

**Original Research Article**

**Preliminary Studies on the Effect of Size Reduction on Mechanical Properties of Kenaf Particle Reinforced Polymer (K-PRP) Composites for Industrial Application**

**Abstract**

Over the years, kenaf fibre has shown diversity in industrial utilization with increasing number of potential commercial products such as automobile products development, building and semi-structural applications, variety of applications in the field of medicine, plastic and packaging materials, pulp and paper production, agro-sack production, geo-textile applications, substrate for mushroom cultivation, absorption particles, bioremediation and oil spill clean-up etc. The unique properties of kenaf fibre and its short life cycle of 130-150 days have kept it competitive in the market. This research investigates the effect of size reduction on the mechanical properties of fabricated kenaf micro particle reinforced composite. Thermosetting matrix was used on Hand layup contact molding technique with varying fibre loading of 0%, 10%, 20%, 30% and 40% of Ball milled, screened and classified micro particle sizes of 120  $\mu\text{m}$ , 100  $\mu\text{m}$  and 80  $\mu\text{m}$  respectively. The results showed that the optimum fibre loading and particle size for achieving highest tensile strength of reinforced composite was 30% and 80  $\mu\text{m}$  respectively. The elongation at break of the composite decreased as the fibre loading increased. The environmental stability of reinforced composite was studied using ASTM standard D-570. It was also observed that the fabricated composite sheets applying optimum fibre loading and particle size were stable to an aggressive hygrothermal environment. Prototype packaging material was fabricated and

this project gears towards attaining Nanoparticles (K-NPs) for strength enhancement and structural flexibility.

**Key words:** Kenaf fibres, kenaf decorticator, ball mill machine, Instron machine.

## 1 Introduction

Composite materials have gained significant momentum in recent years and has become highly competitive due to its diverse industrial applications, new products have appeared in the market with newly developed materials and sophisticated structural designs. These products are fabricated from different reinforcement and processes that enhance product integrity. Composite materials have become very attractive for their applications in the field of engineering and advance material development. The society requires scientists and manufacturers to focus research on sustainable materials, biodegradable, energy efficient processes due to the increasing concern about our environment. This demand clearly favours greater usage of natural fibres due its convenient renewability, biodegradability, environmentally friendliness and acceptable mechanical properties. Natural fibres such as kenaf, hemp, jute, flax etc have been used by various researchers as reinforcement for thermosetting or thermoplastic composite fabrication. [2].

The aim of this study is to investigate the effect of size reduction on mechanical properties of kenaf particle reinforced polymer (K-PRP) composites for industrial application. Kenaf (*Hibiscus cannabinus* L.) is a fast-growing short duration multipurpose crop. It is among the most valuable hard industrial fibre crop. Kenaf has a high growth rate of between 5-6 months, rising to heights of 12-18 feet in about 4-5 months and its yield is about 6-11 tons (new varieties

may reach 22 tons) of dry weight per hectare per year which is 5-10 times greater than the yield for most conventional trees which can take from 7 –40 years to reach harvestable size. It is a plant that produces fibres similar to hardwoods and softwoods. Kenaf has a single, straight, un-branched stem consisting of two fibre parts such as: the outer bast fibre which is about 35% the stalk's dry weight, as long as the stem, relatively strong and is considered as the most important fraction of kenaf bast plant and the inner core fibre which comprises about 65% of the stalk's dry weight. [1]. The whole stalk of kenaf plant (core and bast) is bound together by lignin. Kenaf core is a semi-hard wood like material reported to absorb 5 times its weight and is mainly used in absorbent applications like potting mixes, packing material, as organic filler, additive for drilling muds and acoustic pads, erosion mats, animal bedding and wood-based composites. [3].

## **2 Materials and methods**

### **2.1 Materials**

Decorticated kenaf mixed (core & bast) fibres were sourced from Institute of Agricultural Research and Training (IAR&T), Ibadan. The matrix used were unsaturated polyester resin, methyl ethyl ketone peroxide (MEKP), cobalt napthenate as catalyst & accelerator and locally fabricated ASTM Standard test piece mold.

### **2.2 Methods**

Decorticated core and bast kenaf fibres were separated, after which the kenaf core fibre was chopped into lengths ranging from 1 to 4 inches, soaked in distilled water for 24 h, washed and dried.

### **2.2.1 Fibre Modification**

In this research paper, chemical modification was employed. Chopped, washed and dried kenaf core fibre was immersed in 10 wt% solution of NaOH for 4 h followed by continuous washing, air drying for 3 days and oven drying at 105°C for 24 h.

### **2.2.2 Composite Fabrication**

The basic fundamental fibres conditions such as purity, moisture and defined uniform particle size distribution were determined prior to composite fabrication. The modified and unmodified kenaf core samples were milled using a ball mill, screened and classified into three different micro particle sizes of 120  $\mu\text{m}$ , 100  $\mu\text{m}$  and 80  $\mu\text{m}$ . The composite was fabricated using a thermosetting matrix (unsaturated polyester resin), varying fibre loading of 0%, 10%, 20%, 30% and 40%, a catalyst (methyl ethyl ketone) and an accelerator (cobalt napthenate) by hand layup contact molding technique.

The catalyst and accelerator were set at 2% weight of the matrix. Proper homogenized flowing sludge was achieved through mixing after which it was hand-laid into a fabricated dumbbell test piece mould. The mould together with the sample was kept for curing at room temperature for 24 h. After curing, the composite was separated from the mould and trimmed for analysis. After the mechanical properties analysis, prototype packaging materials were fabricated using modified particle size and fibre loading of 80  $\mu\text{m}$  and 30% respectively that gave the highest strength and more environmental stability.

### 85 3 Results and discussions

86 Table 1 shows the physicochemical properties of our crude sample and modified samples. The  
 87 mechanical properties of kenaf core particle reinforced composite were tested and the optimum  
 88 fibre loading and particle size as well as the factors leading to the optimum particle size were  
 89 determined. The experiments revealed that the particulate size and fibre loading of 80  $\mu\text{m}$  and  
 90 30% respectively gave the highest strength and environmental stability. Surface modification  
 91 resulted in a significant increase in tensile strength and whose results are shown in Table 2.

92 **Table 1: Physicochemical Properties of Modified& Unmodified kenaf core micro-particles**

| Constituents                                                                                                                                                               | Unmodified sample | Modified sample |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-----------------|
| Cellulose (%)                                                                                                                                                              | 42.0 – 49.0       | 70.0-77.0       |
| Lignin (%)                                                                                                                                                                 | 28.0 – 33.0       | 10.0-14.0       |
| Hemicellulose (%)                                                                                                                                                          | 23.0-27           | 13.0-18.0       |
| Moisture (%)                                                                                                                                                               | 7-10              | 4-6             |
| Ash (%)                                                                                                                                                                    | 4.10-5.02         | 2.0 – 4.0       |
| Particle size ( $\mu\text{m}$ )                                                                                                                                            | 80-120            | 80-120          |
| Density ( $\text{g}/\text{cm}^3$ )                                                                                                                                         | 0.33-1.02         | 0.33-1.02       |
| Fibre Length(mm)                                                                                                                                                           | 0.76              | 0.76            |
| <b>Technical association of pulp and paper industry (TAPPI)- [4] and Direct method of<br/>           cellulose, hemicellulose and lignin (Moubasher et al. 1982) – [5]</b> |                   |                 |

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94 **Table 2: Mechanical Properties of Modified & Unmodified kenaf core micro-particle**

| Parameters                                                                                                                     | Unmodified-KPRC @ 80 $\mu\text{m}$<br>(%Fibre Loading) |      |      |      |     | Modified-KPRC @ 80 $\mu\text{m}$<br>(%Fabre Loading) |      |      |      |     |
|--------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|------|------|------|-----|------------------------------------------------------|------|------|------|-----|
|                                                                                                                                | 0%                                                     | 10%  | 20%  | 30%  | 40% | 0%                                                   | 10%  | 20%  | 30%  | 40% |
| <b>Tensile<br/>Strength (MPa)</b>                                                                                              | 8.5                                                    | 7.8  | 8.7  | 10.8 | 5.3 | 8.5                                                  | 9.5  | 15.3 | 18.5 | 7.0 |
| <b>Elongation<br/>@Break (%)</b>                                                                                               | 2.0                                                    | 1.3  | 0.9  | 0.5  | 0.3 | 2.0                                                  | 1.5  | 1.0  | 0.8  | 0.5 |
| <b>Flexural<br/>Strength (MPa)</b>                                                                                             | 17.5                                                   | 16.8 | 20.4 | 18.8 | 7.8 | 17.5                                                 | 19.4 | 25.5 | 20.0 | 9.5 |
| <b>KPRC = Kenaf Particle Reinforced Composite</b><br><br><b>ASTM D5083(Tensile Strength) and ASTM D 790(Flexural Strength)</b> |                                                        |      |      |      |     |                                                      |      |      |      |     |

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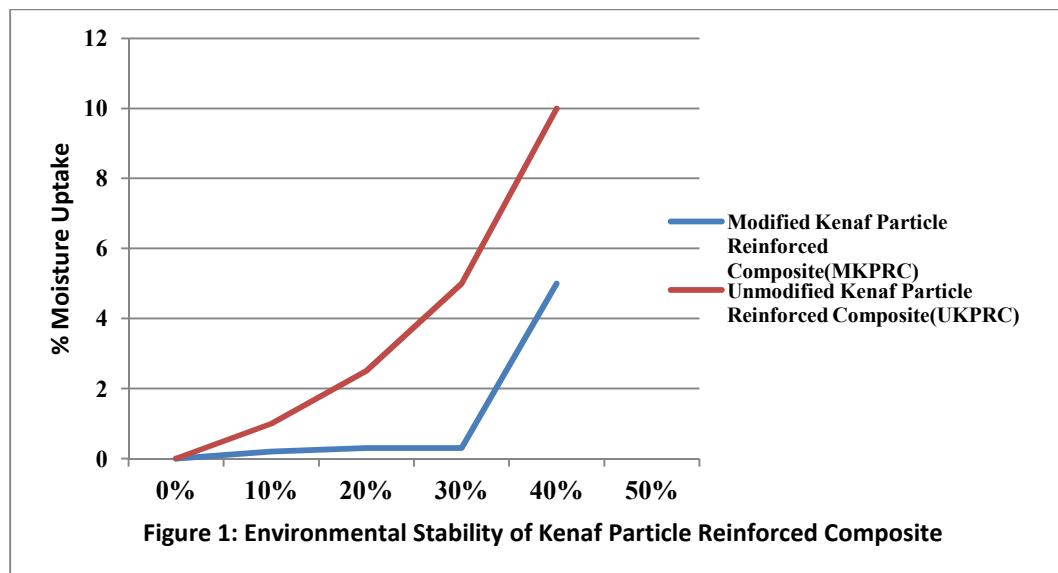


Figure 2: fabricated Prototype packaging material by hand layup contact molding technique.

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#### 104 **4 Conclusion**

105 The properties of composites depend on interfacial compatibility and adhesion between  
 106 hydrophilic fibre and hydrophobic matrix. The unmodified fibre used in composite fabrication  
 107 showed high moisture absorption, poor wettability, environmental instability etc. Alkaline  
 108 treatment with Sodium hydroxide (NaOH), also known as mercerization was used for the fibre  
 109 modification and has been proven to be effective in removing impurities from fibre, extraction of  
 110 lignin and hemicellulose, moisture sorption decrease, improved matrix-reinforcement interaction,  
 111 enabling mechanical bonding and strength improvement. the smaller micro-size of 80  $\mu\text{m}$   
 112 facilitated larger surface to volume ratio, good homogenization with the matrix and also increase  
 113 in mechanical properties. Attaining nano-size is projected for strength enhancement and  
 114 structural flexibility of the material.

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#### 119 **5 References**

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