IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 09, Issue 1 (January. 2019), ||V (III) || PP 77-85

Effect of Chemical Treatment on the Mechanical Properties of Luffa Fibre

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Abstract: This paper presents, the effect of chemical treatment on the mechanical properties of luffa fibre reinforced polyester composites. The luffa fibre was extracted from luffa plant by manual stripping into strands. Treatment was carried out on the fibre at room temperature for 30 minutes with 10 molar solution of NaOH and then sun drying for 72hours. The treated fibre was used to develop the luffa fibre reinforced polyester composites using hand lay-up method in predetermined proportions of 3, 5, 6 and 9% after which it was tested for mechanical properties. Polyester-resin was used as binder. From the results, it was observed that, the tensile strength varied from 7.9 -11.9MPa. The optimum tensile strength of 11.9MPa was obtained at 6% of fibre volume fraction of treated luffa fibre composites. NaOH treatment was observed to enhance the tensile properties of the luffa fibre reinforced polyester composites. Also the results of SEM revealed that chemical treatment had improved the adhesion property between the fibre and matrix thereby resulting into enhanced mechanical properties. The properties showed that treated luffa fibre composite can be used in synergy as raw material for composites manufacture. As the properties evaluated were in agreement with standard composites used as interior design for cars.

Keywords: Chemical treatment, Mechanical properties, Luffa fibre, Polyester, Composite, Scanning electron microscopy(SEM).

Date of Submission: 12-01-2019 Date of acceptance: 29-01-2018

I. INTRODUCTION

Nowadays, the use of composite materials in engineering field is on the increase day by day. They are being used in various engineering applications to increase the strength and to optimize the weight. Various natural fibres such as banana, sisal, jute, bargasse, coir and luffa are used as reinforcement materials.The application of natural cellulose fibres as reinforcements in composite materials have found increased use over the last few years (Azeez, M.A. et al., 2013). The attractive features of natural fibres have been their low cost, light weight, high specific modulus and health hazards. These advantages place the natural fibre composites among the high performance composites having economic and environmental advantages. In the past, studies were carried out to improve the mechanical properties through the application of various treatment chemicals which also in effect enhanced the interphase performance between the fibres and matrix (Ahmad, et al., 2015).

Luffa fibre is a light-weight material with highspecific energy absorption capacity. Hitherto, onlysmall fraction of research have been conducted on the luffafibre as a source of bio-fibres and bio-composites due tothe lack of information on the mechanical properties Dilara (2008) and Boynard, et al. (2003).The polyester resins used in moulding applications are viscous liquid which require the addition of catalysts and accelerators to complete the curing process. Polyester resins are viscous, pale coloured liquids consisting of mixture of ethylene glycol and maleic anhydride. Hardener is a substance of mixture added to a plastic composition to take part in and promote or control the curing action, also a substance added to control the degree of hardness of the cured film. The resin was cured using 1% of methyl ethyl ketone peroxide catalyst and 0.5% of cobalt–naphthanate accelerator. Generally less temperature and pressure are required for the preparation of composite compared to thermoplastic polymers. Also curing time is less for polyester matrix when compared to epoxy matrix.

The chemical treatment, namely, alkali treatment, followed by bleaching and acid hydrolysis is attempted in order toimprove hydrophobic nature of Luffa fibre. When Luffa fibres are subjected to chemical treatment, wax, fatty acids, hemicellulose, and lignin are removed. Removal of these substances results in a rough surface with pits and that may lead to an increase in mechanical interlocking between treated Luffa fibre and matrix. The treatment probably exposes higher amount of cellulose on the fibre surface. Higher amount of

cellulose reveals more reaction sites which again led to better adhesion between treated Luffa fibre and matrix. With the decrease in fibre diameter, surface area increases which leads to more wet ability of fibres within the matrix. The high interfacial area is the most favorable aspect of composites with treated fibres Kocak (2008).

Lassaad et al. (2011) found that the luffa fibre weight fraction influenced the flexural properties of polyester based composites. The maximum values of strength and strain were reported at 10% weight fraction of fibre. Boyand et al. (2003) studied an effect of alkali treatment of sponge gourd (luffa cylindrical) fibres on the flexural properties of polyester matrix composites. Experimental results showed an increase of flexural strength by 14%. It was discovered that, luffa fibres consist predominantly of holocellulose (82%), lignin (1.6-11.2%), extractives (3.2%) and ashes (0.4-0.9%) Kocak (2008). Boynard et al. (2003) used the sponge gourd (luffa cylindrical) as reinforcements in resin matrix composite materials and investigated the morphology of the fibrous vascular system of luffa fibre and mechanical properties such as tensile strength. The present report also investigated the surface morphology and some mechanical properties of the luffa fibre - polyester based composite that included the tensile strength and the result showed improved tensile strength with an optimum value of 11.9MPa at 6wt%. It wasobserved that the chemical modification of luffa fibreenhanced the flexural strength and the flexural modulus of the luffa fibrereinforced polyester composites Yoldas et al. (2012). This study focuses on the effect of chemical treatment on the mechanical properties of luffa fibre reinforced polyester composites.

II. MATERIAL AND METHOD

The materials and equipment used for this work are; Unsaturated Polyester resin, Metyl Ethyl Ketone Peroxide (catalyst), Cobalt 2% in solution as accelerator, luffa fibre, NaOH, distilled water, wooden mould of 150x100x5mm^3.

Preparation of the raw material

The luffa fibre used, was obtained from a luffa plant stem locally found in Efekwo-Otukpa in Benue State of Nigeria. The fibre is locally called natural sponge (soso) which is domestically used for bathing, weaving of baskets, mats and dish washing. The fibre strands were obtained by light pounding of the plant stem and soaked in water for 24 hours, cut into strands and then sun dried for 72 hours.

Figure 1. Luffa fibre

Pretreatment

After cutting the luffa plant into strands, they were again carefully washed with water to remove contaminants and adhering dirt. Thereafter, sun dried for 72hrs at room temperature.

Alkali treatment of luffa fibres

Before treatment, the strands were cut into the required length of 20mm each to allow for effective treatment. The treatment was applied on the luffa fibre by using 10g of NaOH inside shaker water bath at room temperature for 3hours. The fibre after treatment was allowed to dry naturally in the laboratory.

The treated luffa fibre was further prepared by combing the fibres so as to remove scales from the strands and properly arranged in preparation for manufacturing.

Sample Preparation

To produce the composite laminate, 1.2g of catalyst and accelerator respectively were added to unsaturated polyester resin and mixed properly to form a gel. The mixture after adequate stirring was poured into the mould and the fibre was arranged parallel to one another in order to avoid entanglement. The cast was allowed to set before being stripped from the mould after compressing using a load of 10 kN. Several samples of varying fibre content of predetermined proportions of 3, 5, 6, 9wt% were prepared by the same method as shown in Table 1.

Figure 2. One of the samples produced

Table 1. Designation of Composition

S/n	Sample	Composition
1	SLF – A	Polyester (97wt%) + Luffa fibre (3wt%,20mm)
2	SLF – B	Polyester (95wt%) + Luffa fibre (5wt%),20mm)
3	SLF – C	Polyester (94wt%) + Luffa fibre (6wt%,20mm)
4	SLF –D	Polyester (91wt%) + Luffa fibre (9wt%,20mm)

Mechanical Test

Tensile Testing

In the present study, the tensile strength of the composite was measured with Monsanto Tensometer Type W with S/No. 9875 in the strength of materials in accordance with the ASTM D638 procedure. The dimension of the sample was 100 x 10 x 5mm. The gauge length was 40mm. The test was conducted by gripping each end of a reduced section specimen and slowly pulling it until catastrophic failure occurs.

Figure 3. Tensile Test Specimens

Figure 4. Tensile Specimen in Universal Testing Machine(UTM)

Flexural Testing

The flexural test was performed using the Universal materials Testing Machine 100 KN Capacity, model no. Cat. Nr. 261 in accordance with ASTM D790 using the 3- point bending fixture utilizing centre loading on a simple supported beam. A bar of rectangular cross section rested on two supports and was loaded by means of a loading nose midway between the supports. The dimension of the sample was 100 x 30 x 5mm.

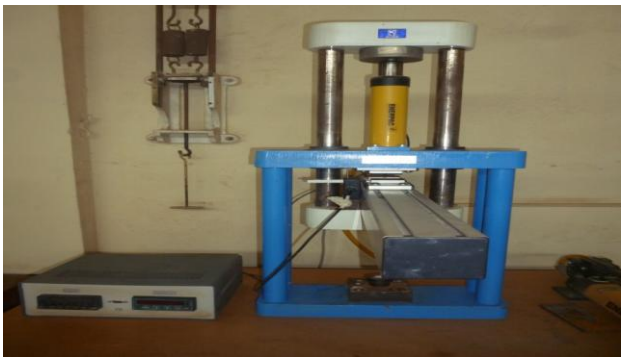

Figure 5. Flexural Testing Machine

Impact Testing

The impact strength of the sample was done using the Charpy impact testing machine with capacities of 15J and 25J. Model no. Cat. Nr. 412 and in according with ASTM standard D- 256. In this method, the specimen was supported horizontally as a simple beam and fractured by a blow delivered in the middle by the pendulum. The sample size was 80 x 10 x 5mm. The figure below shows the machine used.

Figure 6. Impact Testing of the Specimen

III. RESULTS AND DISCUSSION

Tensile Result

The result of the ultimate tensile stress for the samples is shown in Figure 6 below. From the result, it was observed that, the sample of 3wt% has the highest ultimate tensile strength value of 11.8MPa followed by the sample of 6wt% with a value of 11.7MPa, while the sample of 9wt % obtained a value of 10MPa and finally sample 5wt% recorded a value as low as 7.7MPa.

Tensile strength (MPa) = P/bh

Tensile modulus (MPa) = $\sigma/\in$.

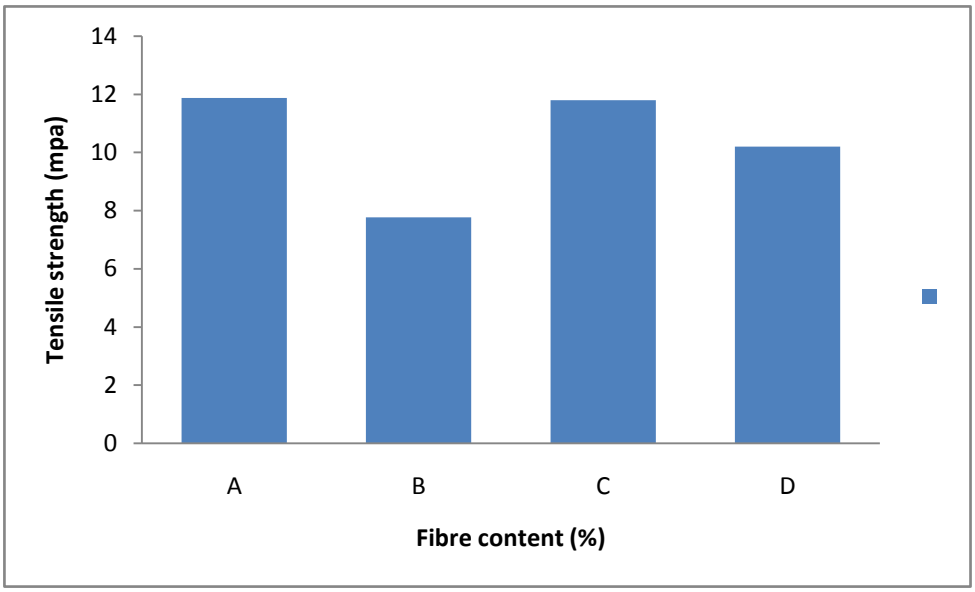

Figure 7. Variation of Ultimate Tensile Stress with Fibre Weight for different Samples

Modulus of elasticity is the ratio of tensile stress to tensile strain. From figure 7 below, it was observed that the sample with 5wt% has the highest modulus of elasticity value of 2.1MPa, followed by 6wt% sample with a value of 2MPa. This shows that all these samples have better stiffness property compared to others, 3wt% and 9wt% samples with 1.4MPa and 1.9MPa respectively.

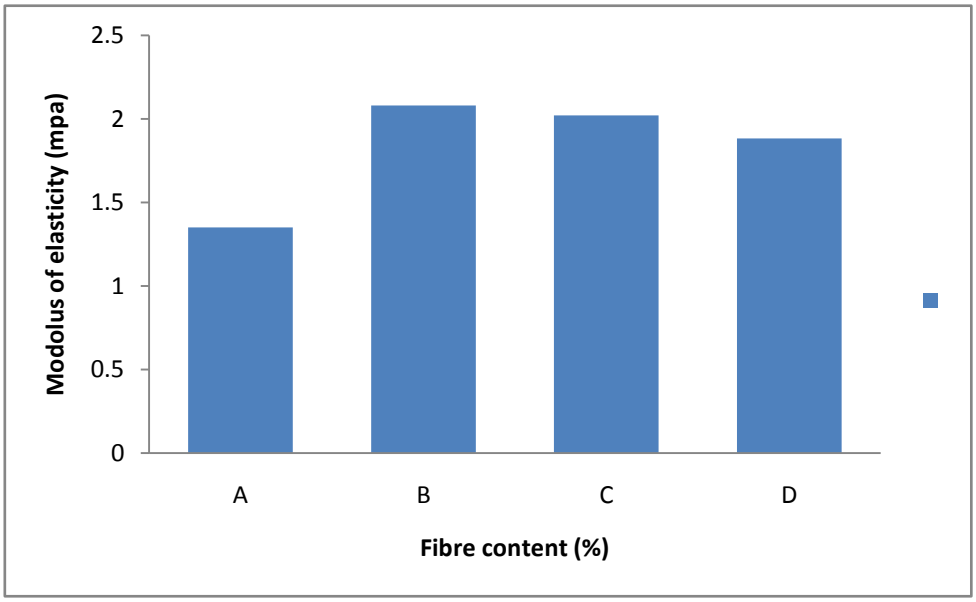

Figure 8. Variation of Modulus of Elasticity with Luffa Fibre Weight %

Yield stress is the stress that causes a permanent deformation in a material at the microstructural level. It is the stress that ends the elasticity nature and the beginning of plasticity of a material. From the figure 8 below, it revealed that sample with 6wt% exhibited the highest tensile stress with a yield of 0.14MPa value. This was followed by sample 3wt% with a value of 0.12MPa. Samples 5wt% and 9wt% recorded values of 0.117MPa and 0.1MPa respectively. Therefore, sample 6wt% recorded the highest resistance to plastic deformation.

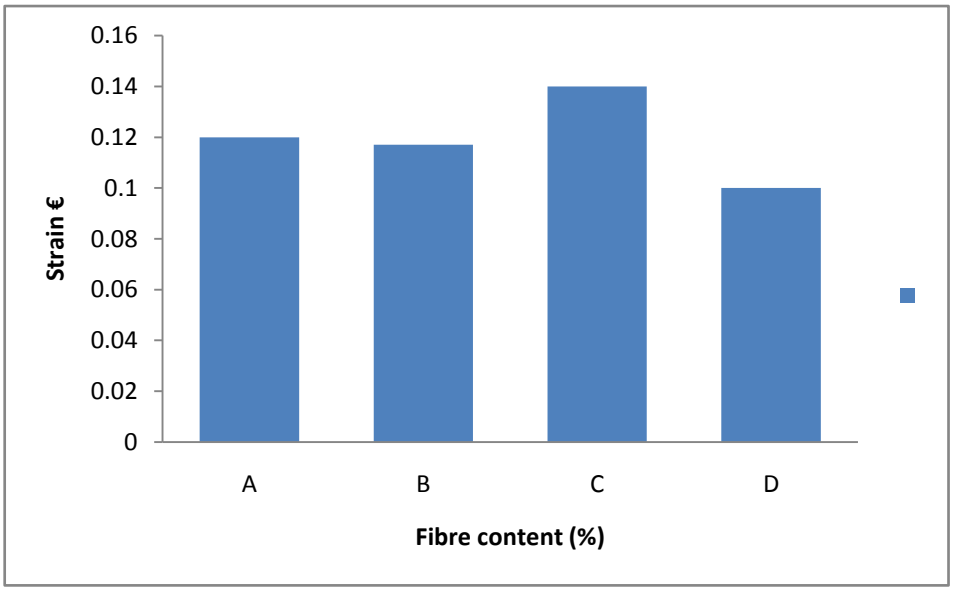

Figure 9. Variation of Tensile Stress at Yield with Luffa Fibre weight %

Flexural Value Result

The flexural strength of a material is the measure of the resistance to bending. From figure 9 below, it was observed that for the modulus of rapture for the various samples, 3wt% and 9wt% showed the same value of 0.022MPa as the highest value for resistance to bending. While samples 5wt% and 6 wt% recorded 0.02MPa and 0.018MPa respectively.

MOR (Flexural strength) = $3PL/2bh^2$ (MPa)

MOE (Flexural modulus) = $mL^3/4bh^3$ (MPa)

Where, P = maximum load applied on test specimen (N)

L = support span (mm)

b = width of specimen tested (mm)

d = thickness of specimen tested (mm)

m = slope of tangent to the initial straight line portion of load deflection curve (N/mm).

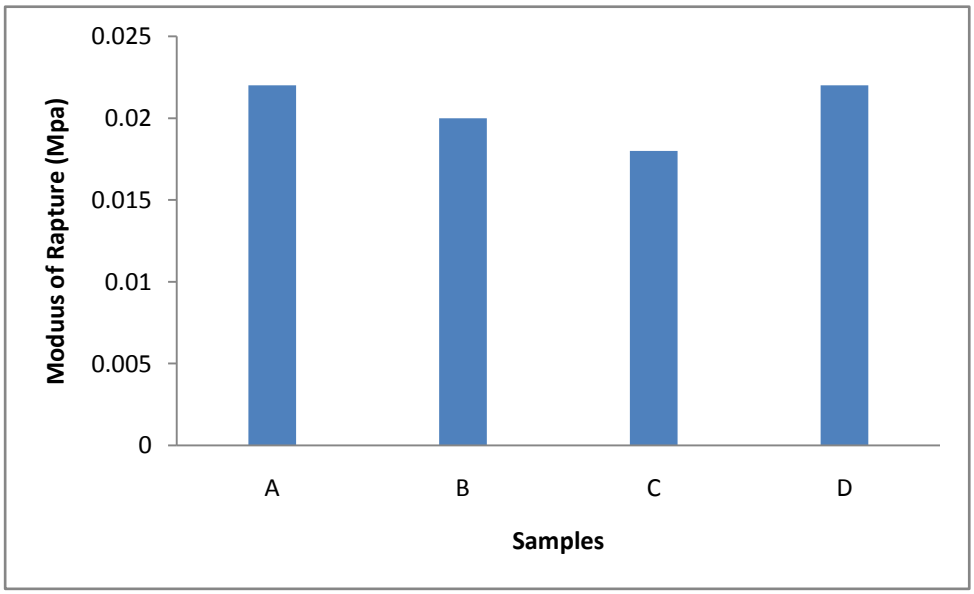

Figure 10. Variation of Flexural Values with Treated Luffa Fibre weight %

Impact Value Result

The relationship between fibre weight % and impact strength is shown in figure 10 below. The impact property of a material shows its capacity to absorb and dissipate energy under impact or shock loading. The

impact energy level of the composites depends upon several factors such as the nature of the constituents, casting and geometry of the composites, fibre arrangement, fibre/matrix adhesion, and test conditions. The matrix fracture, fibre matrix de-bonding, fibre breakage and fibre pull out are important modes of failure in the fibre composites due to impact loading. The breakage fibres may be pulled out of the matrix, and this involves energy dissipation. However, the impact strength of sample 6wt% has a maximum strength value of 0.76J/cm^2.
Impact strength was calculated by:
Impact strength = J/A (KJ/m^2)
Where**,** J=Energy absorbed (KJ)
A= Area of cross section of the specimen below the notch (m^2).

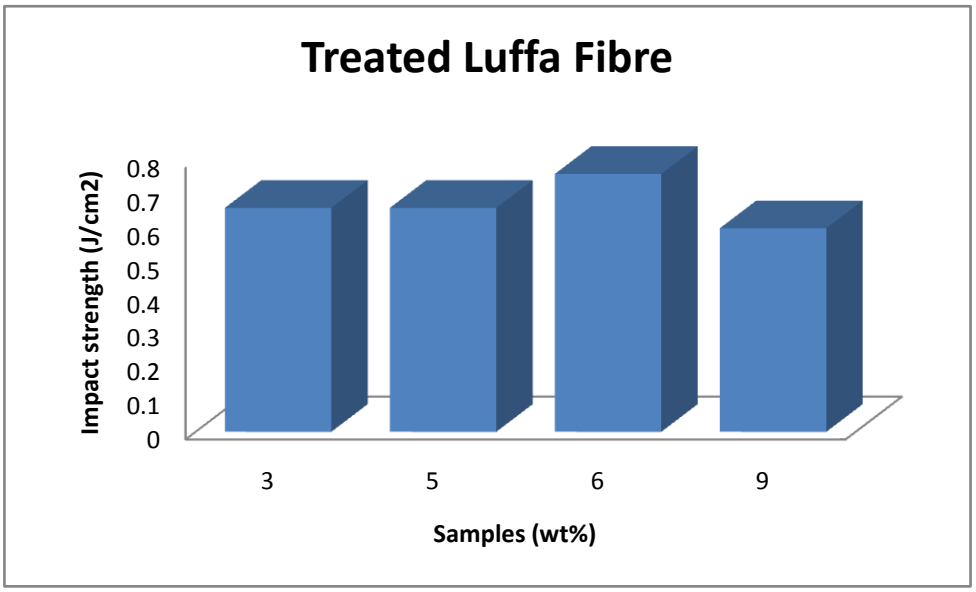

Figure 11. Variation of Impact Strength with Treated Luffa Fibre Weight (%)

SCANNING ELECTRON MICROSCOPY (SEM)
Surface Morphology
The morphological characterization of the composite fracture surface was carried out using scanning electron microscope (SEM). The samples were coated with 5 nanometres thick Gold in sputter ion coater to improve electrical conductivity.
SEM images of alkali treated Luffa fibre of 6wt % composite specimen shown in figures 12, 13, and 14 below are of the following magnifications: 500x, 1000x and 1500x respectively.
Figure 12 shows the 500x magnification after tensile test and it revealed that the arrangement of fibres was dense and devoid of voids as evident in the morphology thereby yielding high mechanical properties.

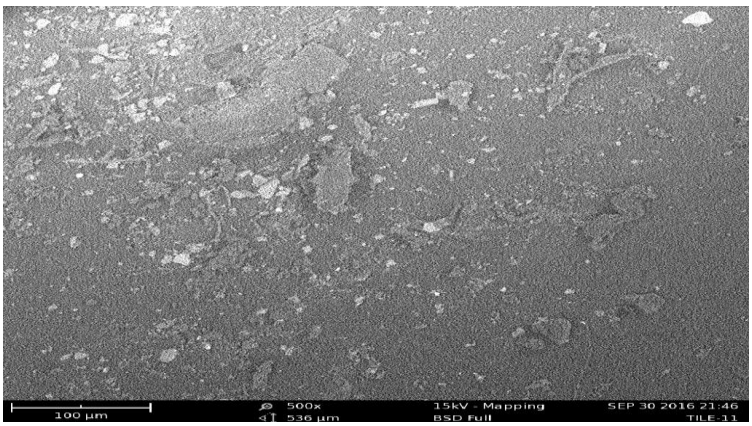

Figure 12. Showing 500x SEM image of Luffa fibre composite (6 wt %)

Figure 13 below, revealed how alkali treatment had improved the adhesion property between fibre and matrix which in turn improved the mechanical strength.

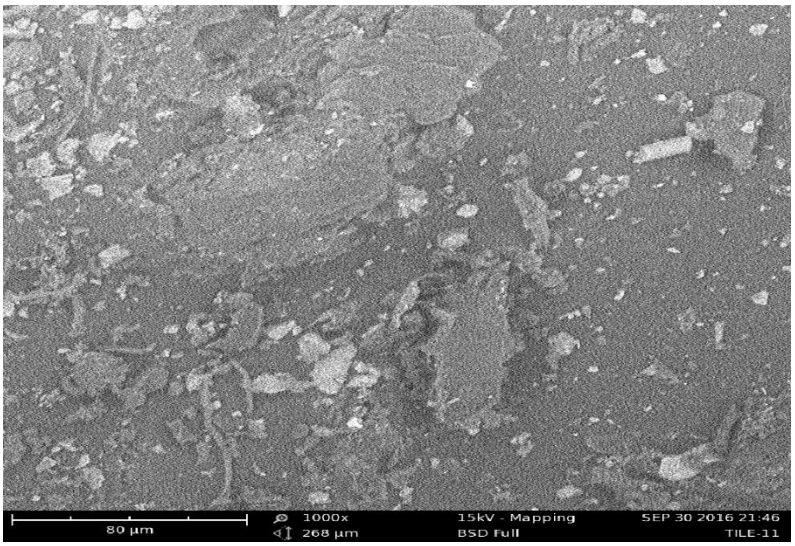

Figure 13. Showing 1000x SEM image of Luffa fibre composite

Figure 14 below, further revealed the great effect of chemical treatment showing interfacial compatibility between the fibre and matrix. We can also observe the distribution of hybrid resin which dominated the fibre thereby resulting into better outcome in this investigation.

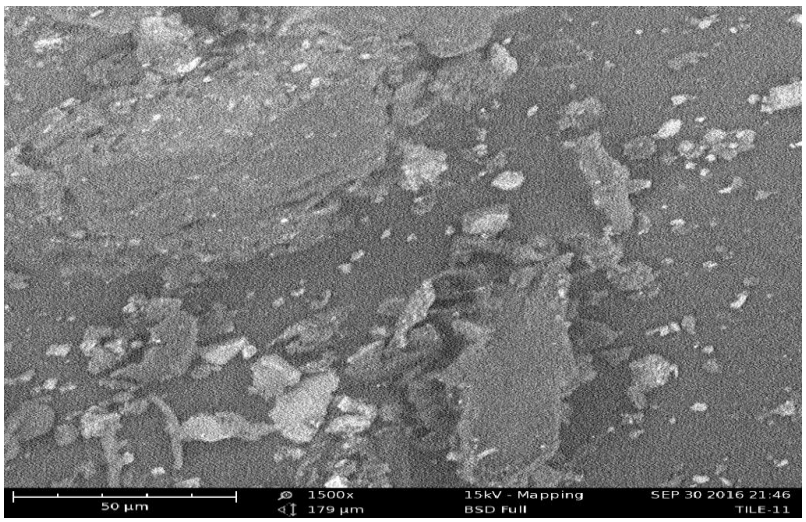

Figure 14. Showing 1500x SEM image of Luffa fibre composite (6 wt %)

IV. CONCLUSIONS

The results of the investigation of the effect of chemical treatment on the mechanical properties of the luffa fibre reinforced polyester composites revealed that the chemical treatment actually enhanced the mechanical properties. The observed enhancement was due to the strong bond that exists between the treated luffa fibre and the polyester matrix. The applied treatment removed the lignin and hemicelluloses which acted as obstructions being a matrix in the natural fibre.

The results analysis showed that, the NaOH treatment gave the best results in all the tensile and flexural properties examined in 3wt % as 11.8MPa and 0.22MPa respectively.

The treatment as well as the fibre weight of 3wt% gave the optimum result while the best impact result was obtained in 6wt% fibre weight. Therefore, the use of NaOH treatment was observed to be good for the enhancement of the mechanical properties of polyester matrix composite when reinforced with the rightvolume fraction of luffa fibre.

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