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

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Authors' contributions

Author EUA designed the study and carried out the production process. Author CSE performed the statistical analysis. Author SOM performed the statistical analysis. Author FCN performed Engineering mold design and Simulations. Author CON managed the literature search. Author CCI Supervised and wrote the first draft of the manuscript. Author GNE supervised and sponsored the R&D.

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ABSTRACT

Aims: The present study aims to investigate the effect of size reduction on mechanical properties of kenaf particle reinforced polymer (K-PRP) composites for industrial application.

Study Design: Decorticated kenaf mixed (core & bast) fibres were sourced from Institute of Agricultural Research and Training (IAR&T), Ibadan. Decorticated core and bast kenaf fibres were separated and chopped into pieces followed by fibre modification and composite fabrication.

Results and Discussion: The results showed that the optimum fibre loading and particle size for achieving the highest tensile strength of reinforced composite was 30% and 80 µm respectively. The elongation break of the composite decreased as the fibre loading is increased. It is revealed 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

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

Conclusion: The properties of composites depend on interfacial compatibility and adhesion between hydrophilic fibre and hydrophobic matrix. The unmodified fibre used in composite fabrication showed high moisture absorption, poor wettability, and environmental instability.

Keywords: Kenaf fibres; kenaf decorticator; ball mill machine; Instron machine.

1. INTRODUCTION

Kenaf fibre has shown diversity in industrial utilisation 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 [1]. The unique properties of kenaf fibre and its short life cycle of 130-150 days have kept it competitive in the market. The composite materials have gained significant momentum in recent years and have become highly competitive due to its diverse industrial applications and 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. This research also investigates the effect of size reduction on the mechanical properties of fabricated kenaf micro particle reinforced composite. 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 [3]. 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 beading and wood-based composites [4].

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 naphthenate 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 105ºC 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 µm, 100 µm and 80 µm. 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 peroxide) and an accelerator (cobalt naphthenate) by hand layup contact molding technique.

The catalyst and accelerator were set at 2% weight of the matrix. Proper homogenised 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 µm and 30% respectively that gave the highest strength and more environmental stability.

3. RESULTS AND DISCUSSION

Table 1 shows the physicochemical properties of our crude sample and modified samples. The mechanical properties of kenaf core particle reinforced composite were tested and the optimum fibre loading and particle size, as well as the factors leading to the optimum particle size, were determined. The experiments revealed that the particulate size and fibre loading of 80 µm and 30% respectively gave the highest strength and environmental stability. Surface modification resulted in a significant increase in tensile strength and whose results are shown in Table 2.

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 (µm)	80-120	80-120
Density (g/cm^3)	0.33-1.02	0.33-1.02
Fibre Length(mm)	0.76	0.76

Technical association of pulp and paper industry (TAPPI)- [5] and Direct method of cellulose, hemicellulose and lignin (Moubasher et al. 1982) – [6]

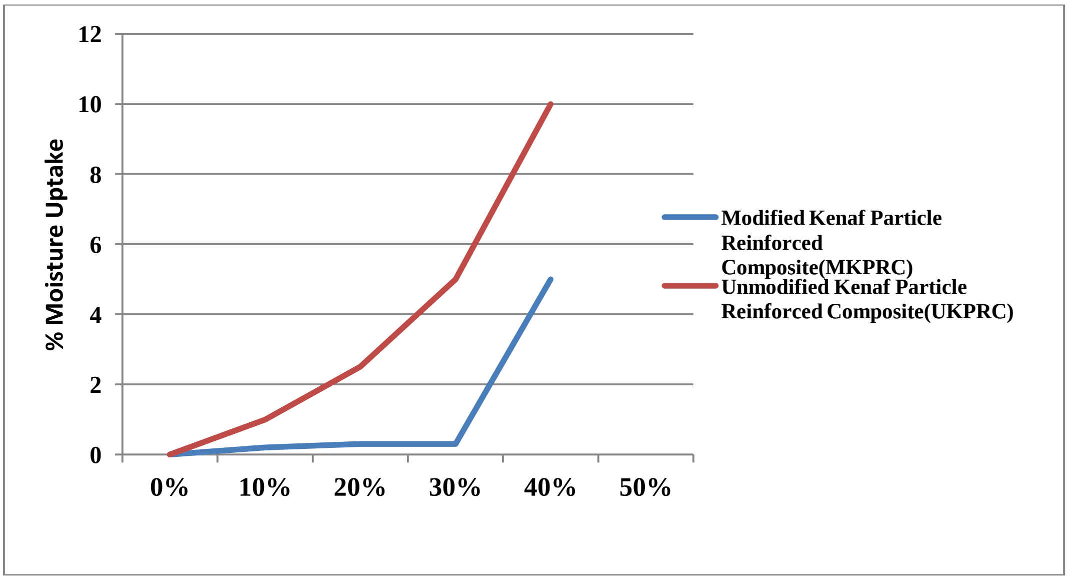

Fig. 1. Environmental stability of Kenaf Particle Reinforced Composite

Table 2. Mechanical properties of modified & unmodified kenaf core micro-particle

Parameters	Unmodified-KPRC @ 80 µm (%Fibre Loading)					Modified-KPRC @ 80 µm (%Fabre Loading)				
	0%	**10%**	**20%**	**30%**	**40%**	**0%**	**10%**	**20%**	**30%**	**40%**
Tensile Strength (MPa)	8.5	7.8	8.7	10.8	5.3	8.5	9.5	15.3	18.5	7.0
Elongation @Break (%)	2.0	1.3	0.9	0.5	0.3	2.0	1.5	1.0	0.8	0.5
Flexural Strength (MPa)	17.5	16.8	20.4	18.8	7.8	17.5	19.4	25.5	20.0	9.5

KPRC = Kenaf Particle Reinforced Composite
ASTM D5083(Tensile Strength) and ASTM D 790(Flexural Strength)

Fig. 2. Fabricated prototype packaging material by hand layup contact molding technique

4. CONCLUSION

The properties of composites depend on interfacial compatibility and adhesion between hydrophilic fibre and hydrophobic matrix. The unmodified fibre used in composite fabrication showed high moisture absorption, poor wettability, environmental instability etc. Alkaline treatment with sodium hydroxide (NaOH) solution, also known as mercerisation was used for the fibre modification and has been proven to be effective in removing impurities from fibre, extraction of lignin and hemicellulose, moisture sorption decrease, improved matrix-reinforcement interaction, enabling mechanical bonding and strength improvement. the smaller micro-size of 80 µm facilitated larger surface to volume ratio, good homogenisation with the matrix and also increased in mechanical properties. Attaining nano-size is projected for strength enhancement and structural flexibility of the material.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Saba N, Paridah MT, Jawaid M, Abdan K, Ibrahim NA. Potential utilization of kenaf

biomass in different applications. In Agricultural Biomass Based Potential Materials. Springer, Cham. 2015;1-34.

2. Ing. Eva Akova. Development of natural fibre reinforced polymer composites; 2013.
3. Aimin Liu. Proceedings of the First International Workshop on Pulp and Paper Making from Kenaf" Yuanjiang, China; 1999.
4. Technical Report TR-2101-ENV. Naval Facilities Engineering Service Center. Evaluation of Bio-based industrial products for navy and DOD use – Phase I Kenaf Absorbent; 1997.
5. Technical association of pulp and paper industry (TAPPI). Available:https://www.tappi.org
6. Moubasher MH, Abdel-Hafez SH, Abdel-Fattah HM, Mohanram AM. Direct estimation of cellulose, Hemicellulose and Lignin. J Agri Res. 1982;46.1467-1476.

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