners. This can be achieved if the government encouraged the development of industrial prefabrication and standardization in the country. Modern bamboo houses can assist government in solving the current housing problem in the country.

4.3 Pulp and paper production.

Paper production is a major activity regarded as a pointer to industrial and educational development worldwide. In Nigeria, efforts made to develop a sustainable pulp and paper industry have proved abortive in view of the high dependence on imported long fibre pulp (Ogunwusi, 2013). As far back as the 1980's, approximately US $85million was required to import 85,000 tons of long fibre pulp required by the three integrated pulp and paper mills in Nigeria (Makinde 2004). Thus, Nigeria currently depends totally on the importation of writing, duplicating, printing and kraft papers including newsprint. However, more recently research and development carried out on bamboo growing in Nigeria has shown positive results. In a study carried out by Ogunsile and Uwaje (2009), the average specific gravity of *Bambusa vulgaris* growing in Nigeria was reported to range between 0.58-0.69. The high density value is an indication of normal liquor to solid ratio, impregnation, short cooking periods and high pulp yield. The study also showed the fibre length of *Bambusa vulgaris* to vary from 2.37-2.92 mm, indicating that strong paper with good tearing resistance could be obtained from the plant as a strong relationship exists between the strength properties of pulp and the fibre length constituting the pulp. No significant difference was however observed in the fibre dimension of *Bambusa vulgaris* at the various stages of maturity indicating that the plant could be utilized at various stages of its growth. This result, coupled with the development of desilification technology for the removal of silica from black liquor will greatly enhance bamboo utilisation for pulp and paper production in the country (Ogunwusi; 2012).

4.4. Bamboo utilisation in the textile industry in Nigeria

The textile industry in Nigeria was one of the most important manufacturing industries that contributed to the development of the nation's economy in the 70's – 80's (RMRDC, 1990). The industry is the second largest employer of labour in the country (RMRDC. 2006). In the 1990's, Nigeria has a share of 24% installed short staple spinning capacity (Aribisala, 1993). In 2002, Nigeria produced about 500 million linear meters of all types of fabrics, representing 72% of the West African production. The existing industries produce primarily African prints of real wax and imitation wax with little products differentiation which affects their competitiveness (Aribisala, 1993). The major determinant of competitiveness in the textile industry is cotton. The index of manufacturing production for cotton declined to 94.5 in 1998 compared to 106.1 recorded in 1997. However, it picked slightly in 2001 to 93.7 as against 93.3 in 2000 (RMRDC, 2009). The declining performance has led to the closure of many industries, leading to loss of jobs estimated at over 60-70% of total employment in the industry within the last 7 years (RMRDC, 2009).

The sector has high propensity for growth and competitiveness if there is adequate and sustainable supply of raw materials (Aribisala, 1993). Cotton fibre contributes more than 70% of the fibre raw material requirements and manmade fibre account for 30%. The textile industries in Nigeria produce fibre**,** yarn and fabric materials. Cotton lint is the most important single apparel fibre. It is the first basic raw material in the textile industry. The domestic availability of this raw material is an essential factor for the establishment of a virile textile industry. The Nigerian cotton board (now abolished) did not have enough productive capacity to sustain and ensure a continuous flow of cotton to the textile mills. Poor crop output has consistently been attributed to factors such as late planting, adverse weather conditions, finance and high cost of production. Local production, planted areas and average local yield is extremely low compared with some other cotton producing countries with similar available potential land resources (RMRDC, 1990).

The most commonly used fibre, cotton and polyester cause serious environmental problems. Cotton production accounts for 11% of all pesticides and 25% of all insecticides used each year worldwide World Wildlife Fund (2005). The growing of cotton consumes large amount of water from 7 to 29 tons per kg of raw cotton fibres (Kalliala and Nousianien, 1999). Polyester is manufactured from oil, a non-renewable resource. The manufacturing process use high energy input and generates large amounts of harmful emission (Anson and Brocklehurst, 2007). Organic textiles which revolves around cultivation of raw material under organic condition is based on a system of farming that maintains and replenishes soil fertility without usage of and persistent pesticides, fertilizers and genetically modified seeds (Green Biz, 2006). Organic cotton is more costly to grow since there are additional costs at each stage of processing (Coster, 2007). In view of the above, textiles from bamboo has been observed to be able to address the aim of sustainable development by utilising a renewable resource to make cloths and other textile applications. Bamboo fabric is widely available in China, India and Japan. A Philadelphia based footprint provide socks made from 95% bamboo to offer anti-bacteria and moisture wicking properties (Textile World, 2008). London based bamboo clothing supply a range of bamboo clothes for men and women that stay naturally cool in the summer and hot in the winter (Bamboo clothing, 2008). In 2006, roughly 10 million USD worth of bamboo textiles were sold in the US and 50 million USD worth worldwide (Durst, 2006). There are over 200 retail stores offering bamboo textile products in the US alone.

The advantages of using bamboo in the textile industry derives from its renewability, its biodegradability, efficient space consumption, low water use, organic status and its carbon sequestration abilities. Another important advantage is predicated on some of the properties of bamboo textile. Since bamboo is naturally hollow in the horizontal cross section, the fibers show abundant gaps. These gaps can absorb and evaporate human skin moisture just as bamboo plant absorbs moisture in the ecosystem (INBAR, 2004). Also, bamboo does not require pesticide as a result of its natural antifungal and antibacterial agent known as Kun (or Kunh). The same natural substance that protects bamboo growing in the field, functions in spun bamboo fibre (FAO, 2007). The Kun stops odour producing bacteria from growing and spreading in the textile. A quantitative antibacterial test was performed in China by the China Industrial Testing Centre in 2003 in which 100% bamboo fabric was tested in bacteria strain type *Staphylococcus aureus.* After 24 hours incubation period, the bamboo fabric showed a 99.8% antibacterial destroy rate (FAO, 2007). To expand activities in Nigeria textile industry, it may be possible to utilize bamboo as a source of raw material for textile production.

4.4.1. Production of bamboo textiles

Bamboo textiles are easy to produce and the investment cost is relatively low. The production process is simple and it requires simple equipment. In the mechanical process, the woody parts of the bamboo plant are crushed and natural enzymes used to break the bamboo walls so that the fibres can be mechanically combed out and spun into yarn. Bamboo fibre products made by this process are called bamboo linen.

Chemically manufactured bamboo textile is a regenerated cellulose fibre called bamboo rayon. The chemical process consists of cooking the bamboo leaves and woody shoots in strong chemical solvents such as sodium hydroxide and carbon disulphide in a process known as hydrolysis alkalization combined with multi phase bleaching (Waite, 2009). According to Waite (2009), the general process for producing regenerated bamboo fibre using hydrolysis alkalization and multi-phase bleaching technology involves the following:

1. Leaves and inner fiber are removed from bamboo
2. Leaves (in some cases) and inner fibers are crushed together to make bamboo cellulose
3. Bamboo cellulose is soaked in a solution of 18% sodium hydroxide, NaOH, at 20-25°C for 1-3 hours.

4. Bamboo cellulose and NaOH mixture is pressed to remove excess NaOH, crushed by a grinder and left to dry for 24 hours.
5. Carbon disulfide, CS_2, is added to the mixture.
6. Bamboo cellulose, NaOH and CS_2 mixture is decompressed to remove excess CS_2, resulting in cellulose sodium xanthogenate.
7. A diluted solution of NaOH is added to the cellulose sodium xanthogenate, which dissolves it into a viscose solution.
8. The viscose is forced through spinneret nozzles into a large container of a dilute sulfuric acid solution, H_2SO_4 (that hardens the viscose and reconverts it to cellulose bamboo fiber).
9. The bamboo fibers are spun into yarns (to be woven or knitted).

4.4.2. Properties of bamboo textiles:

A number of bamboo textile producers used only one species of bamboo while others used as many as 13 species without distinguishing between species and textiles. As a result, any of the five species available in Nigeria can be used to produce bamboo textile. Bamboo makes a wonderful clothing material. The fibre is filled with micro gaps and holes which promotes moisture absorption and ventilation. In addition, the property of bamboo textile is different from those of cotton fibres. Bamboo textiles has antibacterial properties, it is very comfortable to wear in view of its antistatic properties. It is thermal regulating and has superior wicking capability.Bamboo viscose yarn is hypoallergenic, wrinkle resistant, colourfast and energy efficient. The use of bamboo fibre for clothing is a 20^{th} century development pioneered by several bamboo corporations. Bamboo fibre resembles cotton in its unspun form. Many companies bleached the fibres to turn bamboo to white fibre while some of the companies producing organic bamboo fabric leave the bamboo fibre unbleached (Dylewski. 2008).

4.5. Bamboo chemicals and pharmaceuticals.

Many nutritious and active minerals such as vitamins, amino acids, flavine, phenolic acids, polysaccharide, trace elements and steroids can be extracted from bamboo culm, shoot and leaf. Many of these have anti-oxidation, anti-aging, anti-bacterial, and antiviral properties (Naxium, 2001). Consequently, bamboo is valuable in health care delivery and can be processed into beverages, medicines, pesticides and other household items such as toothpaste, soaps, etc. (Naxium, 2001) Bamboo leaf contains to 2% - 5% flavine and phonelic compound that have the power to remove active oxy – free – radicals, stopping nitrification and abating blood fat. Figures of nutrient contents of *Bambusa vulgaris* show it to contain crude protein (10.1)g, crude fibre (21.7g), ether extract (2.5g), ash (21.3g), phosphrous (86mg), iron (13.4mg), vitamin B.1 (0.1mg), vitamins B2 (2.54mg), and Carotene (12.3mg)/100g), respectively (Paglione, 2003). Flavine beverage and beer have been widely accepted particularly in Asian countries such as China, Korea, and Japan mainly because of their value in healthcare. Some materials extracted from bamboo are used in fresh flavour and preservation of food. Bamboo shoot is one kind of vegetable that is free in pollution, low in fat, high in edible fibre and rich in mineral. It functions well in removing sputum, enhancing digestion, relieving toxicity, improving dieresis and it is often used for healing swollen tissues or edema and abdominal disease in which watery fluids collects in cavities or body tissues (Naxium, 2001). The shoot also contain saccharine, which can resist little mouse tumor and also has anti – aging elements. Of late, research has shown bamboo charcoal as one of the base materials for human health, from water treatment to its uses as shield from electro-magnetic radiation. Bamboo extracts contain valuable elements which are used in pharmaceuticals, creams and beverages. Bamboo gas can be used as a substitute to petroleum. Activated charcoal is used as a deodorant, purifier, disinfectant, medicine, agricultural chemicals and an absorbent of pollution and excessive moisture. A number of researchers have also produced bamboo ethanol, and butanol. Butanol is similar to ethanol being a form of alcohol. It has higher density; non corrosive and can therefore be mixed with gasoline. Another important product from bamboo is activated carbon. Activated carbon is a non-graphitic form of carbon, which is produced by activation of any carbonaceous material such as bamboo, wood chips, etc. Activated carbon is employed in the decolourisation of sugar and sweeteners, drinking water treatment, gold recovery, production of pharmaceuticals and fine chemicals, catalytic process, off gas treatment of waste incinerators, automotive vapour filters, colour/odour correction in wines and fruit juices.

4.6. Uses of bamboo for charcoal production and energy generation.

Bamboo charcoal can be used as an absorbent in industries such as vegetable oil, beverages and pharmaceutical industries (Khan and Hazrai, 2012). Its absorption capacity is six times that of wood charcoal of the same weight. At present, Japan, Korea and Taiwan are the main consumers, but its importation is rapidly expanding in Europe and in North America (Khan and Hazrai, 2012). Based on its characteristics, a number of countries are renewing their bio energy strategies to include bamboo. A bamboo fuelled power station is being built in Mizoram state of India to help meet the energy need of India's north east (Biopad, 2006). The Mizoram power station being setup in Sairang village at an estimated cost of $615,000 is expected to assist the state in solving its energy crises (Biopad, 2006).

According to INBAR (2011), bamboo may be the key to combating energy problem in Africa. As a partnership among African nations and communities, INBAR and China are working to substitute fuel wood with bamboo. Currently, 80% of the population in sub-Saharan Africa depends on wood for their fuel needs. The success recorded in Ethiopia and Ghana which have put bamboo biomass at the centre of renewable energy policies, are spurring interest across the continent and prompting calls for greater use of bamboo based charcoal production as a green bio fuel for fighting deforestation and climate change (INBAR 2011). This is imperative as scientists have predicted that the burning of fuel wood by African households will release equivalent of 6.7 billion tons of green house gases into the atmosphere by 2050, resulting in further climate change through clearing of tropical forests. In addition, burning fuel wood claims the lives of an estimated 2 million people each year, mostly women and children who inhale the smoke. Continuous indoor use of forest wood charcoal as a household fuel could cause 10 million premature deaths by 2030 (INBAR, 2011). Currently, it take seven to ten tons of raw wood to produce 1 tonne of wood charcoal, making wood fuel an important driver of deforestation in a continent of nearly 1billion people who have few alternative fuel sources (INBAR,2011). The International Energy Agency (IEA) predicts that if business continues as usual, by 2030; biomass energy in sub- Saharan Africa will account for about ¾ of total residential energy. This underscores the urgency of developing sustainable alternative biomass to replace wood. In view of the above, INBAR’s bamboo and sustainable biomass energy initiative which is currently transferring bamboo charcoal technologies from China to sub-Saharan Africa to produce sustainable green bio fuels using locally available bamboo resources should be adopted in Nigeria through funding from European Union (EU) and Common Fund for Commodities (CFC). Among the advantages of bamboo that make this innovation a sustainable option is that the entire bamboo plant, including the stem, branch and its rhizome can be used to produce charcoal, marking it highly resource efficient with limited wastage (INBAR, 2011). Bamboo charcoal is made through controlled burning of bamboo in kilns. The technology is adapted to producing large quantities of charcoal to serve a large number of rural and urban communities as well as to produce bamboo charcoal briquettes that are ideal for cooking as they last for longer periods, produce less smoke and pollution than natural charcoal (INBAR, 2011).

In the light of the above, there is urgent need for private sector investment in both bamboo charcoal and energy production. This is a viable investment opportunity in the rural communities in the south-south, south-west, and the south-east zones. Bamboo energy production can be sponsored by development agencies but it requires adequate backing by the government at various levels. With development of bamboo in this sector, Nigeria has the potential for increasing its energy output.

4.7. Miscellaneous uses of bamboo in the industrial sector

Apart from those highlighted above, bamboo also have several other industrial uses. Bamboo is used extensively in the electrical, electronics and communications, industries for production of wrist watches, chains, fan blades, etc. Some of the lost investment cost uses of bamboo that can easily be taken up by investors in Nigeria include processing of fresh bamboo leaves for use in the livestock and beverages industries and use of bamboo culms in water drainage.

4.7.1. Livestock feeds

Feeding chickens on organic diets containing fresh bamboo leaves leads to 70% weight gain more than those fed on standard organic diets. This suggests that the fiber in the bamboo leaves enlarge the digestive tract and enable the chicken consume more and grow faster (RMRDC, 2004).

4.7.2. Bamboo leaves tea:

Teas such as bamboo leaf tea are part of the multibillion-dollar nutritional supplement industry. The process for making bamboo leaf tea is the same as for other teas. The leaves are dried and steeped into boiling water to leach their contents into the brew .Bamboo leaf tea is rich in silica which is important in bone and other rigid tissue health. Silica improves bone health, strengthens hair and nails, improves dental health and make the skin more elastic and healthy (RMRDC, 2004). A typical cup of bamboo leaf tea contains1g of dietary fiber which aids the body’s natural cleansing systems. This can contribute to digestive health, as well as help the body to clean bloodstream of harmful Low Density Lipoprotein (LDL). In addition, the micronutrients in bamboo leaf tea have effect on the body systems. Polyphenols can reduce free radical cell damage and may slow aging. Catechins interfere with the processing of dietary fat, which help in weight loss. Bamboo leaf tea is a low calorie health food which is rich in protein and fiber, but free of caffeine. As many cups as possible can be taken as bamboo tea stimulates metabolism without side effects.

4.7.3. Bamboo Culm drainage pipes

In rural Tanzania, a bamboo pipe network is being used for providing safe and constant water supply to a large rural population (Lipangile, 1991). Drainpipes have been made from wood boards or box drains, bricks, and horseshoe shaped ceramic tile, circular clay tile, concrete tile, bituminized fibre perforated pipe, perforated smooth plastic pipe to corrugated plastic pipe. Currently, corrugated pipes are frequently used, although clay and concrete pipes are still being used as well. The use of drainage pipes made of various assorted materials is very common in our markets (Ami, 1987). These materials are very expensive, not readily available, require a high degree of maintenance, and pollute water which they convey due to the pipe's constituents (Singh et al., 2009).

In the light of these shortcomings, bamboo pipes which serve as low cost substitute are used. In a study reported by Akinbile et al (2011), an attempt was made by using Bamboo of predetermined lengths and diameters as field drainage material in Akure, South-western part of Nigeria. On the overall, the use of bamboo (*B. vulgaris*) as a field drainage material was found effective. The result indicated that bamboo could be satisfactorily used as an alternative to the various assorted materials that are very common in our markets to provide an advantage of cost, as well as easy transportation, handling and laying. Also, bamboo pipes do not contaminate the water being conveyed and do not react with the soil; unlike the other assorted materials, thus preventing the excessive cost of treating the water being conveyed for the various human and animal uses (Akinbile et al, 2011).
Thus, the problems of water distribution in a number of villages in Nigeria can adequately be solved by the use of bamboo pipes network. This will not only be an economic way of solving the problems, the maintenance of such networks can readily be assured as bamboo grows naturally in most parts of the country.

5.0 Role of bamboo in environmental conservation and amelioration in Nigeria

The problem of environmental degradation is assuming a serious dimension in most parts of Nigeria. According to Jimoh *et al* (2012), degradation has assumed a definite pattern in Nigeria. For example, erosion has ravaged much of the eastern parts of Nigeria. In the area, both active and inactive gullied surface areas range from 0.7km for Ohafia and 1.15km for Abiriba in Abia state. The width of the gulleys ranges from 2.4km for Abiriba and 0.4km for Ohafia. Furthermore, a minimum depth of 120km gullied surface has been recorded at Abiriba. Also, problems of widespread sheet wash erosion have resulted in the failure of agricultural activities. In the Northern and Western axis of Nigeria, erosion is equally serious, especially in places like Shendam and Western Pankshin of Plateau State, Efon Alaaye in Ondo state, Ankpa and Okene in Kogi state of Nigeria (Jimoh *et al*, 2012). Generally, the observation of the patterned nature of land degradation reveals that no part of Nigeria is spared from this wreckage (Asadu et al., 2004). However, the range of the land degradation is more in the eastern axis and closely followed by the Northern axis of Nigeria. A major advantage of bamboo is that it grows on marginal lands, such as degraded land and steep slopes, leaving better lands for more demanding crops (ABS, 2002b). Consequently, bamboo can be planted in nearly all the degraded areas, most especially in the Eastern part of the country where gully and sheet erosion are ravaging (Ogunwusi, 2012) and in soil damaged by overgrazing and poor agricultural techniques (Pandey and Shyamasundar 2008). Bamboo is very good at holding the soil together, to reduce erosion due to its extensive rhizome system, particularly in areas prone to high amounts of run off like steep slopes, river banks or degraded lands. As a result, the root system create an effective mechanism for watershed protection, stitching the soil together along fragile river banks, deforested areas and in places prone to earthquakes and mud slides. Unlike in most trees, proper harvesting does not kill bamboo plants, so the top soil is held in place. As a result of the widespread root system, uniquely shaped leaves, and dense litter floor, the sum of stem flow rate and canopy intercept of bamboo is 25%, which means that bamboo greatly reduces run off, preventing massive erosion and keeping up twice as much water in the watershed (B. F 2010; Pandey and Shyamasundar, 2008).
Bamboo culms are very elastic. They bend in high winds, but usually do not break. As a result, they are used as windbreaks to protect cash crops, particularly, in coastal areas where high winds are frequent (Pandey and Shymasundar, 2008). Planting bamboo can help speed up conversion of degraded lands into productive and economically viable systems, reducing erosion and raising water table in Nigeria most especially, after mining of minerals such as in Jos Plateau. This will help to improve productivity of other commercial and food crops.

Bamboo can also be grown as a pioneering plant in soil damaged by overgrazing and poor agricultural techniques (Pandey and Shymasundar, 2008). Bamboos are used in the remediation of polluted lands and their roles in filtering animal waste to prevent high nitrogen effluents and in water desalination has been reported (UNIDO, 2009). The use of bamboo in the remediation of oil degraded lands through oil spillage is being investigated (Ogunwusi, 2012)

6.0. Challenge of Bamboo Industry Development in Nigeria

A number of problems are constraining industrial development of bamboo thereby impeding potentials of bamboo to generate income and alleviate poverty in developing countries, including Nigeria. According to Leonard (2000), there is general lack of understanding of the industrial potentials of bamboo among policy makers. The national forest policy under which bamboo is subsumed gives litle or no attention to its development. Consequently, the bamboo sector in Nigeria is still part of the informal and backward rural economy. There has been no concerted effort to grab the large potential which has been successfully demonstrated by the Chinese bamboo industry. Presently bamboo is found in abundance and its underutilized.

As a result, it has been impossible to develop bamboo to the level where it can contribute in any reasonable measure to raw materials supply or as a foreign exchange earner through export of bamboo products. A new National Forest Policy was approved in June 2006 and ratified in October 2008 to be domesticated by all the States in Nigeria (FME, 2012). The new policy, just as the one before it did not give specific consideration to bamboo development as it is treated as one of the numerous non timber forest products. This classification indicated that bamboo does not have official backing despite its multiple industrial potentials. This creates a disjunction between modern international forest policy and needs of many people in developing countries (Buckingham, *et al*, 2011). According to Buckingham *et al*, (2011), recent international forest policy has focused on the implications of tropical deforestation for climate change, biodiversity loss and livelihoods, while key emerging issues for many developing countries continued to be the supply of timber in the face of increasing demand. While bamboo presents a promising alternative to products from trees, the international forestry policy focus on tree lands (Hunter, 2002). Thus, the potential to develop bamboo in developing countries is constrained by continual institutionalization of bamboo as a non timber forest product, while attention is given to development of trees. The situation in Nigeria is more difficult as tropical forests have a significant characteristic which makes monocultures difficult to develop as trees usually respond to minor localized climatic differences that have led to diversification of species (Gorte and Sheik, 2010). This makes sustainable management of tropical forests a difficult objective to pursue (Gorte and Sheik, 2010). According to Buckingham (2011) and Ogunwusi et al (2013), the problem has four dimensions. One of the most important is that bamboo is neither treated as a crop nor as a tree. Thus, it has no apparent sivicultural or cultivation relevance in tropical forestry. Second, historic policy frameworks equate forest with trees which seek to accommodate bamboo in silvicultural management logistics, despite its being a fundamentally different plant. Third, the power and influence of western silvicultural science and practice in international development, continues to expand and as bamboo is not found in most western countries, it is not given primacy in forest policy development. Likewise the growing influence of market based forest policy instrument, notably the Forest Stewardship Council (FSC) are designed for trees and not for bamboo. Four; bamboo receives minimum attention by development agencies, leading to underfinanced research and development (Buckingham, 2011, Ogunwusi 2013).

Nevertheless, in view of the need to accommodate bamboo development UNFCCC (2008) has considered bamboo as being on the same level with trees in the context of afforestation and reforestation. According to (Buckingham, *et. al.* 2011), the importance and utilization potentials of bamboo in various industries are compelling arguments for a more assertive approach category for bamboo on the same level as trees

7.0. Recommendations for bamboo industry development in Nigeria

According to Ogunwusi (2013), Nigeria's bamboo sector are wrought with problems among which are unplanned harvesting, lack of large organized bamboo industries, prevalence of low cost, low added bamboo products and lack of research and inventory data for bamboo lands. Industrialization of a bamboo based sector is very important for generating livelihood without any damage to the environment. The vast and yet untapped potentials needs cultivation, primary processing, integrated processes and transfer of technology and a coordinated sustained national level effort .According to Ogunwusi (2013), for a virile bamboo industry to be established in Nigeria, the following recommendation have to be attended to:

- Establishment of a bamboo development institute or organization to coordinate and midwife activities relating to bamboo development in Nigeria. Such an organization should be in a better position to advice policy makers on bamboo development initiatives.

- There is need for a national bamboo policy. The policy should spell out the objectives of bamboo development and provide detail guidelines for implementation.
- Nigeria needs a bamboo inventory. It is necessary to determine the quantity and quality of bamboo that currently exists, their distribution and types of species and quality of stocks available.
- There is need for the establishment of an association of Nigerian bamboo producers which could help set up quality standards and implement effective quality control, provide a forum for the exchange of information and ideas, collaborate with government agencies to formulate favorable bamboo manufacturing policies with regards to export and import regulations and also organize business promotion activities and build marketing networks.
- Government must promote bamboo tenure reforms. This could be done by giving farmers or groups who are committed to manage bamboo resources proper incentives.

8.0. Conclusion.

Bamboo is fast becoming a very important industrial raw material globally as a result of its multiplicity of uses. The development of bamboo for industrial use in Nigeria will propel development of a number of industries, reduce dependence on imported raw materials and free foreign exchange for other uses. As bamboo engender itself to development of micro and small scale industries with little capital outlay, a virile bamboo industry in Nigeria will lead to wide spread poverty reduction. It is envisaged that the development of bamboo for multi-functional uses in Nigeria will lead to savings of more than 500 billion naira annually. Incorporation of bamboo into the vision 202020 action plan will present more opportunities for a successful outcome. This perhaps can best be achieved by taking stock of the achievement to date and formulating a bamboo 2020 vision. This should be contemplated as a vision with strategic process, benchmarks and target dates. Development of bamboo in tropical countries has a lot of advantages. Among these is the development of the wood products sector of the different economies, reduction in the rate of deforestation and expansion in employment opportunities coupled with skills acquisition. It is explicit that with increase in marketing outlets, farmers will be encouraged to grow bamboo on private lands. It will also facilitate the sustainable management of tropical forests.

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