ACADEMIC INN INTERNATIONAL

South Asian Journal of BIOLOGICAL RESEARCH

open access

BAMBOO: A POTENTIAL ALTERNATIVE TO WOOD AND WOOD PRODUCTS

David Oriabure Ekhuemelo*, Emmanuel Terzungwue Tembe, and Felicity Amuche Ugwueze
Department of Forest Production and Products, University of Agriculture, Makurdi, Nigeria
Corresponding author: davidekhuemelo@gmail.com

To cite the article: David Oriabure Ekhuemelo, Emmanuel Terzungwue Tembe, and Felicity Amuche Ugwueze (2018). Bamboo: a potential alternative to wood and wood products, *South Asian Journal of Biological Research*, 1(1): 9-24

Link to this article:
http://aiipub.com/journals/bamboo-a-potential-alternative-to-wood-and-wood-products/

Article QR

Journal QR

BAMBOO: A POTENTIAL ALTERNATIVE TO WOOD AND WOOD PRODUCTS

David Oriabure Ekhuemelo*, Emmanuel Terzungwue Tembe, and Felicity Amuche Ugwueze
Department of Forest Production and Products, University of Agriculture, Makurdi, Nigeria
Corresponding author: davidekhuemelo@gmail.com

ARTICLE INFO
Article Type: Resea
Received: 23, Sep. 2018.
Accepted: 04, Oct. 2018.
Published: 04, Oct. 2018.

Keywords:
Bamboo, environmental conservation, furniture, landscaping, wood

ABSTRACT
Bamboo is the most essential non-wood species which is abundantly grows in most of the tropical and subtropical zones. It has developed as an exceptionally valuable and superior alternate for wood composites manufactured, such as for furniture, house construction, roofing, flooring, walls, charcoal, kitchenware, ceiling, pulp and paper, fabric and many other things. Bamboo is very important in environmental conservations and performs so many functions like carbon sequestration, as sustainable and renewable resources, regulation of water, soil erosion control, beautification of the landscape, mitigation of climate change among others. Moreover, several types of research researcher have shown that bamboo is a fast-growing species which can also be used for other purposes like animal diet, and medicine. Numerous kinds of bamboo composite are manufactured and marketed globally. Bamboo compete favourably with wood in so many aspects ranging from microscopic and macroscopic features, chemical properties, physical and mechanical characteristics. Bamboo is renewable resource that can be harvested year after year without the need for fertilizer and plays an important role in reducing pressure on forest resources

1. Introduction

Increasing demand for timber and the depletion of natural forest have encouraged the utilization of many less popular species. Bamboos have for a very long time been used as timber (Gill and Kumar, 2016). The world timber demand is reported to be increasing at a fast rate as the timber supply is depleting. It has been established through research that bamboo can suitably replace timber and other materials in construction and other works (Anurag, 2013). Industrial treated bamboo has proven resourcefulness in making composite products and components which are profitable and can be effectively applied in structural and non-structural uses in building. Bamboo has an age long traditional materials used in building by humanity (Anurag, 2013).

Bamboo species is scientifically known as *Bambusa vulgaris*. The bamboos are a subfamily of the flowering perennial evergreen plant in the grass family Poaceae (Zhang *et al.*, 2002). The word bamboo comes from the Canadian term bamboo, which was introduced to English through Indonesian and Malawi. Bamboo has long been considered as the most primitive grasses, mostly because of the presence of bracteote, indeterminate inflorescences, “pseudospikelets”, and flowers with three lodicules, six stamens, and three stigmata. Some of its members are giants, forming by far the largest members of the grass family. There are 91 genera and about 1,000 species of bamboo (Chapman 1996 and Zhang *et al.*, 2002). Bamboo species are found in diverse climates, from cold mountains to hot tropical regions.

Bamboo also occurs in sub-Saharan Africa and in the American from the USA mid-Atlantic State south to Argentina and Chile, reaching their southernmost point at 47^{o}C South latitude (Lobovikov, *et al.*, 2007). Although bamboo is a grass, many of the larger bamboos are very tree-like in appearance and they are sometimes called "bamboo tree". The stems or culms can range in height from a few centimeters to 40 meters, with stem diameters ranging from 1mm to 30cm. The stems are jointed, with regular nodes. Bamboo is of the fastest growing plant on earth, with reported growth rates up to 91cm (36in) in 24 hours (Zhang, 2002). However, the growth rate is dependent on local soil and climatic conditions, as well as species, and a more typical growth rate for many cultivated bamboos in a temperate climate is in the range of 3−10cm (1.2−3.9 inches) per day during the growing period. Many bamboos are favorite in cultivation as garden plants (Megal *et al* 2005).

Bamboo has a vital role to play in reducing pressure on forestry resources. For instance, in China, since nationwide logging bans of certain forests came into effect in 1998, bamboo has increasingly been seen as a possible substitute to timber and has entered many markets traditionally dominated by wood. The successful use of bamboo in different product lines, ranging from furniture and flooring to paper and packaging demonstrates the high potential for bamboo as a more sustainable alternative material in the production of many products. Apart from bamboo being a substitute for wood products and environmental conservation, they can also be used for other resources like animal diet, and medicine.

Plate 1: Bamboo stand in China

Source: Guomo *et al.*, (2010)

1.1 Chemical composition of bamboo

The chemical composition of bamboo determines its properties, influences, and its utilization. The main chemical constituents of bamboo are cellulose, hemicellulose, and lignin, which amount to over 90% of the total mass (Chaowana, and Robkorb, 2012). The minor constituents of the bamboo amount to 10%, which are composed of resins, tannins, waxes and inorganic salts, as presented in Table 1.

Compared to the other wood species, the chemical compositions of bamboo are similar to those of hardwoods, except for the higher ash content. The ash of bamboo is composed of inorganic minerals, primarily silica, calcium, and potassium. Silica content is the highest in the epidermis, with very little in the nodes and is absent in the internodes. Higher ash content in some bamboo species can adversely affect the processing machinery (Chaowana and Robkorb, 2012). Additionally, bamboo contains

starch, saccharide, fat, and protein. The carbohydrate content of bamboo plays an adverse effect on its durability and service life. The presence of large amounts of starch makes bamboo easily attacked by fungi and insects. Then, an efficiency process reducing the starch content or increasing the resistance to the insect and fungi may be needed to improve the durability of bamboo composites (Chaowana and Robkorb, 2012).

Table 1: Chemical composition of banboo

Sources: Chaowana (2013)

Bamboo species	Holocellulose	Lignin	Ash	Cold-water Solubility	Hot-water Solubility	1% NaOH Solubility	Alcohol-benzene Solubility
Bambusa clumeana	69.2	21.6	–	4.3	7.3	23.3	3.8
Dendrocalamus asper	74.0	28.5	1.5	6.4	9.2	24.7	5.5
Gigantochloa scortechinii	67.4	26.4	1.3	4.8	5.9	19.4	3.4
Phyllostachy makinoi	79.9	25.5	–	–	–	–	2.6
Phyllostachy nigra	66.4	23.8	2.0	–	–	–	3.4
Phyllostachy pubescen	71.7	23.6	1.4	–	–	–	4.6
phyllostachy reticulate	51.8	25.3	1.9	–	–	–	3.4
Phyllostachys heterocycla	76.8	26.1	1.3	–	–	–	4.6
Schizostachloa zollingeri	71.6	21.6	–	4.1	24.3	24.3	2.5

1.2 Physical properties of bamboo

The basic density of bamboo is in the range of 0.4 - 0.9 g/cm³, depending mainly on the anatomical structure. In general, the location along the bamboo culm is significant for the density value. The density of bamboo increases from inner to outer part and from lower to upper part of the culm (Malanit *et al*, 2008). Moreover, the density of nodes is higher than that of internodes. When compared to the hardwoods or massive tropical timber species which are normally used in composites panels manufacturing, the specific gravity of bamboo is relatively high (Ahmad and Kamke, 2005). On the other hand, the specific gravity of bamboo would be strongly affected by its position along the culm compared to wood species. Thus, if the 98 composites are made from bamboo, a potential higher specific gravity variation should be considered (Chaowana *et al.*, 2012). Like wood, the dimensional shrinkage of bamboo varies in different orthotropic directions. It is clear that the tangential shrinkage is about one-half as much in radial, and much less along the longitudinal direction (Liese, 1985). They also revealed the relation between bamboo shrinkage and specific gravity. The shrinkage value decreases when specific gravity value increases. When compared to the wood species, the dimensional stability of bamboo is more favorable. Moreover, the bamboo shrinkage slightly varies along the culm length. These are the favorable properties for the use of bamboo as a raw material in composite products (Malanit *et al.*, 2008). Bamboo has a higher dimensional stability than wood.

1.3 Mechanical Properties of bamboo

Similar to wood, bamboo is a heterogeneous and anisotropic material (Abd. Latif, 1993). Therefore, its mechanical properties are volatile related to the microstructure characteristics, culm height, culm location, density and moisture content (Chaowana, and Robkorb, 2012). The mechanical properties of some bamboo species from several studies are presented in Table 2.

Table 2. Mechanical properties of some bamboo species

Bamboo species	Modulus of rupture (Mpa)	Modulus of elasticity (Mpa)	Shear strength parallel to grain (Mpa)	Compression strength parallel to grain (Mpa)
Balanocarpus hemi	122.0	1800	13.7	69.0
Bambusa blumeana	99.8	4100	4.5	24.0
Bambusa vulgaris	62.3	6100	4.0	25.3
Dendrocalamus asper	85.7	6300	5.4	31.5
Gigantochloa levis	78.5	5100	4.8	40.0
Gigantochloa scortechinii	52.4	4800	4.3	27.0
Koompasia malaccensis	100.0	1700	10.0	54.7

Source: Liese (1985).

2.0 Bamboo: a substitute for wood products

There are a lot of reasons why bamboo has become the substitute for hardwood in manufacturing big things like furniture, clothing manufacturers, interior designers, houses and so on which are recently use in most countries especially in China and some other developing countries (Campbell, 2009). Some of them are:

2.1 Bamboo as a resource for furniture making

In recent years, bamboo furniture has become increasingly popular as environmentally conscious consumers with an eye for style discover classic and contemporary furniture that is now available in this beautiful and renewable material (Belcher, *et al* 2001). Traditional bamboo furniture uses natural round or splits bamboo. A new type of 'pack-flat,' 'knockdown' furniture uses glue-laminated bamboo panels. Unlike the conventional design, this furniture may be shipped in compact flat packs, to be assembled on the spot. The new design overcomes many of the problems of conventional bamboo furniture, such as high labour and transportation costs, low productivity, instability, varying quality and susceptibility to insects and fungi. At the same time, it retains the distinct physical, mechanical, chemical, environmental and aesthetic features of bamboo. Export of laminated bamboo furniture is growing rapidly. However, trade statistics currently do not capture the value, owing to the absence of a special code for bamboo furniture. It is usually classified as wooden furniture.

Reasons why people buy bamboo furniture

The reasons for purchasing bamboo furniture are as varied and unique as the people that buy it. Some of the more popular reasons that some consumers buy bamboo furniture include: Selection no longer is bamboo furniture just for the patio. Using innovative designs and composite materials, furniture made with bamboo comes in a wide variety of styles and finishes. Environmentally friendly unlike hardwoods, bamboo is a sustainable and quickly renewable resource that can be harvested year after year without the need for fertilizer or pesticides (Belcher *et al* 200).

Durability Bamboo furniture can withstand the wear and tear of everyday use and is far more resistant to damage than traditional hardwoods. What's more, bamboo does not swell or shrink from changing atmospheric conditions. Strength Ounce for ounce, bamboo is stronger than many types of steel. Lamination further enhances the inherent strength of this fantastic plant and adds another layer of resistance to scratches and dings (Belcher *et al*., 2001)

This furniture is available in distinctive styles that add lasting beauty to any room. Whether you admire bamboo furniture for the look, the price, the environmental sustainability, or these three reasons and more, you're certain to find that bamboo furniture is an investment that will retain its

beauty and value for many years to come (Campbell, 2009).

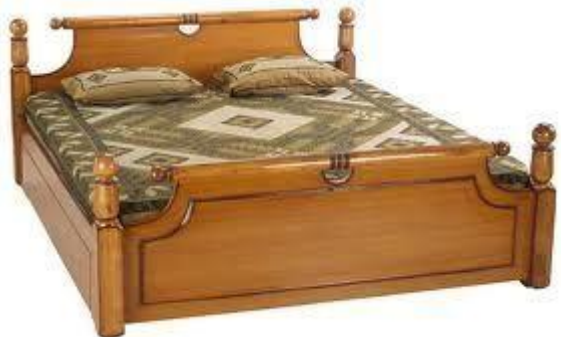

Plate 2: Bed made from bamboo

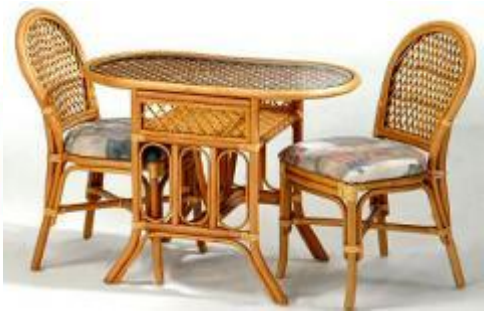

Plate 3: darning table made from bamboo

Source: (PCARRD, 2011)

2.2 Bamboo has potential in housing construction.

Bamboo has a long and well-established tradition as a building material throughout the world's tropical and sub-tropical regions. It is widely used for many forms of construction, in particular for housing in rural areas *(*Sajad, 2013). *Bamboo is one of the most amazingly versatile and sustainable building materials available. It is exceedingly strong for its weight and can be used both structurally and as a finish material. The canes are beautiful when exposed and they can be cut in such a way as to be re-combined into useful products such as bamboo flooring.* Rough data of the energy needed for production, compared with strength (Janssen, 1981 as reported by Sigit, 2000) is given in table 3.

Table 3. Comparison of bamboo to other construction material

Energy Requirement of Construction Material	Energy for production MJ/Kg	Weight per volume Kg/nr	Energy for production Kg/m1	Stress when in use	Energy per unit stress
Concrete	0.8	2400	1920	8.0	240
Steel	30	7800	234000	160	1500
Wood	1.0	600	600	7.5	80
Bamboo	0.5	600	300	10	30

Source: Janssen, 1981

Types Houses made from Bamboo

There are three main types of bamboo housing: (a.) Traditional houses, which use bamboo culms as a primary building material; (b.) Conventional *bahareque* bamboo houses, in which a bamboo frame is plastered with cement or clay; and (c.) Modern prefabricated houses made of bamboo laminated boards, veneers and panels. Experts estimate that over one billion people live in traditional bamboo houses. These buildings are usually cheaper than wooden houses, light, strong and earthquake resistant, unlike brick or cement constructions. They are better designed and environmentally friendly. Bamboo materials are widely available and can be cultivated at a low cost.

Building materials accounts for nearly 60 to 65% of the cost of house construction. With the constant rise in the cost of traditional building materials and with the poor affordability of large segments of our population the cost of an adequate house is increasingly going beyond the affordable limits of

more than 30-35% of our population lying in the lower income segments.

2.3 Bamboo as potential material for roofing

Bamboo has a lot of potential as a building material for low-cost housing. Corrugated bamboo roofing sheets (CBRS) are produced from woven mats of bamboo that are soaked in adhesive resin and then pressed firmly together. The corrugations are formed by pressing the mats between two corrugated pressing plates. The sheets can be produced in a range of sizes to suit particular requirements and can easily be trimmed for special situations. Bamboos are the only raw material used for the sheets. The sheets are durable and stable and resistant to pest attack, severe weathering, and fire (INBAR, 2001). The production of corrugated bamboo roofing sheets is a commercially viable and socially effective means of utilizing bamboo resources to produce value-added items for the benefit of consumers and producers alike. Corrugated bamboo sheets have good noise insulating properties. In table 4, bamboo sound obstructing data is 9 dB higher than that of the plastic sheet and therefore better than the zinc sheet (which is only 4 dB better than the plastic sheet). The asbestos corrugated sheets have the best sound insulating performance. Its sound obstructing execution is 15 dB higher than that of plastic compositesheets

Table 4. Bamboo noise transmission performance

Material	The data of noise obstructing comparing with the reference board (dB)
Bamboo	9
Zinc	4
Plastic	0 (benchmark)
Asbestos	15

Source: Schröder, (2014)

Bamboo has the highest thermal resistance and the lowest thermal transmission coefficient; therefore, bamboo has the best thermal isolation properties (table 5) compared to the other three materials (Stéphane, 2014).

Table 5. Bamboo thermal transmission performance

Material	Thermal resistance m^2K/W	The coefficient of thermal transmission $W/(m^2K)$
Bamboo	0.030	5.6
Zinc	0.012	6.2
Plastic	0.007	6.4
Asbestos	0.019	5

Source: Schröder, (2014)

2 .4 Bamboo as a flooring Material

Bamboo flooring is a quality product that can be used widely and has a large, global consumer market (FAO, 2005). It has certain advantages over wooden floors due to its smoothness, brightness, stability, high resistance, insulation qualities, and flexibility. Bamboo flooring has a soft natural luster and maintains the natural gloss and elegance of bamboo fiber. This flooring is attractive to the demanding markets in Europe, Japan and North America (FAO, 2005). The estimated annual production of bamboo flooring in China was 17.5 million in 2004. Exports account for some 65 percent of the total

output (CGAC, Customs General Administration of China|2004).

Reasons for bamboo for flooring

Reasons why bamboo is selected for flooring include:

i. Bamboo is very light and flexible but also very solid. Pound for pound, bamboo is stronger than many types of steel.
ii. Bamboo for floors can be harvested in one to three years with no additional planting or cultivation required. Virtually all parts of the plant are used for different applications so there is very little waste.
iii. Traditional hardwoods such as oak and hard maple take at least 60 years to reach harvestable size.
iv. Bamboo requires little or no fertilizer or pesticides to produce and absorbs a greater percentage of carbon dioxide than many types of trees.
v. When properly dried and milled, bamboo is stronger than wood, brick, and concrete.

Initially, some consumers were cautious about purchasing bamboo floors due to a perceived softness of the material. In a wood floor hardness scale developed by the National Hardwood Flooring Association, bamboo compares very favorably for resistance to stains, wear, and everyday use (CGAC 2004).

2.5 Bamboo walls

Bamboo walls are constructed by nailing a thin bamboo mat to either side of a braced timber frame. The walls are constructed between the vertical bamboo columns, as infills. The main posts are erected at all corners, and throughout the house envelope, spaced at about 1.2 m. Split bamboo grids are assembled by rope or wire ties and are fixed to plinth and bamboo posts. To reinforce the bamboo grids, as well as to provide a base for the mortar, a chicken steel wire mesh is fixed to the grids. Cement based mortar is then plastered on top to provide overall stability to the wall infills. The finished wall thickness is about 50 mm thick. Prefabricated timber frames are mounted for windows and door openings (Village Volunteers, 2017).

2.6 Bamboo charcoal

Bamboo charcoal is traditionally used as a substitute for wood charcoal or mineral coal. It can serve as fuel, absorbent and conductor for cleaning drinking water, cooking, bathing, improving soil, regulating room humidity, preserving freshness of vegetables, fruits and flowers, deodorizing, for conducting electricity among others (Chaowana 2013). Activated bamboo charcoal can be used for cleaning the environment, absorbing excess moisture and producing medicines. The absorption capacity of bamboo charcoal is six times that of wood charcoal of the same weight. China is a leader in its production. At present, Japan, the Republic of Korea and Taiwan Province of China are the main consumers, but its importation is rapidly expanding in Europe and North America (BMTPC, 2016). Three main reasons are contributing to the success of bamboo charcoal in international trade:

a. Bamboo grows faster and has a shorter rotation compared with tree species;
b. The calorific value and absorption properties of bamboo charcoal are similar to or better than those of wood charcoal and
c. It is cheaper and easier to produce.

2.7 Bamboo kitchenware

Bamboo kitchenware is becoming more in demand as people discover the virtues of the material. The natural finish of bamboo kitchenware is good for different uses, depending on the utensil being utilized. Bamboo cutting boards are becoming very popular because they do not dull knives as quickly

as hardwood cutting boards do. Bamboo utensils are also becoming a coveted addition to wedding gift lists. These utensils are unique because unlike many other silicones, plastic, or metal utensils, ones made of bamboo do not scratch the surface of expensive non-stick cookware (PCARRD, 2011). Bamboo utensils are also excellent for cooking because they do not conduct heat very well. This means that you won't burn your hand on the handle, even if you leave it in the pot you are using. Finally, bamboo utensils are very versatile. Some utensils that are frequently made out of bamboo include cutlery (knives, spoons, forks, spatulas), cutting boards, chopsticks, tea strainers, sink. etc All of these utensils have the same strength and environmentally friendly properties as other objects made of bamboo. But fully mature bamboo isn't the only thing used in the kitchen.

[a] Cutlery (spoons, forks) [b] A sink

Plate 4: [a & b] Bamboo kitchenwares

Source: PCARRD (2011)

2.8 Bamboo ceilings

As homeowners and decorators looking for distinctive but environmentally responsible ways to decorate homes, increasingly popular and affordable solutions are bamboo ceiling materials. Bamboo ceilings are available in many styles and finishes and, like wood, add warmth to any room in the house.

Advantages of Bamboo Ceilings

Benefits of using bamboo as a ceiling accent include:

a. It features a beautiful natural grain that can be stained to warm or cool a room.
b. Bamboo re-grows quickly after it has been harvested so it is sustainable and easily renewable.
c. It is very light but incredibly strong. When treated, it is stronger than most types of steel.
d. Treated bamboo is easy to clean and install.
e. Bamboo is far less likely than wood to swell and warp from humid conditions.
f. It is inexpensive and available in a wide range of styles and finishes.
g. Bamboo Ceilings are an Environmentally Responsible Option.

2.8 Bamboo paper

Computer revolution has not ironically decreased our use of paper as was predicted when computers began to appear in our homes and businesses (Chaowana, 2013). Instead, the demand for *paper* products has skyrocketed over the last 20 years. In the U.S. alone, per capital consumption of paper and paperboard exceeds 800 pounds each year which place enormous strain on forests that take decades to recover (Belcher *et al* 2001). The increasing popularity of bamboo paper may help to decrease reliance on wood pulp in papermaking and offer some relief to our remaining woodlands

(CGAC, 2004).

The Chinese have been making paper from bamboo for over 1,500 years but recent demand has grown considerably as consumers look for environmentally friendly products from renewable resources (FAO 2005). Responding to the demand, paper manufacturers are introducing new bamboo paper products to the market that are comparable in strength, brightness, and printability to paper made from wood pulp.

2.8.1 Reasons for Bamboo Paper

Listed below are several reasons to purchase and use bamboo paper products including:

a. Bamboo is a quickly renewable resource. Bamboo is the single fastest growing species of plant on the planet with some species growing more than a meter a day. In sharp contrast to trees which require decades to recover from harvesting, bamboo reaches maturity in 3 to 5 years or less and when it is cut, the stem is left in the soil to sprout a new shoot and start the growing process again.
b. Bamboo thrives in depleted soil. In environmentally stressed areas where rainforests have been clear-cut and burned, bamboo is one of the few plants that can grow quickly and begin the process of returning nutrients to the soil. Bamboo also grows on mountainsides and on steep slopes where few other cash crops can.
c. Bamboo paper is recyclable. Just like paper made from wood pulp, bamboo paper can be recycled to lessen our impact on the environment and further reduce our reliance on trees.
d. Bamboo provides jobs and economic development. In economically depressed areas bamboo offers farmers a viable cash crop and jobs in bamboo paper mills give residents a chance to give a higher standard of living for their families. (SFA, 2005).

As more and more consumers look for everyday products that are environmentally responsible, the emergence of bamboo paper products on the world's markets offers us a chance to save our remaining hardwood forests and reduce the catastrophic environmental effects of clear-cutting and deforestation (BMTPC, 2016). The impact of bamboo paper on the worldwide paper industry is still being determined but the largest manufacturers are taking notice of this trend in the marketplace and introducing innovative uses for bamboo paper every day.

2.9 Bamboo fabric

One of the most innovative parts of the bamboo industry has got to be the bamboo fabric that is being produced. Anti-bacterial, wicking, and biodegradable, bamboo fibers are becoming more and more popular when it comes to making fabric. From bedding to clothing, industries are making more products with bamboo fabric, extolling the virtues of using the alternative source to cotton as shown in figure 5, (CGAC, 2004). Bamboo pulp can be further processed into bamboo fiber, yarn and filament for industrial usages and garment producing.

Figure 5. Bamboo textile and fiber

Source: Xiaobing (2007).

2.9.1 Reason for the use of bamboo fabric

i. **Aesthetic Qualities:** The most noticeable qualities of bamboo fabric are the aesthetic qualities that are gathered from the first touch or sight of bamboo. These qualities include:

a. Texture - Bamboo fabric feels softer than the most refined cotton.

b. Colour - Bamboo fabric tests as well as every other material for colour fastness when washing and wear over time.

c. Appearance - The fabrics made of bamboo appear to look like other materials which are more expensive, such as silk.

ii. **Anti-bacterial:** One of the many reasons that bamboo fabric is becoming more popular is because of the anti-bacterial properties that it has. When growing, bamboo requires very little to no pesticides, an attribute which scientist have discovered is from an anti-bacterial bio-agent called bamboo kun. Bamboo Kun is bound closely in the bamboo cells, thus why it lasts so long in bamboo fabric. It makes the fabric resistant to bacteria, and scientists have done tests to show that a large portion of bacteria that naturally incubates on bamboo fabric doesn't survive because of the bamboo kun property.

This makes products made from bamboo fabric, such as bed sheets and bath towels, good for people with allergies. With the fabric unable to host the bacteria and allergens that cause people with allergies to react, these people are able to find a healthy alternative to other fabrics (BPT, 2014).

iii. **Breathable and Absorbent**: Another attractive property of bamboo fabric is how breathable and absorbent it is. Many people who have worn clothing made of this fabric have stated how they are kept cooler because the breathable fabric doesn't cling to skin. The absorbent fabric also wicks away moisture, keeping the skin cool and dry. These insulating characteristics also make the bamboo fabric warm in colder months. It is also because bamboo fabric is breathable that it is good at remaining odourless, even when attacked by odour-causing bacteria.

iv. **Economic and Ecological purposes:** Bamboo fabric is one of the most economical and ecological products in the world today. Because of how it grows, there is only a fraction of the time and resources spent on producing bamboo for fabric as there is for cotton. Bamboo does not require the massive amounts of water and pesticides that cotton does to be produced, nor does it need the attentive care of cotton.

Bamboo fabric is also quite ecologically friendly. 100% biodegradable, the fibers used to make bamboo fabric don't need to be sprayed with chemical additives of any sort. Economical, ecological, aesthetically pleasing, comfortable, and long-lasting, bamboo fabric is obviously going to be the way of the future. With soft fabric that is easy to produce, and has health benefits like being anti-bacterial as well as insulating, the bamboo fabric will become the favorite textile of many in years to come (BPT 2014).

v. **Uses of Bamboo Fabric**

Bamboo fabric is used for many applications these days, from bedding to clothing. This is because this environmentally responsible fabric is silky to the touch, looks like a much more expensive fabric such as silk or cashmere, and is durable as well as being good for those who are health conscious. Of course, bedding and t-shirts aren't the only uses for that material these days. Some of these include; intimate apparel garments, Non-woven Fabric (Schröder, 2016).

2.10. Bamboo weaving product and crafts

Bamboo crafts and woven mats are traditional products in China, India, Malaysia, the Philippines and Thailand (BMTPC, 2016). The technique has been known for several thousand years. These diverse products have become an indispensable part of daily life, literature and art. There are nearly 20 categories of woven bamboo products in Asia, including fruit baskets, trays, bottles, jars, boxes, cases, bowls, fans, screens, curtains, cushions, lampshades and lanterns (BMTPC, 2016).

3.0 Bamboo: Environmental Conservation

Bamboo forests have many environmental benefits because they function as carbon sinks, produce oxygen, control soil erosion, provide organic matter, regulate water levels in watersheds, conserve biodiversity, beautify the landscape, and essentially contribute to the purification and regulation of the environment (Schrude, 2012).

3.1 Bamboo absorbs huge amounts of CO_2

Although bamboos are grasses, they possess the remarkable ability to sequester carbon through photosynthesis and to lock carbon in the fibrous root system which is an important aspect of the forest ecosystem and the carbon sink (Keppler,2006). Through their inherent ability to take up large amounts of CO_2 and convert it into oxygen, bamboo forests can help regulate CO_2 emissions that contribute to global warming (Loreto, *et al.*, 2002.). The CO_2 absorbed by the bamboos does not release back into the ecosystem as the plant retains it, and after harvesting, the harvested timber is used in value-added products for construction, flooring, panels, etc. it still functions as a carbon sink also the culms and leaves are used for various value-added products in industries. Bamboo thus serves as an important niche for carbon conversion and locking and hence the broad spectrum of bamboo products and services should be regarded as an important contribution to mitigating climate change. Bamboo captures huge amounts of carbon dioxide which they generate and converts into oxygen. Scientific studies in commercial bamboo plantations in Mexico show that Guadua angustifolia can capture 149.9 tons of CO_2 per hectare in the first seven years after planting (average of 21.41 tons / ha / year) (Schrude, 2012). One hectare of adult bamboo can also produce 5.8 times more biomass compared to most other forest species (Schröder, 2012).

3.2 Bamboo: a sustainable and renewable resource

Furthermore, bamboo is a sustainable and renewable resource because it continuously spreads vegetatively. This allows the formation of forests much faster compared to most other tree species. Unlike other types of commercial forestry crops where trees must be clear-cut and replanted, in bamboo plantations only mature stems are harvested while younger stems are left untouched to mature and develop (Schrude 2012).

All these characteristics have called the attention of industrialized countries and reveals the environmental impact and potential of Bamboo as a high yielding forestry crop (Schrude 2012). These countries which according to the Kyoto Protocol must reduce the effects of greenhouse gas emissions, see bamboo as an alternative that could help solve a global problem, perhaps, even at fewer costs compared to other expensive technological processes, which are much more complicated as well.

3.3 Bamboo as water regulation

"One hectare of Bamboo Forest can store over 30,000 liters of water in its culms during rainy season which it gradually deposits back in the soil during dry season (Schrude 2012). Bamboo regulates the quantity and quality of water, which are essential characteristics when managing watersheds (Ongugo *et al* 2000*)*. Bamboo forests also serve for sediment control. They form a sort of wall that prevent the loss of flow in rivers (Schrude 2012). In addition, the forest cover of their canopy prevents the

evaporation of streams. Therefore, the environmental impact of bamboo is indisputable if it comes to effective watershed protection (Schrude 2012).

3.4 Bamboo as soil erosion control

Bamboo plants with their interwoven system of roots and rhizomes contribute to the recovery and conservation of soils present on riverbanks. Beneath the ground lays an extensive network of rhizomes that ties together and prevents soil erosion on hillsides or river banks (Ongugo *et al* 2000). Planting bamboo to control soil erosion is recommended in areas susceptible to landslides or slopes in the process of slowly losing its soil (Schrude (2012).

This woven root system acts as a cohesive for colloidal particles, making the plant a very important species as a soil protector near rivers. In the rainy season bamboo absorbs large amounts of water, it stores the water both in its rhizomes as in the stems and soil. This means that bamboo has a high-water storage capacity. Later on, due to the effects of concentration, the water is returned to the soil, rivers and streams during the dry season (Schrude 2012).

The leaves of the bamboo plants prevent the impact of raindrops, favoring the dispersion of the raindrops into smaller particles. This contributes that ground water is distributed smoothly throughout the forested area (Schrude 2012). If bamboo does not exist on hillsides or slopes, heavy rains will probably cause erosion problems sooner or later.

Soil erosion is a major environmental threat to the sustainability and productive capacity of agriculture. It is a worldwide problem approaching disaster proportions in many countries. It is estimated that the world's arable land is lost at a rate of more than 10million hm^2 per year. Seventy-five billion metric ton of soil is removed from the land each year (Eliasch2008*)*. One analysis of globe soil erosion estimates that, depending on the region, topsoil is currently being lost 16 to 300 times faster than it can be replaced (IPCC, Intergovernmental Panel on Climate Change 2007). Soil is eroded by wind, water, and gravity aided and hurried by tillage and poor soil management.

In addition to many industrial and construction uses, bamboo also is valuable for controlling soil erosion. The Brazilian introduced *Bambusa blumeana and* Phyllostachys *pubescens* for controlling soil structure (Mohamed, *et al* 2007). The valuable features of bamboo for controlling soil erosion are its extensive fibrous root system, connected rhizome system, the leafy mulch it may produce on the soil surface, its comparatively dense foliage which protects against beating rains, and its habit of producing new culms from underground rhizomes which allows harvesting without disturbing the soil (Schrude, 2012).

3.5 Bamboo beautifies the landscape

Bamboo that grows near rivers and streams form spectacular gallery forests that enrich the landscape. Bamboo forests due to the different stages of development of their individual stems generate a wide variety of greens that enhance the landscape in contrast to other crops or plants nearby (Schrude, 2012).

3.6 Bamboo stabilize climate change

Climate change is considered to be one of the greatest threats facing humanity. According to the IPCC, global warming is unequivocal, with evidence from increases in average air and ocean temperatures, melting of snow and ice and sea level rise (IPCC, 2007). In order to avoid the most damaging effects of climate change, it is estimated that global levels of atmospheric greenhouse gases (GHGs) need to be stabilized at approximately 445-490 parts per million CO_2 (CO_2 equivalent) or less. To achieve this target, it is essential that urgent international action is taken. Forests will have a central role in meeting this target (Eliasch, 2008). Bamboo absorbs carbon dioxide and releases 35% more oxygen into the atmosphere than an equivalent stand of hardwood tree (Gullison *et al*., 2007). Bamboo's fast

growth is one of its many attributes which make it a useful resource for mankind. It is also commonly seen as an indication of a high ability to capture and sequester atmospheric carbon and consequently mitigate climate change, in a similar way that trees do (Lou, 2010).

4. Conclusion

Many African countries like Nigeria are not utilizing the potentials bamboo to the full. Bamboo has a remarkable ability to substitute wood and can be used for furniture, house construction, roofing, flooring, walls, charcoal, kitchenware, ceiling, paper, fabric among others. It is also a source of environmental conservation as sequester of carbon through photosynthesis. It locks carbon in the fibrous root system which is an essential aspect of the forest ecosystem, for regulating water, soil erosion control, beautifies the landscape, climate change control etc. Bamboo is an excellent substitute for wood that is slowly going into extinction. It is a sustainable and quickly renewable resource that can be harvested year after year without the need for fertilizer and plays a vital role in reducing pressure on forest resources.

5. Recommendations

i. Hence bamboo has some peculiar qualities like fast growing rate, and versatility, more concern should be given towards establishing bamboo plantations.
ii. Bamboo should be used as a substitute for wood by wood-based industries in order to reduce pressure on the dwindling forest resources.
iii. There is a need for the industrialist to improve on the necessary technology involved in producing these wonderful and beautiful products from bamboo.

References

1. Abd. Latif, M., Ashaari, A., Jamaludin, K., & Mohd. Zin, J. (1993). Effects of anatomical characteristics on the physical and mechanical properties of Bambusa bluemeana. *Journal Tropical Forest Science*, 6(2), 159-170.
2. Ahmadl, M., & Kamke, F. A. (2005). Analysis of Calcutta bamboo for structural composite materials: Physical and mechanical properties. *Wood Science and Technology*, 39, 448-459 http://dx.doi.org/10.1007/s00226-005-0016-y
3. Anurag, N., Arehant S. B, Abhishek J., Apoorv K., & Hirdesh T. (2013). Replacement of Steel by Bamboo Reinforcement. *IOSR Journal of Mechanical and Civil Engineering* (IOSR-JMCE), 8(1) 50-61.
4. Belcher, B., Ruiz-Perez, M., Fu, M., & Yang, X. (2001). Bamboo forestry in China: Toward environmentally friendly expansion. *Journal of Forestry;* 99 (7): 14-20.
5. Campbell, R (2009). Technical Report Non-Timber Forest Product inventory and value in Bolikhamxay Province, Lao PDR. Available at: http://lad.nafri.org.la/fulltext/2105-0.pdf. Retrieved 30th November 2014.
6. Chaowana, P. (2013). Bamboo: An Alternative Raw Material for Wood and Wood-Based Composites. *Journal of Materials Science Research*; 2(2); 2013. ISSN 1927-0585 E-ISSN 1927-0593, Published by Canadian Center of Science and Education.
7. Chaowana, P., Robkorb, K., Sriwilai, S., & Barbu, M. C. (2012). Gluability Variation of *Dendrocalamus asper* for Bamboo Composites. *In the 9th World Bamboo Congress Proceedings (pp. 307-315).* Antwerp, Belgium.
8. Chapman, G. P. (1996). The biology of grasses. Department of Biochemistry and Biological Sciences, Wye College, University of London, United Kingdom. Composites. *Journal of Materials Science Research*, 2(2).

9. Customs General Administration of China| (2004). China customs statistics yearbook. Beijing, Customs General Administration of China Publishing, 2005.
10. Eco-Securities (2007). Five Policy Brief: REDD Policy Scenarios and Carbon Markets.
11. Eliasch, J, (2008. Climate change: financing global forests: The Eliasch Review.
12. FAO, (2005). World bamboo resources A thematic study prepared in the framework of the Global Forest Resources Assessment 2005 1 NON-WOOD FOREST PRODUCTS 18 World bamboo resources A thematic study prepared in the framework of the Global Forest Resources Assessment 2005. Edited by Lobovikov, M. Ball, L. Guardia, M. and Russo, L.
13. Gill, S. & kumar, R. (2016). To experimental study and use of bamboo in civil structure as reinforced concrete. *International Journal of Latest Research in Science and Technology,* 5(2), 102-105.
14. Gullison, R. E., & Frumhoff, P.C. (2007). Tropical Forests and Climate Policy, Policy Forum, Science. 316.
15. INBAR (2015). International Network for Bamboo and Rattan. International Trade of Bamboo and Rattan 2012. Available at: *http://www.inbar.int/wp-content/uploads/downloads/2014/08/InternationalTradeBambooRattan2012.pdf*. Accessed 4th November, 2015.
16. International Network for Bamboo and Rattan (INBAR), (2001). Corrugated Bamboo Roofing Sheets. Research Centre for Forest Ecology and Environment, Forest Science Institute, Chem, Tu Liem, Hanoi. Vietnam.
17. IPCC, (2007). Solomon, S., Qin D., Manning M., Chen Z., Marquis M., Averyt K.B., M. Tignor and H.L. Miller (eds.). The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996.
18. Janssen, J.A. (1981). Building with Bamboo. London: Intermediate Technology Publication
19. Li, X. B., Shupe, T. F., Peter, G. F., &Hse, C. Y. (2007). Chemical changes with maturation of the bamboo species *Phyllostachys pubescens*. Journal of Tropical Forest Science, 19(1), 6-12.
20. Liese, W. (1985). Bamboos-biology, silvics, properties, utilization. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Germany.
21. Lobovikov, M., Paudel, S., Piazza, M., Ren, H., & Wu, J. (2007). World bamboo resources–A Thematic Study Prepared in the Framework of the Global Forest Resources Assessment 2005: Non-wood Forest Products (Non-Wood Forest Products). Food and Agriculture Organization of the United Nations (FAO), Rome, Italy.
22. Loreto, F., Centritto, M., Baraldi, R., Rapparini, F. & Liu, S. (2002). "Emission of isoprenoids from natural vegetation in the Beijing region (Northern China)." Plant Biosystems. 136(2). 251-256.
23. Lou Y., Li Y., Kathleen B. G., & Zhou G. (2010.) Bamboo and Climate Change Mitigation: a comparative analysis of carbon sequestration. International Network for Bamboo and Rattan (INBAR), China.
24. Malanit, P., Barbu, M. C., Liese, W., & Frühwald, A. (2008). Macroscopic aspects and physical properties of *Dendrocalamus asper* Backer for composite panels. *Journal of Bamboo and Rattan*, 7(3&4), 151-163.
25. Megal, E.; Kruse, S.; Lütje, G.; & Liese, W. (2005). Soluble Carbohydrates and Acid Ivertases involved in the rapid growth of the developing culms in Sasa palmata (Bean) Camus. Bamboo

Science and Culture, Baton Rouge/USA, 23-29.

26. Mohamed, A. H. J., Hall, J. B., Sulaiman, O., Wahab, R. & Kadir, W. R. (2007). "Quality management of the bamboo resource and its contribution to environmental conservation in Malaysia". *Management of Environmental Quality*; 18(6): 643-656.

27. PCARRD, (2011). Philippine Council for Agriculture, Forestry and Nature Resources Research and Development. "Growing Bamboo for Money and Healthy Environment.

28. Sajad H. M. (2013). Bamboo as a Cost-effective Structural Material in Buildings. *International Journal of Engineering and Technical Research (IJETR)*, 1(9), 45-49.

29. Schröder *S.*, (2014). Corrugated Bamboo Roofing Sheets an Untapped Opportunity for Latin America. Guadua Bamboo.

30. SFA (2005). State Forestry Administration of China. National Forest Resources Report. Beijing, China

31. Sigit W. (2000). The use of bamboo for lightweight construction system. ANZAScA 2000: Proceedings of the 34th Conference of the Australia and New Zealand Architectural Science Association, December 1-3, 2000

32. Xiaobing Y. (2007). Bamboo: Structure and Culture. Utilizing bamboo in the industrial context with reference to its structural and cultural dimensions. Inaugural-Dissertation zur Erlangung des Grades eines Doktors der Philosophie (Dr. Phil.) im Fachbereich Kunst und Design der Universität Duisburg-Essen. aus Yibin, China.

33. Zhang, Q. S., Jiang, S. X., &Tang, Y. Y. (2002). Industrial utilization on bamboo: Technical report No. 26. The International Network for Bamboo and Rattan (INBAR), People's Republic of China.