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Development and Determination of the Physical Properties of Long Nigerian Bamboo Fibre (LNBF)

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ABSTRACT:*Natural fibre has emerged as a renewable and cheaper substitute to synthetic materials such as glass, carbon and aramid, which are used as reinforcements. The chemical composition of natural fibres may differ with the growing condition and test methods even for the same kind of fibre, hence the need to develop fiber using bamboo from Nigeria to carry out this research. In this work, the objective was to develop, investigate and analyze the physical properties of long bamboo fiber obtained locally from Nigeria. Fresh bamboo was obtained and the fibre extracted using maceration method. Different physical properties of the long bamboo fibre were determined to ascertain their applicability. It was found that the pH values of the solution before and after extraction were 3.0 and 4.0 respectively. Thedensity of the dry bamboo (1.11g/cm^3) is slightly above that of water and that of the long bamboo fibre was found to be 0.5580 g/cm^3.*

Keywords*: Bamboo, Fiber, Nigeria, Density, Properties, Physical, Reinforcement, Natural fiber.*

I. INTRODUCTION

Bamboo is perennial, giant, woody grass belonging to the group angiosperms and the order monocotyledon. They are in the sub-family of bambusoideae.

In Nigeria there are two varieties of bamboo; Bambusa vulgaris and oxystenanthera abyssynica. The former attains a height of between 14-20 metre at maturity with a girth of about 20cm, the later reaches between 8-12 meters at maturity. The two varieties grow naturally in the forests below River Niger and in Taraba states [24]. The dominant bamboo in Nigeria is commonly referred to as the Indian bamboo. Analysis of result revealed that the bamboo species across Nigeria have similar morphological characteristics, though there is variation in size, suggesting influence of age and perhaps the soil conditions. Bamboo is particularly adapted to the rain forest belt of Nigeria where it is found in abundance along riverbanks and other relatively marshy areas [10].

Bamboo survives in every environment except where it is cold for long periods of time. Once planted, the grass is hard to get rid of. The only way to kill off bamboo is to plow the area where it is growing. When planting, you can limit the spread of your bamboo by planting it in a big pot or spreading large plastic bags around the planting area to contain them. It is true though, from edible bamboo shoots to construction, medicine, bamboo fabric or bio fuel it is all been done before. The challenges we face today are to further improve the uses of bamboo. Since bamboo is the fastest growing plant on earth and a sustainable building material, it could easily substitute all known wood applications without having to cut down entire bamboo groves or plantations. Better yet, bamboo continuously grows after harvest without having to re-plant it. Bamboo also converts about 35% more CO_2 into oxygen than a regular tree[14].

While bamboo grows everywhere in the world except those places with extremely cold climates, it is thought to have originated in China, where the first use of bamboo to make every day items was recorded. This tall, hearty grass (bamboo is technically grass) was used for as many products as they could manage, as it was a quickly renewable resource.

The species of bamboo that we know today evolved from prehistoric grasses between thirty and forty million years ago, long after the extinction of the dinosaurs. It then became the major food source for herbivorous animals, eventually becoming a food source for the modern human being as well [6].

Bamboo is the most wonderful, natural and renewable resource capable of rapid growth that can avoid future deforestation of our precious tropical rainforests.

Bamboo is easy to cut, handle, repair, reposition and maintain, without the need for sophisticated tools or equipment. Because of its extraordinary physical characteristics, Guadua bamboo is suitable for all types of structures and constructions.

Bamboo is non-polluting and does not have crusts or parts that can be considered waste. Instead of adding to the problems of polluting land-fills like conventional building waste, any part of the bamboo that is not used is recycled back into the earth as fertilizer or can be processed as bamboo charcoal [12].

Besides being used as a structural element, bamboo can also serve other functions, such as: flooring, wall paneling, water pipes, drainage, and furniture.

Bamboo can be used in combination with other types of construction materials.

Bamboo is one material that has good economic advantages, it reaches its full growth in just a few years, and it is also one of the fastest renewable plants with a maturity cycle of 3 to 4 years.

Although the utilization potential of this material for a number of applications has been explored, such superior mechanical properties have not been adequately well drawn for polymer-based composite [12].

The mechanical properties of different natural fibres such as sisal, vakka, banana, bamboo were compared and it was found that the bamboo fibers have much higher tensile and flexural properties than other fibres [15]

Bamboo fibres have emerged as a renewable and cheaper substitute for synthetic fibres such as glass and carbon, which are used as reinforcement in making structural components. They have high specific properties such as stiffness, impact resistance, flexibility and modulus, and are comparable to those of glass fiber [7].

Bamboo can be used for reinforcement such as the whole bamboo, section, strips and the fibers. These various forms of bamboo have been used in applications such as low rise construction to resist earthquake and wind loads, bamboo mats composite in combination with wood for beam, and shear wall in low rise construction in addition bamboo fibre can be used as reinforcement with various thermoplastic and thermoset polymer [7].

According to [18], the major uses in all the states are as scaffolding materials. The use of bamboo for this purpose has opened up domestic trade for bamboo culms. Other uses include fencing, yam stakes, environmental amelioration, handicrafts and fuel wood. In the construction of story buildings, bamboo culms are used as pillars to provide temporary support for the decking. In many of the rural areas, especially in Cross River and Akwa Ibom States, bamboo is also used in the construction of mud houses. In these areas, bamboo culms are used as frames to provide the skeleton for buildings. Mud is then used to cover the entire skeleton. Houses built this way usually have very straight walls, and are stronger than mud houses built without bamboo. Apart from the above, several other uses exist, though on a relatively small scale.

Consequently, bamboo is valuable in health care delivery and can be processed into beverage, medicines, pesticides and other household items such as toothpaste, soaps, etc.

Natural fiber composites used for structural purposes do exist, but then usually with synthetic thermo-set matrices which of course limit the environmental benefits [3], [19].

Plant fibres, such as hemp, flax and wood, have large potential as reinforcement in structural materials due to the high aspect ratio and high specific strength- and stiffness of the fibers [15], [4], [2].

Apart from good specific mechanical properties and positive environmental impact, other benefits from using natural fibres worth mentioning are low cost, friendly processing, low tool wear, no skin irritation and good thermal and acoustic insulating properties [2].

Some of these systems show encouraging results. For example, [16] have reported that flax fiber composites with PLA matrix can compete with and even outperform flax/polypropylene composites in terms of mechanical properties.

Natural fibre composites tend to swell considerably with water uptake and as a consequence mechanical properties, such as stiffness and strength, are negatively influenced. However, the natural fibre is not inert. The fibre-matrix adhesion may be improved and the fibre swelling reduced by means of chemical, enzymatic or mechanical modifications [1], [14].

In addition, fibres like sisal, jute, coir, oil palm, bamboo, bagasse, wheat and flax straw, waste silk and banana [12], [6], [21], [19], have proved to be good and effective reinforcements in the thermoset andthermoplastic matrices. Nevertheless, some aspects of natural fibre-reinforced composite behaviour is still poorly understood such as their visco-elastic, visco-plastic or time-dependent behaviour due to creep and fatigue loadings, interfacial adhesion [8] and tribological properties;[20] are available in literatures. In this context, long plant fibres, like hemp, flax [8], [12] bagasse and bamboo [20], [5], have considerable potentials in the manufacture of composite materials for tribo applications.

Natural fibres are increasingly used in automotive and packaging materials, in some countries of the world that are solely agricultural dependent for instance Pakistan, Malaysia etc, thousands of tons of different crops are produced but most of their waste do not have any further utilization. These agricultural wastes include wheat husk, rice husk and straw, hemp fibre and shells of various dry fruits [9], [11].

Among the various natural fibres, bamboo finds widespread use in housing construction around the world, and is considered as a promising candidate for housing material in underdeveloped and developed countries. Being a conventional construction material many decades past, bamboo fiber is a good candidate for use as natural fibre in composite materials. Many studies focused on bamboo fibre is due to the fact that it is an abundant natural resources with overall comparative, mechanical properties advantages to those of wood. This has informed the need for which the physical properties of long bamboo fibres are exploited for material development.

II. MATERIALS AND METHODS

The materials used here included but not limited to the following; Hydrogen peroxide, concentrated acetic acid, enamel bowl, oven, ladle, bamboo chips, weighing scale, water, plastic cup,bisphenol-A-diglycidlyl ether, poly vinyl alcohol, brush, polish(gel), metal bars of 300mm x 3mm, metal sheet, tile of 300mm x 200mm square area, weight of 8kg, thermometer, pH meter and a graduated cylinder.

Extraction of long bamboo fiber

The extraction of fiber from the bamboo plant was done using maceration method.

Matured bamboo stems were cut from Calabar environment and the nodes of the bamboo were sawed off. The nodes were discarded while the bamboo stem was manually reduced to chips. The bamboo chips were further reduced to match 'stick size'.

The length of the average reduced bamboo stick was measured and it was determined to be 51mm.

The bamboo sticks were transferred to the laboratory where they were weighed to be 663.88g.

The weighed sticks were transferred into an enamel bowl. Hydrogen peroxide was measured in a beaker, and then transferred into the enamel bowl. Glacial acetic acid was also measured with a beaker and transferred into the enamel bowl containing hydrogen peroxide and bamboo Sticks. The ratio of hydrogen peroxide to glacial acetic acid was estimated at 1:1. This is shown chemically in equation 1.0:

$C_2H_4O_2 + 3H_2O_2 \rightarrow 2CH_3OH + 2H_2O + 2O_2$ -1.0

The mixture of bamboo chips and reagents in the enamel bowl was stirred and placed in an oven and allowed to heat for hours. The oven temperature was read from the thermometer inserted into the oven.

Relevant physical factors obtained were;

a Weight of bamboo used
b The moisture content in the bamboo used
c Quantity of the bamboo used relative to the fiber obtained
d Temperature of the solution before the dipping of the bamboo
e Chemical ratio for the solution
f Temperature of the oven
g pH value of the solution before heating
h pH value of the solution after heating

Determination of the Moisture content of Bamboo by Gravitational Method

The moisture content of any material influences the physical properties as weight, density, viscosity, refractive index, electrical conductivity etc. It also enables the designer predict the behavior of the material during processing. In this work the moisture content of the bamboo was determined using the gravitational method. Two samples were separately prepared and put into empty cans, whose weights were taken and recorded as shown in Table 1.0. Quantities of bamboo chips were loaded in the cans and corked appropriately. The cans with the bamboo chips samples were put in the oven and the temperature set to 105°C. Samples A and B were reweighed at interval of one hour, the values were recorded as shown in Table 2.0 The heating and reweighing was done until it was observed that there was no significant change in the weight of the samples, a point that could be termed "constant final weight"

Table 1.0: Determination of moisture content of bamboo

Table of results	Sample A	Sample B
Weight of empty can and lid	42.049g	45.552g
Weight of can, lid and sample	85.034g	84.550g
Weight of oven dried sample	42.985g	38.998g

Table 2.0: Drying of samples at 105°C to constant weight

Samples	Initial weight (g)	1 hour	2 hours	3 hours	4 hours
Sample A	85.03	76.73	76.58	76.57	76.57
Sample B	84.55	76.69	76.67	76.55	76.55

Weight of dried sample A = 76.570g
Weight of dried sample B = 76.553g
Weight of sample A = 76.570 – 42.049 = 34.521g
Weight of sample B = 76.553 – 45.552 = 31.001g
Weight of moisture content on sample A = 42.985 – 34.521 = 8.464g
Weight of moisture content on sample B = 38.998 – 31.001 = 7.997g

Moisture Content (M.C) % A = 8.464/42.985 = 19.69%
Moisture Content (M.C) % B = 7.998/38.998 = 20.509%

Quantity of the bamboo used relative to the fibre obtained

The quantity of bamboo used was determined by weighing the bamboo sticks with an electric weighing scale. The value was 663.88g. The fibre extracted was weighed and the value obtained was recorded as 148.46g using chemical digestion method.

This represents a percentage of $(\frac{148.46}{663.88} \text{ x } 100)$ = 22.36 %

Temperature of the solution before dipping the bamboo

The temperature of the solution was determined by dipping a mercury in-glass thermometer in the solution and taking the reading on the meniscus line, the value was 23°C.

Temperature of the oven

The temperature of the oven was recorded by mounting the thermometer on the oven through a hole on the top of it and the temperature was 103°C.

pH value of the solution before heating

The pH value of the solution was determined using a digital pH meter. The electrodes of the meter were dipped into the solution which was taken after constitution and poured in the bowl containing the bamboo sticks and the pH value of the solution was displayed on the screen. The pH value was 3.0 which suggested that the solution was acidic.

pH value of the solution after heating

The pH of the solution was determined after heating, the pH value obtained was 4.0

III. RESULTS AND DISCUSSION

Moisture Content of Bamboo

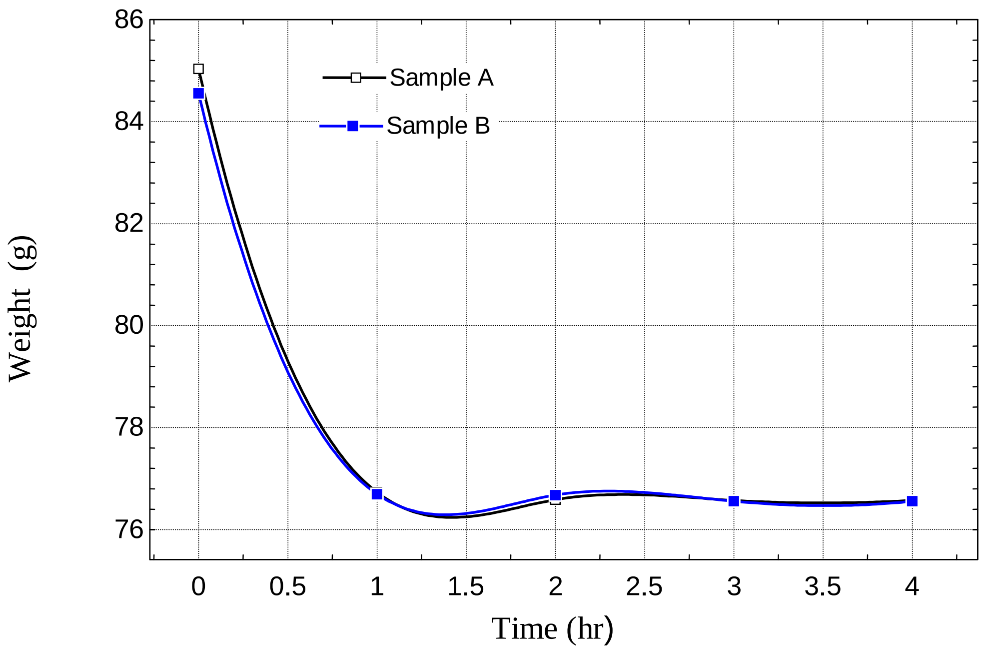

Figure 1.0: Moisture content values plotted for weight (g) against time (hr)

The moisture content values obtained were plotted as shown in Figure 1.0.
It took about one and a half hour to dry 85g of fresh bamboo.
The sample labeled A in Figure 1.0 dried at the same rate as sample B, though the two were not from the same variety.

IV. DISCUSSION OF RESULTS

Fibre Extraction
The fibres used in this work were extracted from a typical Nigerian bamboo plant using maceration method.

Physical Properties
Determination of the Moisture Content of Bamboo: Moisture content of the bamboo was determined to ensure that a completely dry bamboo was used for the extraction, from the observation made the blemish free bamboo was subjected to a constant temperature of 105^0C for a period of 4 hours. At the third and fourth hour it was observed that there was no significant change in the weight of the bamboo, therefore it was established that the bamboo was within 4 hours. The moisture extracted was 20.1% of the weight of the fresh bamboo. It was also observed that at 105^0C and 4 hours of drying, the bamboo can be made ready for fiber extraction. Figure 1.0 shows the behavoiur of two samples of dry bamboo subjected to a temperature of 105^0C for 4 hours.
Determination of the Weight of Bamboo: The essence of the weight of bamboo taken was to ensure that the physical state of the bamboo in terms of the mass was established to determine the fibre output of the fed (input) bamboo. Upon processing of the bamboo of a known weight, the weight of fibre produced was determined. It was observed that 22.36% was the yield from the chemical digestion method while 48% was obtained from the maceration method.

Determination of the p^H value: In this research the value of the p^H before the heating process was commenced was 3.0 indicating that the combination of the glacial acetic acid and hydrogen peroxide produced an acidic solution. Materials with similar acidity include solutions of grape fruits, soda, citrus, red wine, household ammonia. During the process of maceration, the heating raised the value to 4.0 this is equivalent to acid rain, tomato juice, milk of magnesium.

V. CONCLUSION

The physical properties of Nigerian long bamboo fiber extracted were determined. From the results obtained and the examination of the samples, it shows that, the Nigerian long bamboo fiber can be suitable for industrial applications especially for reinforced composites.

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