Natural fibers are abundantly available and potentially valuable biomass that is under-exploited. Regardless of many advantages, one shortcoming of use of natural fiber is the deformation after being formed into composite structure, which is caused essentially by poor adhesion at the interface with the polymer matrix. In this study, the effect of silane treatment on the impact strength properties of oil palm empty fruit bunch fiber-reinforced polyester composites was evaluated. The oil palm empty fruit bunch EFB fibers were used in two distinct tangled masses: as natural (i.e., untreated) form and as treated form. Composites of EFB fiber wastes up to 70% by weight in polyester matrix were fabricated by hand lay-up technique and analyzed. As expected, the results show that the composites of oil palm EFB fiber treated with phenylsilane exhibited improved impact strength properties from 10% fiber content to 60% fiber content after which problems of poor wetting set-in. The result permitted the comparison of the impact strength performance of the ‘as natural’ and surface-treated oil palm EFB fiber composites, for which an indication is made that oil palm EFB fiber represent a promising alternative to wood fillers and glass fiber in the production of composites for medium impact strength application in engineering.

**Keywords:** Oil palm, polyester matrix, silane, fracture, composite, empty fruit bunch

**INTRODUCTION**

Several researches have shown that natural plant fiber can be modified for improved properties. Unsurprisingly, these attempts have not achieved the necessary standardization for engineering application. Thus, development of these alternative composite production materials will provide the necessary varied options in engineering design and application in areas of medium-to-low structural needs.

Particularly attractive are the new materials in which a good part is based on natural renewable resources like the oil palm (Elaeis guineensis) EFB fiber. Oil palm empty fruit bunch fiber and oil palm mesocarp (pressed-fruit) fiber are two important types of fibrous materials left in the palm oil mill after oil extraction. These ‘often regarded’ wastes may offer good potentials for exploitation especially the empty fruit bunch... The oil palm empty fruit bunch fiber is mostly generated than...
other fibers, although highly lignified with moderate cellulose content, they may be fully utilized into economic values in addition to solving some serious environmental problem associated with plant fiber disposal [1]. It is generally noted that oil palm EFB, like other plant fiber systems has the drawback of high moisture absorption which result in swelling and other concerns of dimensional stability of natural plant fiber composites. These affect their use as reinforcements in polymer matrix, i.e. oil palm exhibits a moisture uptake of (12.5%) at 65% relative humidity and 20%, by dry fiber and 14.6% by wet fiber [2]. Findings show that good fiber-matrix bonding decrease the rate and amount of water absorbed by the composite, including the reduction in feathering chiefly achieved by effective surface treatment of natural plant fibers [3]. It is noted that during composite production, the metallic surfaces of the handling chambers often experience wear with time showing that fiber surfaces is responsible. It thus infers that appreciable damage is done to the fiber during the processing, and to withstand destruction, the fibers must be capable of absorbing energy imparted to it during stress application, and releasing this energy upon removal of the stress, without occurrence of failure. Therefore, the oil palm EFB fiber proposed for use as alternative reinforcing material in polyester matrix, should be processed to be tough to absorb great amount of energy to resist early fracture as needed in most engineering application [3].

MATERIALS AND METHODS
Materials and Equipment
Empty fruit bunch EFB fibers were obtained from fruited oil palm plants, the were felled and used within two weeks. The EFB extracts were processed at the Pulp and Paper section of Federal Institute for Industrial Research, (FIIRO) Oshodi, Lagos, Nigeria. The Polymer used was Siropol 7440 unsaturated polyester resin purchased from Dickson Chemicals Ltd, Lagos, Nigeria with specific gravity of 1.04, viscosity of 0.24 Pa.s at 25°C. Other chemicals used were the cobalt in styrene, diglycidylethers and phenylsilane procured from Zayo – Sigma Chemicals Limited, Jos, Nigeria. A two-part mould facility (mild steel flat 4mm thick sheet) - of dimensions of 150mm x 150mm with active surfaces ground, pre-designed cavity of 5mm depth, with clamping bolts in place fabricated at the Dantata & Sawoe Mechanical Workshop, Abuja, Nigeria as shown in Figures 1 & 2, was adopted in the production of test specimen plates.

Other equipment used include:
(i) Impact Testing Machine: Amsler - Nominal energy 450J, Maximum Impact velocity - 5.23m/s, continuous adjustable pendulum.
(ii) Compact Scale/Balance : Model – FEJ, Capacity – 1500g, 1500A.

Methods
Oil Palm EFB Fiber Extraction
The collected oil palm plant EFB were extracted by chemico-mechanical process. The process involved the
impregnation of sample with White Liquor and conversion of the softened sample into fiber by mechanical action, followed by thorough washing, screening and drying. The extracted fibers were separated, re-washed and dried in the forced-air circulation type oven. The fibers were subsequently weighed and percentage yield determined. The fiber systems were fluffed and separated into two tangle-mass bulks, one for surface-treated fiber composite while the other for the ‘as natural’ fiber composite production.

Surface Treatment of the Extracted Oil Palm EFB Fibers

Known Weights of extracted EFB fiber systems were soaked in prepared known volume of 0.5 mol/litre of NaOH in a plastic container. The products are removed after 3 hours and air-dried. Subsequent processes included soaking the treated EFB fiber systems in 2% phenylsilane solution for 30 minutes. These were air-dried for 2 hours, and weighed again and stored in specimen bag ready for use.

Production of Test Specimen

The test specimen panels of 10-70% fiber content were produced by hand lay-up process. Curing was assisted by placing the composite in an oven operated at 110 °C. The mouldings were removed from the oven after 30 minutes and conditioned following the BS ISO 1268-3:2000 instructions and guidelines because of the anticipated changes in humidity level in the laboratory. 5 test samples each were cut from 7 stocks (10-70%) of the surface-treated fiber composite and ‘as natural’ fiber composites to dimensions of 200 mm x 200 mm x 5 mm.

Composite Characterization

The Izod Impact test was conducted according to BS2782-3: Method 352F:1996. During the test, the notched specimens cut into dimensions of 200mm x 200mm x 5mm were mounted in-between machine supports and the pendulum was allowed to strike the specimen after swinging from a fixed height. The support displacement of machine was 240mm. Since the machine scale is graduated on 0 to 10 (kg-m), the first hammer was lifted and locked at the top and then gauge adjusted on 10 (kg-m), then the number on the scaled part was then read as presenting the impact strength of the specimens after dropping hammer. This test was repeated 5 times. The results obtained are presented in Tables 1.

The Scanning Electron Microscopy of fractured Surfaces

The impact fractured surfaces of both surface-treated fiber composite and ‘as natural’ fiber composites with fiber content of 40% were quantitatively analyzed using EVO/MA 10 Scanning Electron Microscope as shown in figures 4 and 5.

RESULTS

The results of effect of oil palm EFB fiber content and silane treatment on the impact strength properties of the composite panels is presented in Table 1 and Figure 3. From the results in figure 3, it is shown that the impact strength properties of oil palm EFB fiber reinforced polyester composite decreased with increasing fiber content. The surface treated EFB fiber composites exhibited an outstanding impact strength property value of 426.97J/m at 10% fiber content in composite, an increase of 221% value of the ‘as natural’ untreated EFB fiber composites. This improvement was consistent till at about 50% fiber content when the effect of silane treatment started to drop to a difference of 2.3 % at 70% fiber content. At higher fiber content, when wetting effects set-in, the energy absorbed by the fibers started to drop leading to very significant drop in impact strength of the oil palm EFB fiber reinforced composites.

<table>
<thead>
<tr>
<th>% Fiber (by wt)</th>
<th>Izod Impact Strength (J/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>20</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>30</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>40</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>50</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>60</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
<tr>
<td>70</td>
<td>Untreated</td>
</tr>
<tr>
<td></td>
<td>Treated</td>
</tr>
</tbody>
</table>

Correlation Coefficient 0.990105

Table 1: This table shows the effect of Percentage Fiber on the Impact Strength Properties and Correlation of the Untreated and Treated Oil Palm EFB Fiber – Reinforced Polyester Composites.
**DISCUSSION**

This behavior is consistent with literature for the use of natural and synthetic fibers as reinforcement [5, 6]. It suggests that the impact strength of various EFB reinforced polymer composites showed a decreasing trend as the filler loading increased. Similarly, it is found that similar EFB-HDPE showed significant impact strength, which is attributed to the ability of HDPE matrix undergoing plastic deformation in the form of crazing and shear yielding during the crack propagation. The high impact strength property of the short oil palm empty fruit fiber reinforced polyester matrix shows that they can be applied as an alternative fiber to glass fiber in most medium-to-low impact strength application, and most importantly, can be used in areas of similar application with natural coconut palm EFB fibers that are resilient with highly durable behavior such as in automobile application [7].

The correlation coefficient of 0.990105 of impact strength properties of the natural (untreated) and treated oil palm EFB fiber reinforced polyester composites suggests that some form of surface treatment may be necessary in areas of impact strength applications needing oil palm EFB fiber.

**Figure 3:** This figure shows the comparison of the effect of percentage fiber on the Izod impact strength of untreated and treated oil palm EFB fiber-reinforced polyester composite.

**Figure 4:** This figure shows the impact fractured surface of an untreated oil palm EFB fiber composite showing both fiber pull-out and peeling in large resin area.
This is necessary as it will be desirable to use the treatment in removing the problem of formation of effective bond at the interface of polar hydroxyl group of natural oil palm EFB and the non-polar matrix which is worsened by the presence of ester compounds in oil, which often affect the efficiency of silane treatment [6].

Generally, the toughness property of fibers improve with surface treatment especially with the notched samples necessitating that the fibers bridged the cracks while increasing the resistance of the propagation of the crack and further limiting fiber pull-out. The significant effect of fiber surface treatment on the impact strength properties of the oil palm EFB reinforced polyester composite is consistent with the literature [8, 9].

Findings show that fracture in polymer-matrix composites usually begins with cracking of the fiber component of the composite. The manner in which this initial fracture progresses determines the toughness of the composite. When a fracture occurs in an isolated fiber at any point along its length, the stresses carried by the fiber in the vicinity of the crack must be transferred to the surrounding matrix and other fibers. Thus if the surrounding matrix and fibers are able to withstand the stresses, the fracture will stabilize at that location, but will begin at other locations if the deformation is continued. This process will continue until the damage is so widely spread that the stress originally carried by the fractured fibers can no longer be carried by the un-cracked matrix, at which point, ultimate fracture of the composite occurs [10].

From the scanned electron microscopy (SEM) observation, it is evident that the short fiber surfaces of oil palm EFB were covered with protrusions and small voids in both sets of reinforced composites. There is a general observation of fiber pulling-out of matrix with both sets of composites which suggests poor fiber-resin bonding. Under loading, the resin at point of load application absorbed the load which, when transferred to the embedded short discontinuous fibers started peeling, causing the resin to go through early failure.

Although, the SEM microscopy showed a less fiber pull-out with gradual fiber damage in the surface-treated oil palm EFB fiber reinforced polyester composites. This is an indication that transfer of load from the matrix to the reinforcing fibers was gradual till the interface failed before the fiber failure, thus achieving the importance of natural fiber surface treatment necessary to block the hydroxyl groups to make them more hydrophobic.
CONCLUSION

From the results, it is shown that the values of impact strength properties of oil palm EFB composites are outstanding which could be improved with suitable fiber surface treatment. The exhibition of dimensional stability is evidence of effect of surface treatment, for which the relatively high dispersion and variance with changing fiber content may be taken is a consequence of the intrinsic variability found on natural plant fibers that ranges from their non-uniform cross-section that often preclude property prediction in application.

In terms of practical interest, the oil palm EFB fiber composites may be regarded as valid alternative to replace some conventional fiber systems as reinforcement in polyester matrix especially in areas of medium-to-low impact strength property requirement. Due to their higher impact strength properties, these composite materials may be suitably applied in areas where gypsum board and wooden panels and ceilings are in present use. The fact that these oil palm EFB fiber composites are impervious to moisture and still support deformation, represent advantages in comparison with the relatively brittle gypsum board, which deteriorates in contact with water.

RECOMMENDATION

Further research is suggested in the area study of molecular interacts between oil palm EFB fibers and polymer matrix. This will aid in predicting the behavior of products of oil palm EFB polymer reinforced composites.

REFERENCES


ACKNOWLEDGEMENT / SOURCE OF SUPPORT

The following organizations are acknowledged for their very useful assistance in many different ways in this work; Pulp & Paper Division, Federal Institute of Industrial Research, Oshodi, Lagos; Shetsco Science and Technology Complex, Gwagwalada, Abuja; National Institute for Pharmaceutical Research and Development, Idu, Abuja; Federal University of Technology, Minna, Nigeria

CONFLICT OF INTEREST

No conflict of interest was declared by authors.

How to Submit Manuscripts

Since we use very fast review system, and since we are dedicated to publishing submitted articles with few weeks of submission, then the easiest and most reliable way of submitting a manuscript for publication in any of the journals from the publisher Research, Reviews and Publications (also known as Research | Reviews | Publications) is by sending an electronic copy of the well formatted manuscript as an email attachment to rrpjournals@gmail.com or upload it at http://rrpjournals.com/blog/SUBMIT-MANUSCRIPT.php . Submissions are often acknowledged within 6 to 24 hours of submission and the review process normally starts within few hours later, except in the rare cases where we are unable to find the appropriate reviewer on time.