Effects of kenaf core and bast fibers as dispersing phases on low density fiberboards (engineered wood)

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Abstract.
Fiberboards are engineered woods made from a composition of wood chippings, wood fibers, sawdust etc., glued together with adhesives. Low density fiberboards (LDF) are part of the classes of fiberboards widely used in Nigeria because they are readily available, relatively cheap and offer good aesthetic values, compared to conventional woods. However, they possess low strength, durability and lifespan, thus making them susceptible to damage during service. The aim of this study was to determine the effect of kenaf core and bast fibers (Hibiscus cannabinus) as one of the dispersing phases in low density fiberboard production, also known as particleboards. The materials and methods employed in the study, followed procedures in established standards and literatures. The different composite materials were weighed and mixed properly for about 10 minutes to ensure homogeneity in the mixture. Thereafter, the materials were placed in a mould of uniform thickness and compressed to different fiber board samples using a compression press machine, for about 10mins. A series of physio-mechanical tests such as water absorption, density, tensile strength, modulus of elasticity and modulus of rupture were conducted on the developed fiberboard samples as well as the control samples. The results showed that the average values for water absorption and density of the developed samples enhanced with kenaf core and bast fibers were 5.480% and 0.027 g/cm³ respectively. These values compare well with that of the control samples. Also, the tensile strength, modulus of elasticity and modulus of rupture of samples enhanced with kenaf gave average values of 31.842 MPa, 2.920 GPa and 16.58 N/mm² respectively. These values also compare well with that of the control samples. From the results gotten and all the properties determined, the study showed that kenaf core and bast fibers can be employed appreciably as dispersing phases for low density fiber board (LDF) composite production.

Key words: Kenaf, Core fibers, Bast fibers, Fiberboard, Composites.

1.0 INTRODUCTION
The use of wood (timber) in the construction industry cannot be overemphasized in this current age, especially in Nigeria. Contemporary construction of tall buildings from timber suggests a growing interest in the potential for building with wood at a scale not previously attainable [1]. Wood is the only significant building material that is grown; hence, we have a natural inclination that building with wood is good for the environment [2]. Nowadays however, due to the low strength of wood, most buildings are made of re-enforced steels both for roofing and for building skyscrapers [3]. In addition, continued usage of wood means increasing felling of trees (deforestation). This does not only affect animals in their natural habitat, but also lead to scarcity of forest materials for mankind. It also results to climate changes and causes natural disaster such as flooding among others [4]. Hence, researchers are continually seeking to develop other materials that could offer competitive performance that would replace or reinforce wood. To reduce the usage of wooden materials in commercial or industrial use, fiberboards were introduced. Fibre
boards are engineered woods made from a composition of wood chippings, wood fibers, sawdust etc, glued together with adhesives [5]. Low density fiberboards are part of the classes of fiberboards widely used in Nigeria because they are readily available, relatively cheaper and offer good aesthetic values compared to conventional woods [6]. However, low density fiberboards possess low strength, durability and lifespan, making them susceptible to damage during service [7]. There are different types fiberboards (low, medium and high density) with different matrices but some of these matrices are hard to find or too expensive to get, thereby making their production costly.

Some researchers have notably worked on particle boards used kenaf core, a light material with density of 150kg/m³ to make binder less particleboard with density ranging from 100 to 300 kg/m³ [8]. Since the density of resin is normally higher than that of wood, and much higher than that of kenaf core, it is possible to make binder less low density panel using low density kenaf core. However, the strength of particleboard with 100kg/m³ was still too poor to satisfy mechanical test requirements [9].

Mohammed et al. (2015) investigated adhesion properties, such as buffering capacity, wet ability of bamboo and rubber wood [10]. They evaluated the physical and mechanical properties of hybrid particleboards made from bamboo (B), veneer waste and rubberwood (RW) particles [11]. The bamboo had an acidic pH value with a high buffering capacity compared with rubberwood. Hybrid bamboo-rubberwood particleboard displayed better mechanical properties compared to 100% bamboo and rubberwood particleboard [12].

Moreover, most researchers have carried out various studies on particle board enhancement, using different fibrous materials as part of the composite mix; none have used Kenaf core and bast fibres together as a dispersing phase on the particleboard composite [13]. Hence, considering the challenges connected with low density fiberboards, the aim of this study was to determine the Effect of Kenaf Core and Bast Fibers (Hibiscus cannabinus) as one of the dispersing phases in Low Density Fiber (LDF) Production [14]. Kenaf plants are readily available in Nigeria and they are rich in natural fibers. They can grow in any type of soil and reach a height of 12-18 feet in 150 days. Studies have also shown that Kenaf fibres have good mechanical properties ranging from high hardness to high compressive strength [15].

2.0 METHODOLOGY

The methods used to achieve the objectives of this study followed established standards and published journals. The methods are classified into three classes: extraction and preparation of kenaf core fiber, production of LDF and physio-mechanical properties determination of the produced LDF.

- **Extraction and preparation of kenaf core fibre:** Kenaf core and bast fibers was extracted from the kenaf stem using water retting process. This process ensured the degradation of the pectic materials, hemicellulose and lignin and also improved the quality of the fiber. The fiber was placed in water for 14 – 24 days and the bast and core were extracted and dried.

- **Production of LDF:** The components were mixed using the ratio shown in the table 2.1 below:

| Samples no. | % of Saw Dust | % of Kenaf | % of Wood Chips |
|-------------|----------------|-------------|-----------------|
| 1(Control 1)| 70             | 0           | 30              |
| 2           | 70              | 10          | 20              |
The sample material composition were scattered in a square shaped wooden former (mould) with dimension 200mm x 200mm x 23mm and pressed to fit into the former. The former was then placed in an oven at a temperature 140°C for 10 minutes to dry before pressing.

Fig 2.1: Produced LDF samples

Physio-mechanical properties determination

i. Thickness: The thickness value of each sample was measured using a vernier caliper. The sample was placed between the fixed jaw blade and movable jaw blade and the readings were recorded from the scale.

ii. Water Absorption: The method used here, conforms with the procedures reported by Behzad (2016). All the samples were weighed on a scale to get the initial weight (W₁). Each sample was then submerged horizontally at a depth of 30 mm fresh water for 24 hours. Afterwards, the samples were removed from the water. Excess water was wiped off and the samples were weighed to get final weight (W₂). The water absorption value was then calculated using the formula below:

\[
\text{Water absorption, } \text{WA} = \frac{W₂ - W₁}{W₁} \times 100\% \quad \text{-------------------------------------- (1)}
\]

Where W₁ the weight (g) before water absorption; W₂ is the weight (g) after water absorption.

iii. Density: The density of the LDF was calculated by measuring its mass and volume. Each sample was weighed on a scale in units of grams. The length, width and height of the LDF were measured. The density was then calculated using the formula below:

\[
\text{Density (ρ)} = \frac{m}{v} \quad \text{-------------------------------------- (2)}
\]

Where \( m = \) the mass of test sample (g) and \( v = \) the measuring volume of test piece (cm³) by liquid displacement method. This procedure is in line with what Wang (2008) reported in his work.

iv. Tensile Stress: The tensile properties were determined using 10 kN Zwick Universal Testing Machine. The samples were characterized using initial grip section of 25mm and 2mm/min respectively with lower and upper jaws perpendicularly aligned. Tensile strength, with elongation at breaking point and young modulus was calculated.

v. Modulus of Elasticity, MOE: The MOE tests were performed using the Zwick 10kN Universal Testing Machine. The samples are placed between the testing machine with...
initial grip 25mm in the upper and lower jaws. The values of the stress and strain were calculated. MOE values were then calculated using stress – strain relationship.

vi. **Modulus of Rupture:** This was determined in a flexure test. The flexure test was based on maximum fiber stress at failure and the torsion test is based on the maximum shear stress in the extreme fiber. Each sample was bent until fracture or yielding using a three-point flexural test technique. Data recorded from the tests including load at breaking distance between edges on which the sample is supported, average sample width and average sample thickness.

Modulus of rupture, \( \text{MOR} = \frac{3PL}{2bt^2} \)  
(3)

Where P is the maximum load (N), L is the span (mm), b is the width of the specimen (mm), t is the thickness (mm). This method conforms with the procedures reported by Behzad (2016).

**3.0 RESULTS AND DISCUSSION**

This chapter discusses the test results obtained for the study. The results are presented on Tables 3.1 to 3.3 and Figures 3.1 to 3.3.

| Table 3.1: Thickness values (mm) of the developed LDF composite samples |
|---------------------------------------------------------------|
| **Sample Composition (g)** | **Thickness (mm)** |
| 2 | 20 |
| 3 | 20 |
| 4 | 20 |
| 5 | 20 |
| 6 | 20 |
| 1 (Control 1) | 20 |
| 7 (Control 2) | 20 |

| Table 3.2: Water absorption rates (%) of the developed LDF composite samples |
|---------------------------------------------------------------|
| **Sample Composition (g)** | **Initial Weight, W_1 (g)** | **Final Weight, W_2 (g)** | **Water Absorption (%)** |
| 2 | 140.00 | 147.00 | 5.00 |
| 3 | 137.00 | 150.00 | 9.49 |
| 4 | 141.00 | 147.00 | 4.25 |
| 5 | 143.00 | 148.50 | 3.84 |
| 6 | 144.00 | 148.00 | 3.47 |
| Average | 140.60 | 148.30 | 5.48 |
| 1 (Control 1) | 137.00 | 143.80 | 4.96 |
| 7 (Control 2) | 139.00 | 145.00 | 4.32 |

| Table 3.3: Density values (g/cm³) of the developed LDF composite samples |
|---------------------------------------------------------------|
| **Sample Composition (g)** | **Density (g/cm³)** |
| Sample | Tensile Strength (MPa) |
|--------|------------------------|
| 1      | 30.56                  |
| 2      | 31.45                  |
| 3      | 31.52                  |
| 4      | 31.8                   |
| 5      | 32.16                  |
| 6      | 32.28                  |
| Average| 0.027                  |
| 7 (Control 2) | 0.023            |

Fig 3.1: Tensile strength (MPa) of the developed LDF composite samples
Fig 3.2: Modulus of Elasticity values (GPa) of the developed LDF composites samples


Fig 3.3: Modulus of Rupture (N/mm²) of the developed LDF composites samples

3.1 DISCUSSION

Table 3.1 shows the results of the thickness values of the developed LDF composite samples and that of the control. It is seen that all samples have uniform thickness of 20mm respectively [16]. Table 3.2 shows the results of the water absorption rates of the developed LDF composite samples and that of the control. The water absorption decreased with increasing percentage of kenaf core and bast fiber for sample 4, 5 and 6 [17]. This phenomenon may be explained by the theory of void over volume of board. This theory emphasizes greater existence of void that can mostly be found in low density particle board. It provides spaces which encourage water absorption [18]. The values gotten from the test ranged from 3.47 – 9.49% while an average of 5.48% was obtained. These values also compare well with that of the control samples [19].

Table 3.3 shows the results of the density values for the developed LDF composite samples and that of the control. It can be observed that the percentage increase in kenaf particle showed increase in the density [20]. The values ranged from 0.019 – 0.033 g/cm³ while an average value of 0.027 was gotten. The results of samples 4, 5, 6 with increasing kenaf core and bast fibers compares closely to values obtained by Mohamad et al. (2010) and also showed better properties than the control samples [21].

Fig 3.1 shows the results of the tensile strength of the developed LDF composite samples and that of the control [22]. The tensile strength was seen to increase as the percentage of kenaf core and bast fibers increased. Also, the values recorded by the samples are more than those given by the control samples. This indicated that, the addition of kenaf increased the strength [23]. The values ranged from 31.45 – 32.28 MPa and an average of 31.84MPa was obtained. The values obtained compares well to the results obtained by [24].

| Samples         | Sample 1 (Control 1) | Sample 2 | Sample 3 | Sample 4 | Sample 5 | Sample 6 | Sample 7 (Control 2) |
|-----------------|----------------------|----------|----------|----------|----------|----------|-----------------------|
| MOR (N/mm²)     | 12.5                 | 13.3     | 14.9     | 17.5     | 18       | 19.2     | 12.8                  |
| Modulus of rupture (N/mm²) | 12.5 | 13.3 | 14.9 | 17.5 | 18 | 19.2 | 12.8 |
Fig. 3.2 shows the results of the modulus of elasticity (MOE) of the developed LDF composite samples and that of the control [25]. MOE is the slope of the tangent line at the stress point of proportional limit. It can be seen that the percentage increase in kenaf core and bast fibers resulted to increase in the modulus of elasticity [26]. Control samples 1 and 2 showed relatively lower values (1.50 GPa and 1.40 GPa). Sample 6 with highest kenaf content gave the best result 4.67 GPa. The values gotten ranged from 1.66 – 4.67 GPa while an average value of 2.92 GPa was seen. The values compare well with what Azer (2010) reported in his work [27].

Fig. 3.3 shows the results of the modulus of rupture of the developed LDF composite samples and that of the control [28]. It was observed that the MOR values increased with the percentage increase in kenaf core and bast particles [29]. This shows the ability of the samples to resist bending force positively. The values obtained ranged from 13.3 – 19.2 N/mm² and the average value was seen to be 16.58 N/mm² [30].

4.0 CONCLUSION

The research was carried out with as much waste and eco-friendly material as possible and these materials can be sourced locally [31]. The Low-Density Fiberboard composite samples were produced successfully using Kenaf bast and core fibers as a dispersing phase [32]. These samples were then tested for thickness, water absorption, density, tensile strength, modulus of elasticity and modulus of rupture. The results were compared with the control samples [33]. The following conclusion can be drawn from the study:

- The results show that the sample with the most percentage of kenaf loading (Sample 6) gave the best properties (Water absorption, density, tensile strength, modulus of elasticity and modulus of rupture).
- Sample 2 with lowest kenaf content gave the lowest values of the mechanical properties determined when compared with the other samples containing kenaf core and bast fiber.
- This study therefore shows that kenaf bast and core fiber has appreciable effect in the developed low density fibreboard.

Based on the result Kenaf core and bast fiber has great potential for the manufacture of the low density fibreboard. It shows improved mechanical properties which will definitely increase service life of boards.
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