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Physical and Mechanical Properties of Pressed Palm Oil Fruit Fiber Reinforced Epoxy Composite for Building Partition Panels

I C Ezema Ike-Eze [1*], N C Obiegbusi[2], V S Aigbodion[3], A D Omah[4], S N Ude[5], C A Mgbemene[6]

[1,2,3,4,5,6]Faculity

[1,2,3,4,5]Department of Metallurgical and Materials Engineering, [6]Department of Mechanical Engineering,

[1,2,3,4,5,6]University of Nigeria Nsukka, Nigeria

***Email:** *ikechukwu.ezema@unn.edu.ng*

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Abstract

The density, water absorption, and mechanical properties of the pressed palm oil fruit fiber (PPOFF) epoxy composite were investigated. The fibers were matted randomly and laminated with epoxy resin and hardener using hand-lay-up method. The result of the analysis of the developed composite indicated that mass fraction of the PPOFF used in this study was less than the threshold to effect increase in the tensile properties of the resin. However, the properties increased with increase in the fiber content. Also, the density of the composite decreased while the water absorption increased as the fiber content increases. The XRD result indicated that the fibers has high crystallinity index indicating rich cellulose content but the scanning electron microscope (SEM) micrograph revealed weakly bonded fibers to the matrix due to the poor dispersion and wet-ability between the two phases. The developed composite can be useful in building partition panels.

***Keywords**: Epoxy resin, mechanical properties, natural fiber, palm fruit fiber, XRD*

INTRODUCTION

Composites area unit the surprise material with light-weight; high strength-to-weight magnitude relation and stiffness properties capable of substitution the standard materials like metals, wood, ceramics and plastics [1]. Every composite is unique and can be tailored to a specific engineering requirement by the simple selection of matrix and the reinforcement in varying quantities. Fibers processed from agro-waste materials such as banana, jute, coir etc are currently playing this role of replacing synthetic fibers such as glass and carbon fibers [2−4].

Natural fiber reinforced polymer composites (NFRPCs) have gained a worldwide acceptance as a potential substitute for glass filled composites over past few years especially in the automotive, building, transport and energy sectors. In recent years, many researchers have developed natural fiber reinforced polymer composites using jute, sisal, bamboo, banana for various applications [3]**.** Although the stiffness and strength of natural fibers are less than the synthetics they have the following advantages; low density, availability, high toughness, acceptable specific strength, non-irritating, low cost and biodegradability.

Wan and Rosnah [5] reported that oil palm industries generate at least 30 million tons of lignocellulosic biomass annually in the form of oil palm trunks (OPT), empty fruit bunches (EFB), oil palm fronds (OPF) and palm fruit pressed fibers (PFPF). There are serious and increased efforts by researchers in utilizing these oil palm fibers in reinforcement of polymers [5-8]

for both domestic and industrial applications. Mimi et-al [6] studied the mechanical properties of oil palm fibre reinforced epoxy composite for building short span bridge and discovered that the impact strength, tensile strength and flexural modulus increased at 35% fiber content, while the flexural strength decreased.

Ahmad [7] studied oil palm trunk fiber as a bio-waste resource for concrete reinforcement and reported that the compressive, tensile and flexural strength properties of the concrete improved by the addition of 1% OPTF and the OPTF have acted as crack arrester. Agrawal [8] studied the effective thermal conductivity of oil-palm fiber reinforced binary composites and reported that the effective thermal conductivity (ETC) of the composites was affected by the percentage of fiber present in the composite and surface topology of the fiber and the theoretical thermal conductivity fitted well with the experimental data obtained.

This paper is therefore a part of ongoing research on oil palm fruit fiber utilization aimed at investigating the effect of low mass fraction of the pressed palm oil fruit fibers on the physical, tensile, flexural, impact and morphological characteristics a reinforced epoxy resin composite.

MATERIAL AND METHODS

Materials/Equipment

The palm fruit pressed fibers were sourced from local palm fruit processing farmers. Epoxy resin, its hardener, release agent, fevicol adhesives were used as purchased from vendors. Wooden mould, masking tape, mixing bowel, turning tool, steel rule, and beaker, weighing balance, spring balance, universal testing machine, X-ray diffraction machine and Scanning electron microscope machine were used in this work.

Production of Composite Test Specimen

The fibers (Fig. 1a) were separated into strands and soaked in acetone for 72 hours to remove oil usually associated with it. They were washed thoroughly with detergent and rinsed with clean water to remove any trace of oil and other dirts. The fiber were dried under the sun for several days until traces of moisture were not seen. The fibers were matted in a random mat format. The composite were made by impregnation of the fibers with the epoxy resin and hardener in mix ratio of 3:1. The composites were allowed to cure under room tempertaure and thereafter carefully demolded (Fig. 1b). The same procedure were performed with all the different mass fraction of the matted fibers. The content of the palm fruit fibers were varied 0, 5, 6, 7, and 8 wt%.

(a) (b)

Figure 1: *(a) Press palm oil fruit fibers (b) Pressed palm oil fruit epoxy composites.*

Tensile Strength

Tensile testing was carried out according to the ASTM D3039 standard test method for tensile properties of plastics. Samples were tested using a manual griping universal testing machine model TUE-C100 with serial No 2010132 made by Fine Spavy Associates & Engineers Pvt. Ltd. WIRAJ 416410 India using an approximate cross head speed of 5mm/min.

Flexural Strength

The flexural strength testing was carried out according to the ASTM D-790 standard test methods for flexural properties of plastics. Samples were tested using a manual griping universal testing machine model TUE-C100 with serial No 2010132 made by Fine Spavy Associates & Engineers Pvt. Ltd. WIRAJ 416410 India using an approximate cross head speed of 5mm/min. The flexural strength (F_S) was calculated using equation:

$$Fs = \frac{3PL}{2bh^2} \quad (1)$$

Impact Strength

The impact test was conducted to measure the toughness of materials using Samuel Demson Ltd Leeds LS102DE England SN-EXT94064/6705CE with an impact velocity of 5.24m/s. The test was carried out using a universal impact-testing machine based on Charpy test method in which a hammer like weight strikes a specimen and the energy-to-break it determined from the loss in the kinetic energy of the hammer. In Charpy test, the specimens measuring 10mm x 55mm x 4mm were given a 2mm notch of the ball and the impact strength was calculated from the relation of equation (2) in line with the work of Abbas [9]

$G_c = U/A\ (J/m^2)$ (2)

Where, G_c = Impact strength, U= Energy of fracture in (Joule), A=cross section area in (m^2).

Fiber and Composite Densities

The experimental density of the composite was obtained by measuring the mass and the volume of the composite and calculated using equation 3.

$$\rho_C = \frac{Mass}{Volume}. \quad (3)$$

While the theoretical density of the composite was obtained using the following relations.

$$\rho_c = \rho_f V_f + \rho_m V_m \quad (4)$$

Where, V_f = volume fraction of the fiber, V_m = volume fraction of the fiber

ρ_f = density of the fiber, ρ_m = density of the matrix

Water Absorption

In this test, the composites were cut to dimensions. Specimens were dried in an oven at 24°C and weighed (W_O). They were immersed in water for 24 hours and at the end of the immersion periods, the specimens were removed from the distilled water. The surface water was wiped off using dry cloth and the wet weight (W_t) recorded. The percentage of water absorption (M_w) was calculated according ASTM D570 as follows.

$$W_w = \frac{W_t - W_O}{W_O} x100 \quad (5)$$

Where, W_t is the wet weight and W_o is the dry weight of the samples

X-Ray Diffraction

Sisal fibers were cut to small pieces and ground into powder of about 600µm. The diffraction intensity was in the range 0 to 100^o of 2θ (Bragg angle) and the scanning speed was 0.02^o/sec.

Scanning Electron Microscope

The morphological behavior of the specimens was observed using scanning electron microscope (SEM) equipment model-JOEL-JSM-6100 after sputter coating the samples with gold for 45 seconds in a JOELJFC-1200 fine coater at

a voltage of 12 kV. Micrographs were taken at various magnifications in order to know the surface characteristics of specimens.

RESULTS AND DISCUSSIONS

Table 1: *Description of matrix and reinforcement proportion.*

Code	Wt % of Fiber (g)	Wt % of epoxy resin (g)	Mass of Fiber (g)	Mass of epoxy resin (g)
A	0	100	o	331
B	5	95	16.44	317.85
C	6	94	19.73	311.27
D	7	93	23.02	307.98
E	8	92	26.30	304,70

Tensile Properties

Fig. 2 presents the tensile strength and the Young's modulus against the variation of the weight percentages of pressed palm oil fruit fiber (PPOFF) epoxy composite.

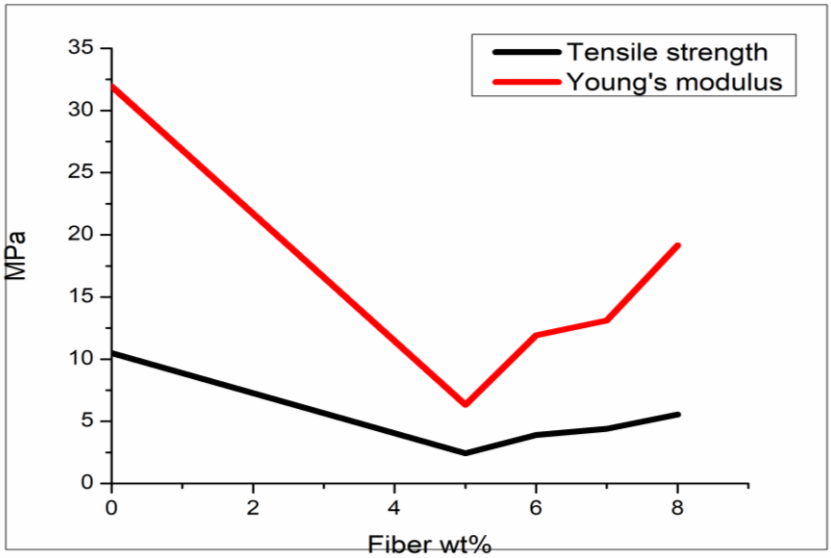


Figure 2: *Variation of palm fruit fiber mass fraction on the tensile strength and modulus of the composite.*

From Fig. 2, it was observed that the elastic strength and elastic modulus of unreinforced epoxy is much higher than that of reinforced epoxy composites. However, after the initial drop the strength and the modulus continued to increase as the fiber content increases such that the tensile properties for 8 wt% is higher than 7wt% and much higher than 6wt% and 5wt%. The overall implication is that the reinforcement is not enough to cause improvement in these properties over that of the unreinforced. Consequently, it is possible that a higher value of fibers loading, the strength of the reinforced composite will be much higher than the unreinforced epoxy resin. Again, the fibers could not carry and transfer the applied load reasonably not only because of the quantity but also because their length is small (chopped mat strands). In effect the fiber length plays an important role in the mechanical performance of fiber reinforced composites [14].

Flexural Test

The result of the flexural test of the PPOFF reinforced epoxy composite is as

presented in Fig. 3. From the Fig. 3, it can be seen that the flexural strength of all the reinforced composites are very much lower than that of unreinforced epoxy similar to the tensile result of the composite, however as the flexural strength of the reinforced composites increased with increase in the fiber loading.

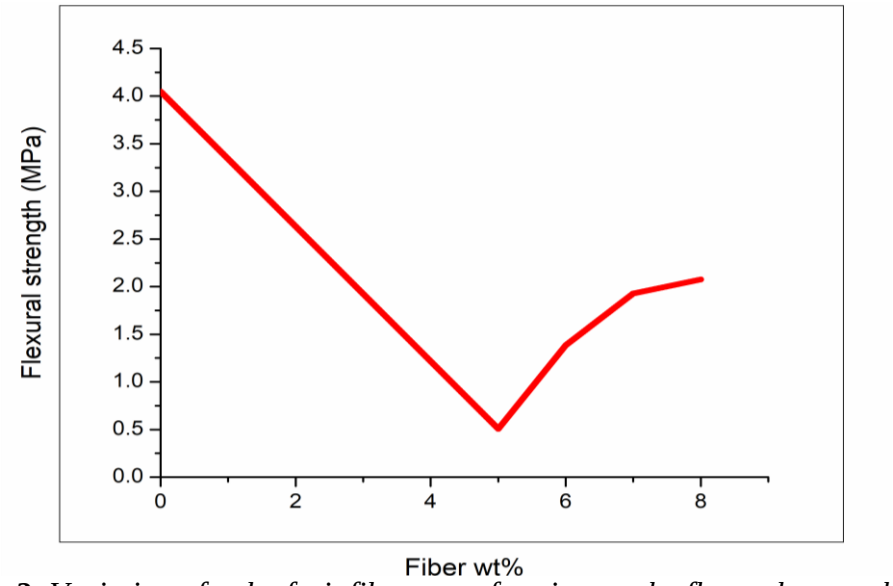


Figure 3: *Variation of palm fruit fiber mass fraction on the flexural strength of the composite.*

Again, the overall implication is that the reinforcement is not enough to cause improvement in the flexural property. Consequently, it is possible that in a higher value of fibers loading, the flexural strength of the reinforced composite will be much higher than the unreinforced epoxy resin.

Impact Strength

The result of the impact of the developed PPOFF/epoxy composite is as presented in Fig. 4. From the Fig. 4, it can be seen that the impact strength of all the reinforced composites are much higher than that of unreinforced epoxy and that the impact strength increased with increase in the fiber loading.

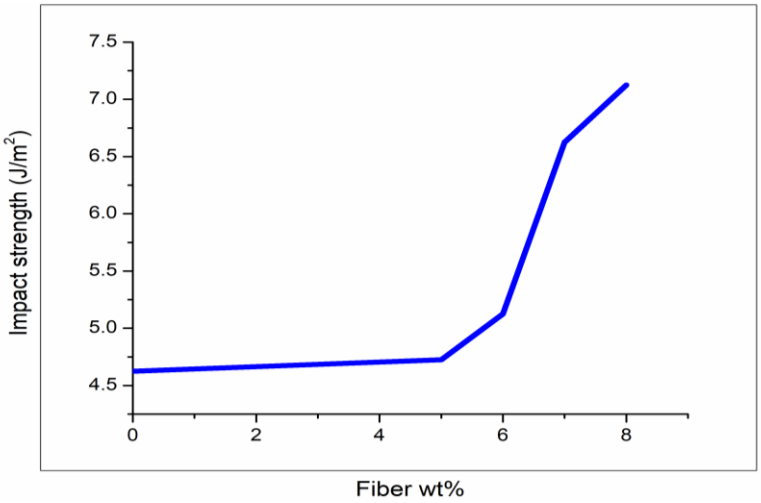


Figure 4: *Variation of palm fruit fiber mass fraction on the impact strength of the composite.*

Density of the Composite

From Fig. 5, it was observed that the theorical density is higher in value than the experimental density. Again, it was observed that the experimental density of the composite decreased as the fiber mass fraction increases. This is a positive indication that the palm oil fruit fiber is a good reinforcement in achieving light weight in polymer matrices.

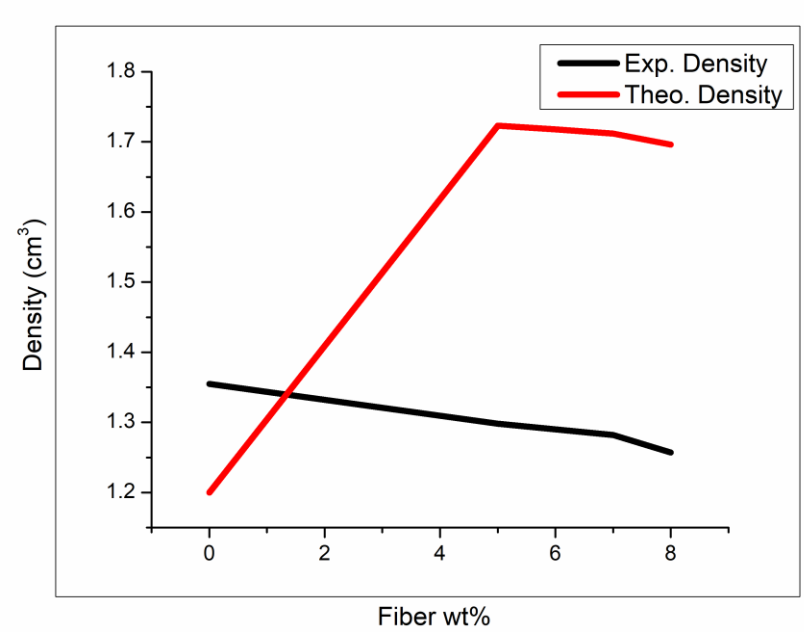


Figure 5: *Variation of palm fruit fiber mass fraction on the density of the composite.*

Water Absorption

From Fig. 6, it can be deduced that increase in fiber content caused an increase in the water absorption of the composite. This is because natural fibers are believed to be hydrophilic meaning high affinity for water/moisture, while the polymer matrix is hydrophobic. Therefore, increase in water absorption due to increase in fiber content has just followed the normal trend mainly because pores were created, again because the fibers were not surface treated to reject water intake.

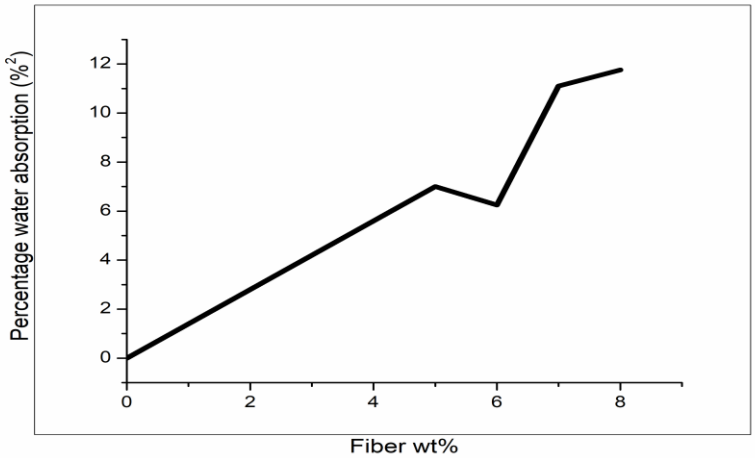


Figure 6: *Variation of palm fruit fiber mass fraction on the water absorption of the composite.*

X-Ray Diffraction

The XRD graph for the untreated PPOF fiber was presented in Fig. 7 which measures the percentage of crystalline fibers against the amorphous. The counter reading at peak intensity at 22° is said to represent the crystalline material and peak intensity at 18° correspond to the amorphous material in the cellulose, [11, 12]. The crystalline peak data is indicating 80% crystallinity, which is an indication of good cellulose content of the fibers while the remaining 20% indicates the semi-cellulose and/or the amorphous content of the fiber. It is only the cellulose content that contributes to the load bearing capacity of the fiber.

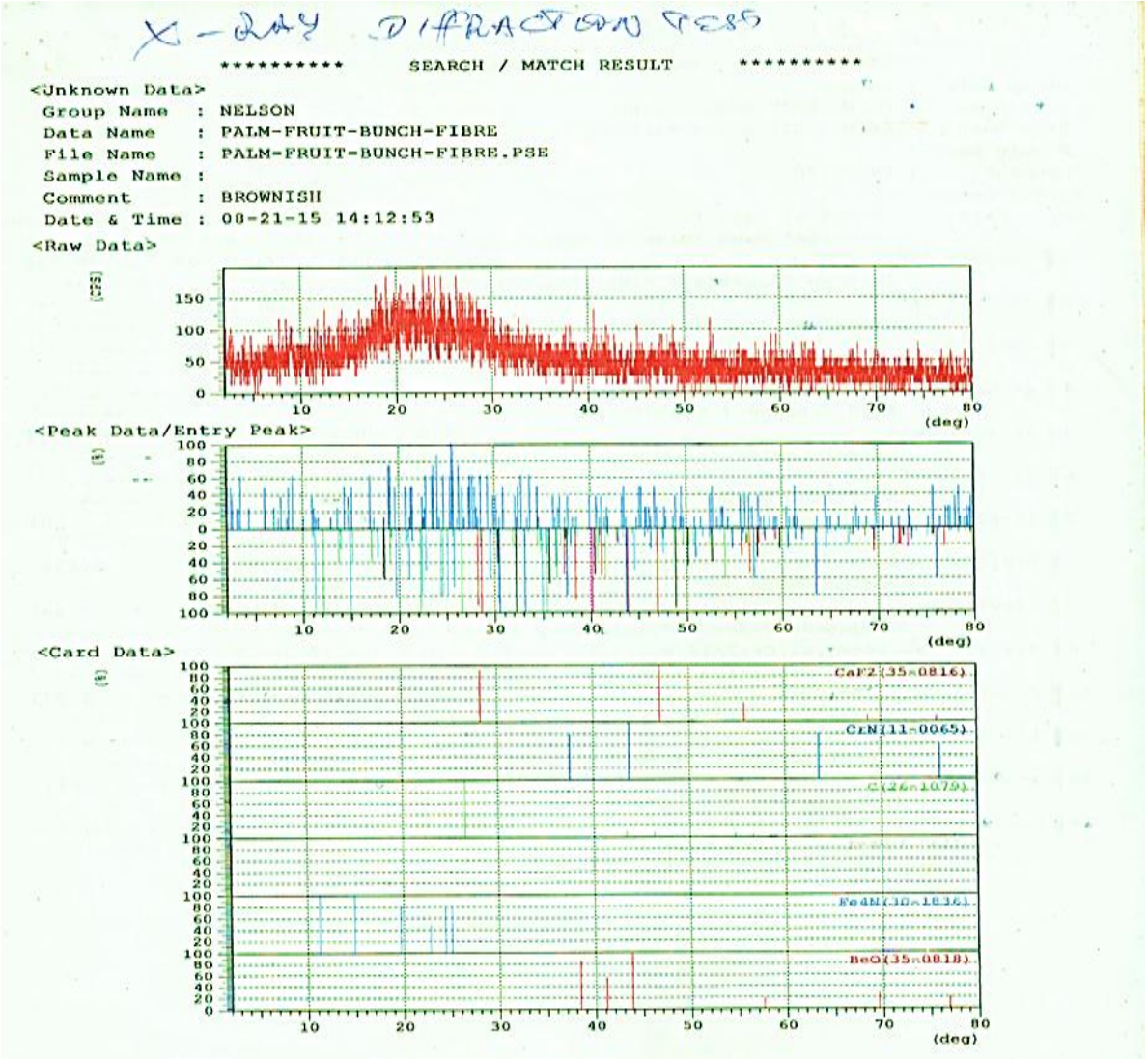
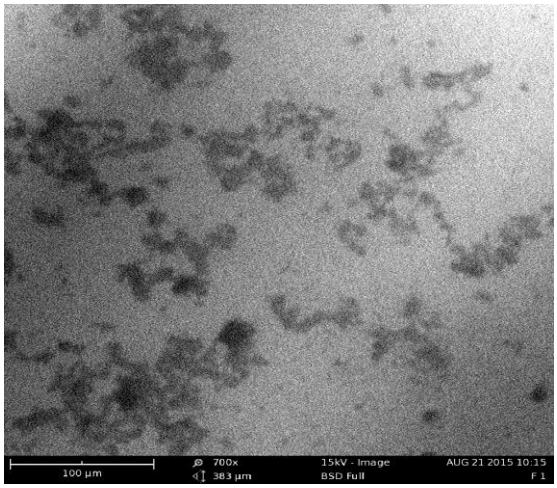


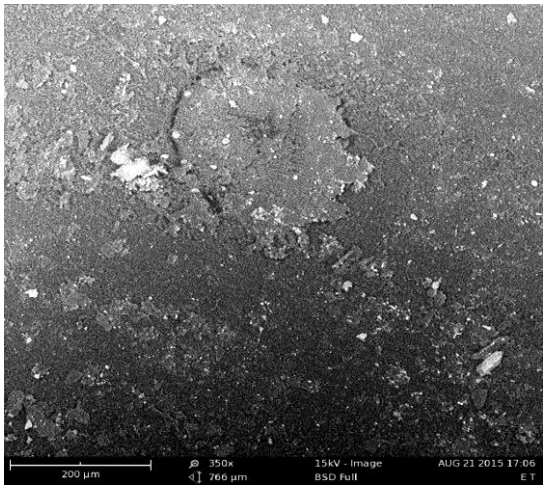
Figure 7: *X-ray Diffraction of the palm fruit fiber.*

Micrograph of the Composites

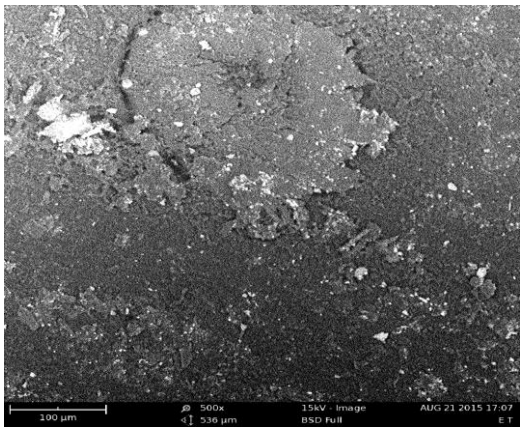
The micrograph of the developed composite were presented in Fig. 8 (a, b, c, d, e) for the unreinforced epoxy and each incremental PPOFF additions respectively. From the images in Fig. 8b, it was observed that there were distinct cluster of fibers and gaps between epoxy matrix and the fibers while Fig. 8b clearly shows no presence of any reinforcement. This is an indication of weakly bonded fibers to the matrix. This suggests that the interface between the fibers and the epoxy matrix was weak due to the poor dispersion and wet-ability between the two phases.



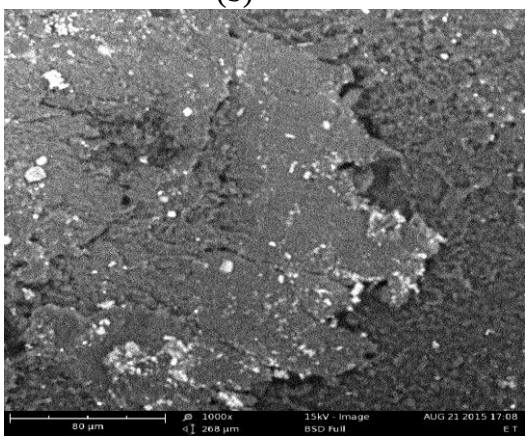
(a)



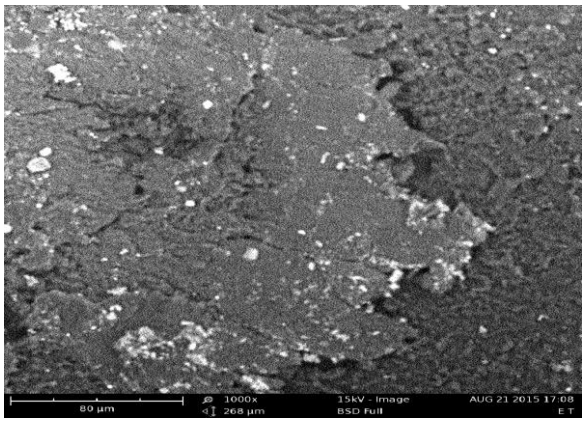
(b)



(c)



(d)



(e)

Figure 8: *SEM images of (a) unreinforced epoxy matrix (b) 8g wt% palm oil fruit–epoxy composite.(C) 6g wt% palm oil fruit–epoxy (d) 7g wt% palm oil fruit–epoxy (e) 5g wt% palm oil fruit–epoxy*

The gap and cluster increased with fiber loading as can be seen in Fig. 8, c, d and 8e, resulting in the segregation and clear weak interfacial bond connection between the epoxy resin and the PPOFF bond. This may have resulted in the lower tensile and flexural property values obtained. In this scenario the reinforcements may have

acted as defects that initiate failure instead of acting as reinforcement that resist failure and failure propagation. Again because of the segregation, the epoxy resin may be incapable of transferring loads from one fiber to the other, thereby contributing to lower tensile strength and flexural strength values. This problem may be due to the hand lay-up method against compression moulding that could have exerted a uniform and compact pressure on the composites.

CONCLUSIONS

An investigation into the physical, mechanical and morphological properties of pressed palm oil fruit fiber reinforced epoxy composite was carried and the following conclusions drawn:

- The tensile strength and elastic modulus of unreinforced epoxy is much higher than that of reinforced composites; however, these properties increased as the fiber content increases.
- The experimental density of the composite decreased as the fiber weight fraction increases, which indicates that the palm oil fruit fiber is a good reinforcement in achieving light-weight in polymer matrices.
- The water absorption of the composite increased with increase in the fiber content.
- The pressed oil palm fruit fibers used were rich in cellulose content with 80% crystallinity.
- The SEM result revealed of weakly bonded fibers to the matrix, which suggests that the interface between the fibers and the epoxy matrix was weak due to the poor dispersion and wet-ability between the two phases.
- The developed composite may be usefully applied as building partitions panels in buildings.

REFERENCES

1. Md. Mahfujul Islam, Humayun Kabir, Md. Abdul Gafur, Md. Mahbubur Rahman Bhuiyan, Md. Alamgir Kabir, Md. Rakibul Qadir, Farid Ahmed (2015), "Study on Physio-Mechanical Properties of Rice Husk Ash Polyester Resin Composite", *International Letters of Chemistry, Physics and Astronomy*, Volume 53, pp. 95−110. doi:10.18052/www.scipress.com/ILCPA.53.95.
2. Harish S, Michael DP, Bansely A, Mohan Lal D, Rajadurai A (2009), "Mechanical property evaluation of natural fiber coir composite", *Materials characterization*, Volume 60, pp. 44−49.
3. Khalid AA, Sahari B, Khalid YA (1998), "Environmental Effects on the Progressive Crushing of Cotton and Glass Fibre/Epoxy Composite Cones", *In: Proceedings of the Fourth International Conference on Advances in Materials and Processing Technologies*, Volume 98, pp. 680–689. Kuala Lumpur.
4. Avinash R Pai, Ramanand N Jagtap. (2015), "Surface Morphology & Mechanical properties of some unique Natural Fiber Reinforced Polymer Composites- A Review.", *J. Mater. Environ. Sci.*, Volume 6, Issue 4, pp. 902−917.
5. Wan Hasamudin, Rosnah Mat Soom (2002), "Road Making Using Oil Palm Fiber", *MPOB Information Series*, ISSN 1511-7871.
6. Mimi Azlina Abu Bakar, Valliyappan D. Natarajan, Anizah Kalam, Nor Hayati Kudiran (1–6 July 2007), "Mechanical Properties of Oil Palm Fibre Reinforced Epoxy for Building Short Span Bridge, Experimental Analysis of Nano and Engineering

Materials and Structures", *Proceedings of the 13th International Conference on Experimental Mechanics*, Alexandroupolis, Greece. Available at: http://link.springer.com/book/10.1007/978-1-4020-6239-1

7. Ahmad Z, Saman H.M.and P.M. Tahir P.M. (2010), "Oil Palm Trunk Fiber as a Bio-Waste Resource for Concrete Reinforcement", *International Journal of Mechanical and Materials Engineering (IJMME)*, Volume 5, Issue 2, pp. 199−207.
8. Agrawal Richa (2014), "Oil-Palm Fiber Reinforced Binary Composites: Evaluation of Effective Thermal Conductivity", *International Journal of Chemical and Physical Sciences*, Volume 3, Issue–NCRTSM, pp. 21−26. ISSN: 2319-6602.
9. 9 Abbas Qayes Abdullah (2011), "Effect of water absorption on impact strength for epoxy-glass fibers composite", *J. of University of Anbar for Pure Science*, Volume 5, Issue 2, ISSN: 1991-8941. pp. 1−7.
10. Sreekala MS, MG Kumaran, S Joseph, M Jacob, S Thomas (2000), "Oil palm fiber reinforced phenol formaldehyde composites: influence of fiber surface modifications on the mechanical performance", *Applied Composite Materials*, Volume 7, pp. 295−329.
11. Melidi Jonobi, Jalaludin Harun, Alireza Shakeri Manjusri Misra, Kristina Oksman (2009), "Chemical Composition, Crystallinity and thermal degradation of bleached and unbleached kenaf Bast (Hibiscus Cannabin as) Pulp and Nano fibers", *Broresources*, Volume 4, Issue 2, pp. 626−639.
12. Mileana AE, Antonio CH, B Jose EBF, Pierre BA, F Antonio SBS, Elisangela CG, M Alfonso M, Selma EM (2010), "Dwarf Green coconut fibers: A versatile Natural Renewable Raw Bioresources. Treatment, Morphology and Physiochemical Properties", *Bioresources*, Volume 5, Issue 4, pp. 2478−2501.
13. Palla Hari Sankar, YV Mohana Reddy, K Hemachandra Reddy, M Ashok Kumar, A Ramesh (2014), "The Effect of Fiber Length on Tensile Properties of Polyester Resin Composites Reinforced by the Fibers of Sansevieria trifasciata", *International Letters of Natural Sciences*, Volume 8, pp. 7−13. doi:10.18052/www.scipress.com/ILNS.8.7 2014: 7-13.
14. Farshid Basiji, Vahidreza Safdari, Amir Nourbakhsh, Srikanth Pilla (2010), "The effects of fiber length and fiber loading on the mechanical properties of wood-plastic (polypropylene) composites", *Turk J Agric For*, Volume 34, pp. 191−196.

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