



INFLUENCE OF SURFACE TREATMENT ON THE PHYSICO-MECHANICAL PROPERTIES OF PALMYRA FRUIT FIBER (*Borassus aethiopicum*) REINFORCED EPOXY COMPOSITES

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INTRODUCTION

Composites consists of two or more distinct materials, which have different chemical and physical properties, merged together to give a well define structure. Composites consist of a matrix reinforced with either a particle or fibre. Natural fibres such as sisal, flax and jute possess good reinforcing capability with polymers, they are relatively inexpensive, originate from renewable resources and possess favourable value of specific strength and specific modulus. Fibre reinforced composites earlier use various types of glass, carbon and aluminum oxide and many others like flax, hemp, jute as reinforcement for composites. Properties of the composites are governed by the properties of the fibre, aspect ratio of the fibre, thermal stability of the fibre and fibre-matrix interface. The surface adhesion between the fibre and the polymer plays vital roles in transmitting stress from the matrix to the fibre and thus, contributes towards the performance of the composite both for domestic and industrial purposes. Palmyra is a genus of five species of palms native to tropical regions of Africa, Asia and New Guinea, belongs to the palmae family, most common specie in Africa is *Borassus aethiopicum*. They are tall palms, have long leaves, fan-shaped of 2-3m length, small flowers which bear densely clustered and bear large green roundish fruit. It is a long lived plant which can leave as long as 100years. Has multi-purpose uses, its fibre can be used where much strength is needed and can also be mixed with cotton to produce fabric which has less cost and increased strength. Significant and effective method of formulating biocomposites of desired and highly qualitative properties includes: effective chemical modification of fibre, efficient processing and fabrication techniques, and matrix modification by blending and functionalizing (Salisu *et al.*, 2016).

For years, agricultural waste materials tend to pose problems in the environment, most of which are lignocellulose in nature, these include Palmyra fruit, rice husk, corn stalk among others. Global warming arising from human activities which include burning of materials obtained from fossil fuel has brought about climate change, pollution of the environment and depletion of the ozone layer. The use of conventional materials for human activities is quite expensive, more technical and the materials are non-degradable (Yakasai, 2014). To curb the aforementioned problems, this research intends to use Palmyra fruit fibres to produce cheap and biodegradable composite materials with light weight, better strength, easy production and have less or no effect on the environment. The objectives of this research is to extract Palmyra fruit fibre by enzymatic retting method, convert the fibres into nano-particles and subject portions of the fibres to alkali treatments fabricate palmyra fibre composites using Epoxy resin (LM-556) and Hardener HY-951 by hand lay-up technique using both the treated and untreated fibre, evaluate the physico-mechanical properties through chemical resistance, water absorption, tensile and flexural tests, and characterize the composites using Fourier Transform Infrared Spectrophotometry (FTIR). Based on the results obtained, evaluate the composites for use in furniture, automobile, packaging and construction, among others.

RESEARCH METHODOLOGY

Fibre extraction

Palmyra fruit shell was retted for **some** days to extract the fibre by gently squashing the fruit followed by scraping and carding with soft nylon brush. Clean water was used to wash up the surplus wastes on the fibre. The clean extracted fibre obtained was dried under shade for two days, after which combing was done to give fine Palmyra fruit fibre strands and subsequent conversion to nano-size using ball mill and laboratory sieve was done (Yakasai *et al.*, 2016).



Plate 1: (a) Palmyra fruit

(b) Palmyra fruit Shell.

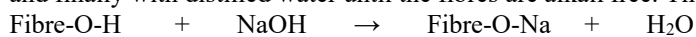
(c) Retting of Palmyra fruit Shell.

Fibre treatment

Portions of the fibre was subjected to chemical modification to investigate the changes and variation in properties of the fibres after the treatment:

Alkali Treatment

The fibre was treated with 5% NaOH solution for 1 hour to activate the OH groups of the fibre, it was then rinsed with distilled water. The fibre was washed with very dilute acid (HCl) to remove any particle of alkali. The fibres was then rinsed with water and finally with distilled water until the fibres are alkali free. The washed fibres were dried under shade



Scheme 1: Reaction between cellulosic Palmyra fibre and alkali (Yakasai *et al.*, 2021).

Matrix formation

Epoxy resin (BADGE) of the grade LM-556 with a density of 1.5 g/cm³ mix with hardener HY-951(TETA) was used as the matrix material, petroleum jelly as a debonding agent. Nanoparticle Palmyra fibre was weighed on an analytical balance to the nearest 0.001 mg and poured into the matrix, mechanically stirred to form a paste.

Composite fabrication

A hand lay-up mold was used, the paste formed was poured into the mold and spread homogeneously and allowed to cure at room temperature before removal of the composite.

Composite Evaluation and Characterization

The fabricated composites was subjected to chemical resistance in accordance with ASTM D-543 -14, multiple specimens of 5 for each sample of cured composites with dimension (56 × 13 × 3) mm were tested using various acids, alkalis and solvents, the samples were weighed before and after immersion in the reagents for 24 hours at room temperature and the mean of the results obtained was evaluated. Water absorption was conducted based on the ASTM D5229 / D5229M – 14 standard. Five specimens for each sample were used. The specimens were then weighed on an analytical balance a Mettler Toledo (Model ES320) with precision was ±0.001 g. The percentage moisture absorption at equilibrium was evaluated. Tensile strength was performed using the dog bone shape specimens of size 150mm×27mm×4mm according to ASTM-D 638-91 using Ultimate testing machine (UTM) Shimadzu (MODEL AG-1), 100 kN capacity load cell was applied and the cross-head speed was 2mm/min. Flexural strength test was conducted using same machine as in tensile strength, according to ASTM-D 790-97A standard. The three-point test method in accordance with the standard procedure was employed at a cross head speed of 2mm/min and a support of 80mm. The horizontal attenuated totally reflectance Fourier transform spectroscopy technique (FTIR-HATR) was employed with a Cary 630 FTIR machine of Agilent Technology.

RESULT AND DISCUSSIONS

3.1 Chemical Resistance of Composites

Table 3.1: Chemical Resistance of Palmyra fruit shell fibre Reinforced Epoxy Composite.

Samples	% Weight gain/loss of Composites					
	10% Hydrochloric acid (HCl)	8% Acetic acid (CH ₃ COOH)	10% Sodium hydroxide(NaOH)	10% Ammonium hydroxide(NH ₄ OH)	Toluene (C ₇ H ₈)	Diethlyether (C ₂ H ₅) ₂ O
A	0.48	0.36	0.42	0.22	-0.04	0.21
B	0.33	0.62	0.61	0.28	-0.01	0.33

A: Untreated Palmyra fruit shell fibre Composite B: Alkali modified Palmyra fruit fibre Composite.

Table 3.2: Physico-mechanical properties of Palmyra fruit shell fibre reinforced epoxy composites

Sample	Water Absorption (%)	Tensile Strength (MPa)	Flexural Strength (MPa)
A	1.67	16.9	68.6
B	0.83	20.6	75.7

Fig. 3.1a: FTIR of Untreated Palmyra fruit shell fibre Composite

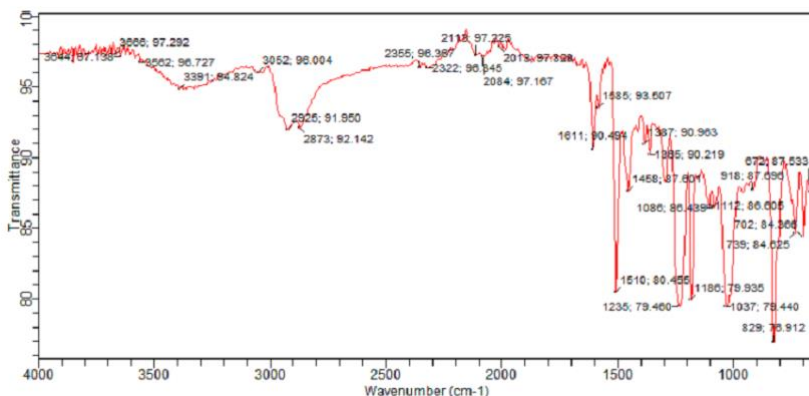


Fig. 3.1b: FTIR of Alkali modified Palmyra fruit shell fibre Composite

Chemical Resistance

Chemical resistance test was conducted to evaluate possible application of the composites in furniture as table tops for home, offices and laboratories, as well as floors, walls and other surfaces subjected to cleaning and disinfecting with various reagents. Table 3.1 show resistance of the composites to commonly used acids, alkalis and solvents. The result indicate that the alkali modified Palmyra fruit shell fibre composites are more resistant to mineral acids compared to the untreated composites, this may be attributed to stronger bond formed between the modified fibre composites compared to unmodified which contain natural components that weakens the fibre-matrix interaction as well as the resistance of the composites to various solvents. In some of the composites, weight gain was observed due to absorption and reaction between the solvent and the composites, leading to plasticization. Weight loss observed in some cases may be due to reaction brought about by dissolution of some portion of the composites. Most of the composites are more resistant to alkalis compared to acids while some nonpolar solvents like toluene dissolves the composites (Jayaseelan *et al.*, 2017; Yakasai *et al.*, 2021).

Water Absorption

The result of water absorption test is shown in Table 3.2, highest value of 1.67% and least value of 0.83% moisture absorption for the unmodified and modified palmyra fruit shell fibre composite respectively. The difference may be due to presence of natural components such as hemi-cellulose and lignin present in the unmodified fibre composite. Partial removal of the

components in the alkali modified fibre composite reduced the moisture absorption. (Mohanta, and Acharya 2016; Adekomaya and Adama, (2018)).

Tensile Strength

The tensile strength of unmodified and modified palmyra fruit shell fibre composite was found to be 16.9MPa and 20.6MPa respectively as shown in Table 3.2 . The resulting value in the unmodified fibre composite may be due to weak compatibility between the fibre and the matrix as a result of the presence of hemicellulose, lignin and pectin. An increase observed in the alkali modified fibre composite may be a result of increased fibre-matrix interaction due to partial removal of natural components in the cellulose fibre, affecting the structure of the fibre filaments which leads to increase in surface area between the fibre and the matrix (Sathish *et al.*, (2017) ; Daramola, *et al.*, (2017) and Yakasai *et al.*, 2021).

Flexural Strength

The result of the flexural strength of the composites as shown in Table 3.2 indicates 68.6MPa and 75.5MPa in the unmodified and modified palmyra fruit shell fibre composites respectively. The increase in the modified fibre composite may be attributed to good fibre-matrix interaction resulting from removal of impurities. All the composites show good flexural strength (Daramola, *et al.*, (2017); and Silva *et al.*, (2018).

Fourier Transform Infrared Spectrophotometry (FTIR)

Fig. 3.1a shows a broad peak at about 3355 cm^{-1} , ascribed to $-\text{OH}$ in lignin, cellulose and hemicellulose, a sharp peak at 2921 cm^{-1} and 2869 cm^{-1} are due to C-H stretching in $-\text{CH}_2$ and $-\text{CH}_3$ respectively, 1607 cm^{-1} is due to C=O of aldehyde in lignin and hemicellulose, 1458 cm^{-1} due to O-CH₃ of lignin, 1235 cm^{-1} due to C-O-C stretching of acetyl groups in lignin and confirmation of ester bond, 1182 cm^{-1} is due to C-O-C in ether present in cellulose, hemicellulose and lignin and due to interaction with the matrix, 1033 cm^{-1} due to C-O stretch in C-OH and C-OOC of lignin and cellulose, 829 cm^{-1} indicates interaction of the fibre with the epoxy matrix, in the untreated palmyra fibre composite. Table 3.1b, alkali modified palmyra fruit shell fibre composite;s spectrum shows a less broad peak at 3350 cm^{-1} for the $-\text{OH}$, this may be due to partial removal of lignin and reduction in the number of OH groups, 2925 cm^{-1} and 2873 cm^{-1} for C-H and 1458 cm^{-1} may be attributed to the CH₂ deformation in cellulose. The difference among the FTIR spectra may be due to surface modification by alkali. The result is consistent with the findings of Birniwa *et al.*, (2021) and Yakasai *et al.*, (2021)

CONCLUSION

The use of Palmyra fruit shell fibre as reinforcement in epoxy- based composite was used to produce biodegradable composites with excellent physical and mechanical properties at a cheaper cost, reduce waste production, environmental pollution and create avenue for skills acquisition and provide wealth creation for the unemployed, thereby promoting economy of the country.

Recommendation

To improve the value and highly evaluate the composite, other analysis such as hardness, impact, density and thickness tests can be conducted in further researches.

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