

COMPARATIVE STUDY OF ALKALI AND SILANE TREATMENT ON THE PHYSICAL AND MORPHOLOGICAL PROPERTIES OF SUGARCANE BAGASSE REINFORCED EPOXY RESIN COMPOSITE

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ABSTRACT

Due to continuous search for new material and increase in environmental awareness. The nano composite of sugarcane bagasse and epoxy resin were prepared through the hand layup technique by using a glass mold. The fiber was initially treated with caustic soda and silane solution prior to the composite fabrication. Three different polymer composites (untreated, alkali, silane) at six different weight percentage of SCBP reinforcement (0wt%, 5wt%, 10wt%, 15wt%, 20wt%, 25wt%) were fabricated. Density, water absorption and scanning electron microscopy were carried out. Both alkali and silane treated SCBP nano composite have better interfacial adhesion between the fiber and the matrix as compared with the untreated composite. The absorption capacity of both the untreated, alkali and silane treated SCBP nano composite increases with increase in fiber loading. The density of all the composites appears to be decreasing with increase in fiber loading with alkali treated nano composite having higher density than the silane treated nano composite. SEM studies reveal that the silane treated nano composites have better interfacial adhesion between the fiber and the matrix than the alkali treated composites.

Keywords: Sugarcane Bagasse Powder, Alkali Treatment, Silane Treatment, Epoxy Resin

1 INTRODUCTION

Agriculture is at the heart of sub-Saharan Africa's economic growth. This contributes significantly up to roughly 50% to the GDP in sub-Saharan Africa. Through agro-industries, the refining of crops into a refined product increases value according to [1] A significant agricultural crop that is produced all over the world is sugarcane. Sugarcane produces a significant amount of waste. Global socioeconomic development and growth have found this to be relevant. Asia was the original home of sugarcane. Typical weather that is humid and sub humid is ideal for sugarcane growth [2]. By 2050, due to population growth, protecting and enhancing the means of subsistence for small-scale families and tenant farmers has become problematic [3] This is because unsustainable practices and soil degradation have put agricultural natural resources under duress. The low yield has been documented in the last ten years despite advancements in technology. The high cost of processed and raw food is a result of this worldwide. Consequently, protecting and improving tenant farmers' and small-scale families' means of subsistence has become problematic [4] To meet the world's growing and changing need for sustenance, significant advances in resource efficiency and the reduction of waste generated from sugarcane are therefore necessary, and they may even be able to stop environmental damage. More money needs to be spent on research and agriculture, especially in emerging nations. In order to

encourage the adoption of sustainable production, this is necessary. This will support the realignment of implicit and explicit agriculture to fulfill the needs of the growing population, as well as farmers, ecosystems, and communities in adapting to reduce and create resilience against the unsustainable agriculture productivity [4]. Bagasse comprises roughly 45–50% water, 2–5% sugar that has been dissolved, and 40 to 45% fibers. After the juice is extracted, it is a byproduct of the sugarcane business. The components of sugarcane bagasse are cellulose (36.0%), pentosans (26.0%), lignin (20.0%), and ash (2.2%). Molasses and mill mud are further by products [5] The main chemical constituents of bagasse are cellulose, hemi cellulose and lignin [6] Composite materials formed by natural fiber and polymeric matrices constitute a current area of interest in composite research [7]. There exists an excellent application in fabricating bagasse-based composite toward a wide array of application in building construction such as Roads, Boards and block as reconstituted wood, pump and flowing tiles to mention a few [8] Sugarcane bagasse is the residue obtained from extracting the sugarcane juice in industries for sugar or wine [9]. Alkali treatment can lower polymerization, lignin concentration, and hemicellulose in the fiber. Alkaline treatment can affect the number of reaction sites on fiber surfaces and increase surface roughness, leading to improved mechanical characteristics [10] The use of sugarcane bagasse increased the tensile and flexural characteristics of materials. The highest tensile and flexural strength were observed at 15wt% fiber loading. Composites with 15wt% fiber loading demonstrated improved thermal stability compared to other samples [11]. [12] reported that the tensile modulus of fiber-reinforced polyester composites treated with silane improved by 150%, whereas the tensile strength of fiber-reinforced polyester composites treated with acetylated and alkali significantly increased. Furthermore, acetylated, permanganate, and silane-treated fiber-reinforced composites showed higher flexural modulus and flexural strength compared to untreated panels. The investigation of the effect of chemical treatment on the mechanical properties of SCB fibers was achieved by [13]. It explains that when compared to untreated SCB fibers, the alkali treatment of SCB greatly increases the tensile strength and modulus of all fiber-reinforced composites. When compared to untreated SCB fibers, the impact and hardness parameters of the SCB/LDPE composite are also markedly improved by the alkalization treatment of SCB. When fiber content increased from 10% to 30% of the total weight, chemical resistance decreased. In a NaOH solution, composites have demonstrated maximal absorption.

2 METHODOLOGY

Table 1 shows the materials used and their sources.

Table 1. Materials and their sources

SN	Materials	Sources
1	Fresh sugarcane bagasse waste	Sugarcane center in Samaru, Zaria
2	Epoxy resin (grade 3554A)	Juneng Nigeria Limited, Enugu state
3	Hardner (grade 3554 B)	Juneng Nigeria Limited, Enugu state
4	Distilled Water	Chemistry department, ABU Zaria
5	Glass mold	Polymer and Textile Engineering, ABU Zaria
6	Weighing balance	Polymer and Textile Engineering, ABU Zaria
7	Stirring rod	Polymer and Textile Engineering, ABU Zaria

2.1 Sampling and Treatment

The sugarcane bagasse was collected from Samaru cane center, Zaria, Kaduna State. It was then washed thoroughly with distilled water to remove both access sugar and dirt particles and then dried in an open air for 48 hours. The dried sample was then grinded to a more smaller particle size and then ball milled for 80 hours using a laboratory mill machine from the department of chemical engineering, Ahmadu Bello University. The bagasse fiber was then divided into three portions. The first portion remain untreated while the other two portions were subjected to Alkali and silane treatment respectively.

2.2 Alkali Treatment

The sugarcane bagasse fiber was treated with 5%wt solution of NaOH for 2 hours at room temperature. The fiber was then rinsed thoroughly with distilled water and dried at room temperature for 3 days [14].

2.3 Silane Treatment

The pretreated bagasse fiber was soaked in a concentration of 5%wt of 3 amino propyl trimethoxy silane solution diluted in water and Acetone. Concentration by 50/50 volume, for 2 hours, the fiber was then dried indirect sunlight for three days after removing it from the solution [15].

2.4 Composite Preparation

The composite was prepared in the department of Polymer and Textile engineering laboratory, ABU Zaria. A hand layup technique was adopted by using a glass mold having a size of 200cm by 150 cm by 5cm via manual mixing using a stirring rod. The resin used was epoxy resin which was prepared in the ration of 2:1 amount by weight of epoxy resin and the Hardner. The overall weight of the composite is 100 grams. There was a variation in the composition of the epoxy resin and the sugarcane bagasse fiber. The weight of the sugarcane bagasse which was the reinforcement to that of the matrix was given in table 2 The measured matrix was thoroughly mixed in a container and stirred at low speed for 15 minutes to achieve uniformity. The mixture was then poured onto a 5gram SCBP. It was then cured for 24 hours at room temperature and then removed from the mold. To achieve faster and easier removal of the composite from the mold, Vaseline was used as a releasing agent which was applied onto the surface of the mold prior to applying the mixture of the matrix onto it. The fabricated composite was then cut into a suitable dimension to facilitate for further analysis based on the ASTM standards.

Table 2. Nomenclature of the SCBP\Epoxy resin composites material

COMPOSITE	RATIO	MATRIX (g) 2:1		SCBP(g)
		Epoxy resin	Hardner	
0wt%SCBP\Epoxy resin	100:00:00	66.6	33.3	0
5wt%SCBP\Epoxy resin	95:05:00	63.33	31.66	5
10wt%SCBP\Epoxy resin	90:10:00	60	30	10
15wt%SCBP\Epoxy resin	85:15:00	56.66	28.33	15
20wt%SCBP\Epoxy resin	80:20:00	53.33	26.66	20
25wt%SCBP\Epoxy resin	75:25:00	50	25	25

2.5 TEM Studies

TEM studies was carried out in accordance with ASTM F1877. For study under an electron microscope, the sample should be transparent to allow the passage of electron beams through it. To achieve this semitransparent nature, the sample is sectioned into fine sections using glass or diamond knife attach to a device known as ultramicrotome. The device has a trough that is filled with distilled water. The section cut is collected in this trough and are then moved to a copper grid to be viewed under the microscope. The size of each section should be between 30nm and 60nm to get the best solution. During preparation of the sample for this study, the sample undergoes fixation, dehydration, infiltration, polishing, cutting and staining.

2.6 FTIR analysis

FTIR analysis was carried out in accordance with ASTM E1252. FTIR allows the measurements of variation in the fiber composition after chemical treatments. The chemical structure of both pretreated and treated sugarcane bagasse will be evaluated by FTIR spectrophotometer. The sample will be prepared by mixing the material with KBr in a proportion of 1:200 for all spectra. 16 scans will be accumulated within a 4cm resolution [16].

2.7 Density

Density studies was carried out in accordance with ASTM D7777. The mass of each sample was determined using analytical weighing balance and the volume was determined using displacement method. Water was added into a measuring cylinder and its label was recorded as the initial volume.

The composite sample was then carefully placed into the cylinder and the new record on the cylinder was recorded as the final volume. The difference in the water level in the cylinder was recorded as the volume of the volume of the sample. The density of the sample was computed as the ration of the mass of the sample to the volume of the sample in Kg/m³.

2.8 Water absorption test

Water absorption was carried out in accordance with ASTM D570. The samples were weighed and recorded and then immersed in water in a container for 24hours. They were removed and re weighed again and recorded. The same procedure continues and recorded after every 24 hours until the sample stop absorbing the water completely. The percentage water absorption is measured using the equation 1.

$$\% \text{ water absorption} = \frac{\text{final weight} - \text{initial weight}}{\text{final weight}} \times 100 \quad (1)$$

2.9 Scanning electron microscopy

The interfacial bonding and nature of the fibers on composite will be investigated using scanning electron microscopy analysis. The test is to be conducted on the fabricated fiber reinforced polymer composite specimen measured by using ASTM D 256 standard using a SEM instrument. This analysis was performed on cryogenically fractured surface of composite samples [17].

3 RESULTS AND DISCUSSION

3.1 Transmission Electron Microscopy

The transmission electronic microscopy (TEM) studies as shown in Figure 1 shows a representative sample of nano particles with a relatively spherical shape. The particles are mostly dispersed with some aggregation observed. The size distribution is narrow with an average particle size of 19.3nm at a range of 20nm, 50nm and 100nm. This TEM result shows that the nano particles have a uniform size distribution with an average size of 19.3nm. The spherical shape and dispersed state of the particles shows a high degree of uniformity and stability. These results confirm the expected size range of the SCBP which is essential for their intended applications. [18] in the comparison of SEM and DLS methods to characterize size distribution of ceramic nano particles, the TEM image show good sample preparation and dispersion of the nano particles.

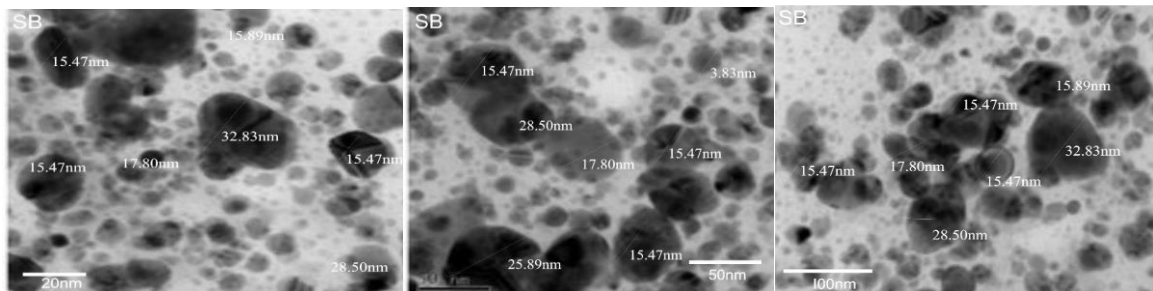


Figure 1. TEM image of SCBP at 20nm, 50nm and 100nm.

3.2 FTIR

Figure 2 shows the FTIR spectra of SCBP of the untreated and the modified alkali and silane treated ones. For the alkali treated SCBP, the spectra show peaks that are attributed to SCBP. For the untreated SCBP, the hemicellulose and lignin show an obvious peak of 1733cm⁻¹ and 1242cm⁻¹, the peak for both the hemicellulose and lignin is weaker for the alkali treated SCBP which suggest that they were removed by the Alkali treatment. As for the silane SCBP, its IR spectrum is relatively similar to that of the untreated SCBP bar the little reduction of the hemicellulose and lignin. However, there is an identifiable peak of Si-O-C at 1323.2 cm⁻¹. This bond is formed between the coupling agent and the bagasse. This result is in agreement with [19]. They studied, The effect of alkaline and silane treatments on mechanical properties and breakage of sisal fibers and poly lactic acid/sisal fiber composites. Their result show that alkali treatment helps in the removal of hemicellulose and lignin from the sisal fiber and silane treatment modifies the surface properties of the fiber hence improving the strength and stiffness of the fiber. It also improves the compatibility of the fiber with the polymer. Silane treatment

did not result in the loss of any peak in the FTIR spectra, the removal of hemicellulose and lignin observed is attributed to the alkali treatment. Si-C peak was not observed in this study most likely due to the low silane concentration used [20].

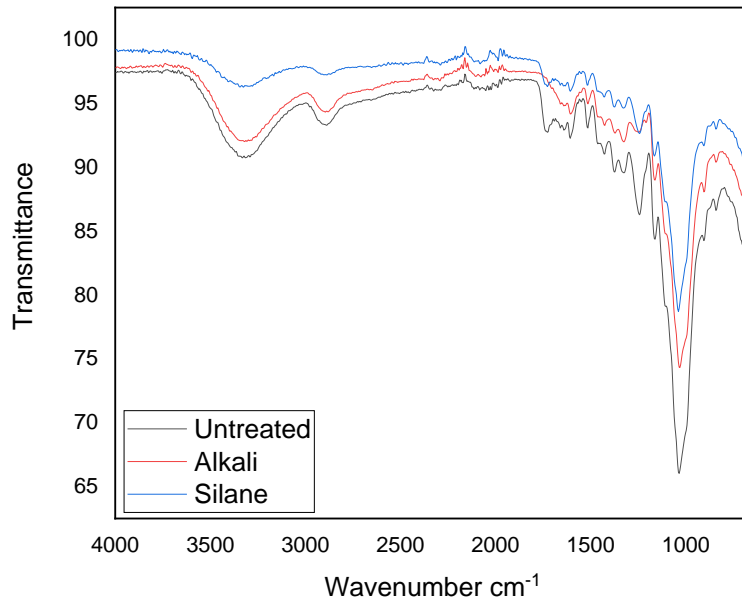


Figure 2. FTIR spectra of untreated, alkali and silane treated SCBP.

3.3 Density

Figure 3 shows the density values of both the untreated and treated SCBP\Epoxy nano composite. The untreated have 1.1795 g/cm³, 1.1665 g/cm³, 1.15 g/cm³, 1.1477 g/cm³ and 1.0862 g/cm³ for the 5wt%, 10wt%, 15wt%, 20wt% and 25wt%. the alkali treated have 1.2474 g/cm³, 1.1701 g/cm³, 1.1679 g/cm³, 1.12 and 1.11 g/cm³ for the 5wt%, 10wt%, 15wt%, 20wt% and 25wt%. the silane treated have 1.1905 g/cm³, 1.177 g/cm³, 1.1543 g/cm³, 1.12 g/cm³ and 1.1 g/cm³ for 5wt%, 10wt%, 15wt%, 20wt% and 25wt%. Both the alkali, silane and the untreated SCBP nano composite appears to be decreasing with increase in fiber loading. Alkali and silane treated nano composite have higher density than the untreated SCBP nano composite with alkali having the highest density value. This increase could be due to the cell wall densification occurred during treatment. But at 20wt% fiber loading, the untreated and the silane treated appears to be higher than the both the alkali and the silane treated SCBP. This can be due to void or crack that was formed during cutting of the composites. This result is in agreement with Orue [19]. He observed that the density of the Alkali treated sisal fiber composite is better than that of the silane and untreated sisal composite.

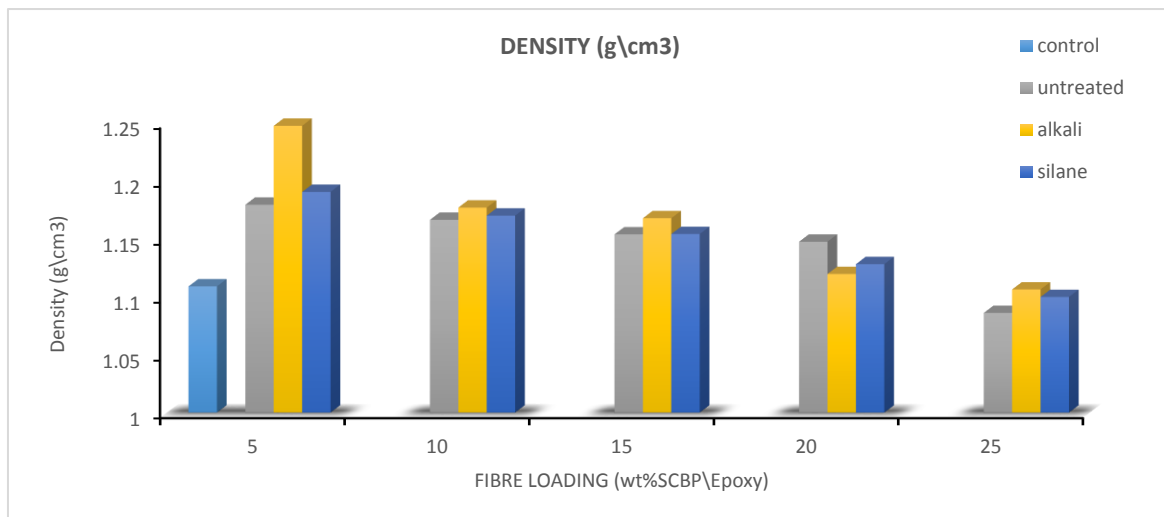


Figure 3. Density profile of SCBP\EPOXY nano composites

3.4 Water Absorption

The effect of alkali treatment and silane treatment on water absorption of SCBP\Epoxy nano composite was studied and presented from figure 4 to 8. the result shows that water absorption increased with increase in immersion time. The control and untreated shows no water absorption for the first two days before they slowly begin to absorb. With increase in immersion time, all the composites show an increase in water absorption. The water absorption of the alkali, untreated and silane nano composite were all found to be increasing as the fiber loading increases. This increase in water absorption is attributed to the hydrophilic nature of the fiber capable of forming hydrogen bonding with hydroxyl group in the water molecules. This property could be due to an increase in porosity with gaps caused by the fiber within the polymer matrix structure as such, the higher the fiber loading, the higher the water intake [21] states that as the particle content increases, the formation of the agglomeration increases due to the difficulty of achieving a homogenous dispersion of particle at higher particle content. This agglomeration of the particles in the composite causes increase in its water absorption [22] in their study states that water absorption test shows that composite prepared from the chemically treated absorb lower amount of water compared to the ones prepared from raw sawdust suggesting that hydrophilic nature of the cellulose in the sawdust has decreased upon chemical treatment. The water absorption property of a composite material could be attributed to the water percentage content in the fiber, on fiber orientation, on temperature, on area of the exposed surface, on permeability of the fiber, on void content and on hydrophilicity of the individual components etc. A reduction in water absorption was observed when the surface treated fiber composite is compared to the corresponding untreated material. This can be attributed to the good interfacial interaction between the fiber and the matrix. This could also be because the chemical treatment has led to more hydrophobic materials, consequently reducing water absorption. It can also be due to better fiber matrix interaction within the material [23].

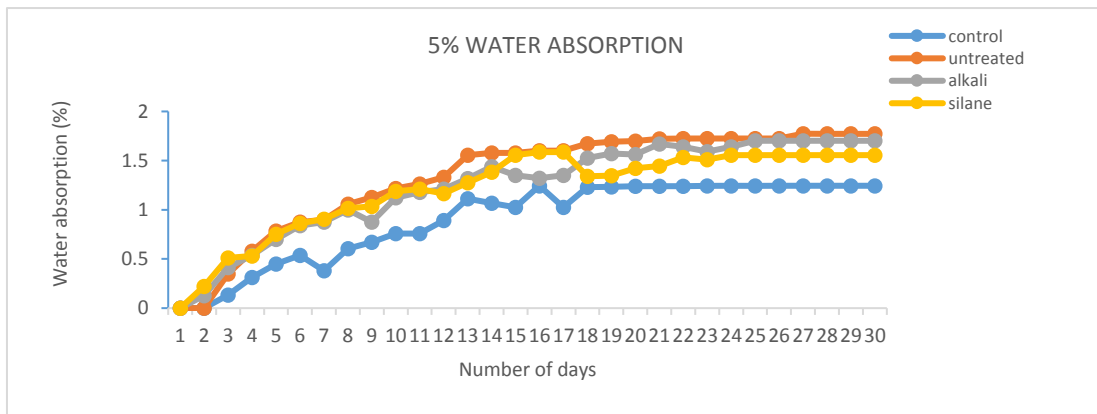


Figure 4. Water absorption (%) profile of 5wt% SCBP\EPOXY nano composites

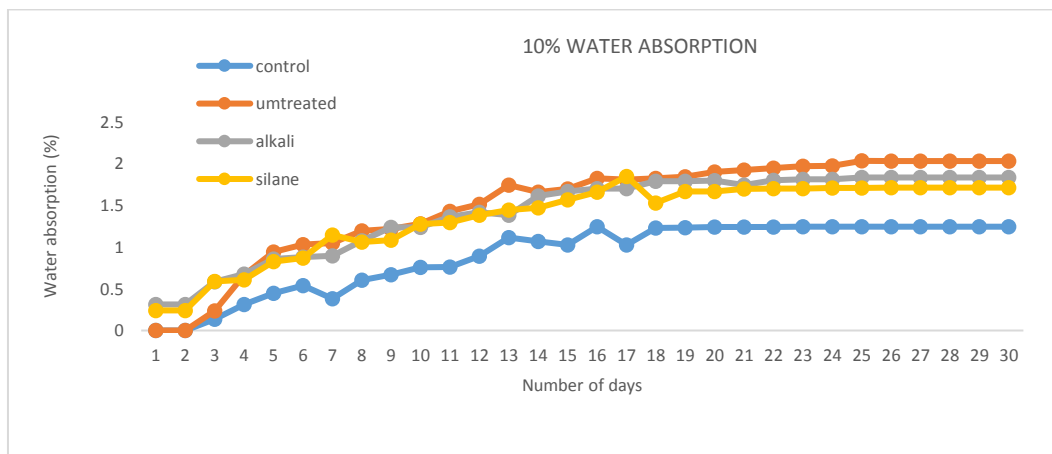


Figure 5. Water absorption (%) profile of 10wt% SCBP\EPOXY nano composites

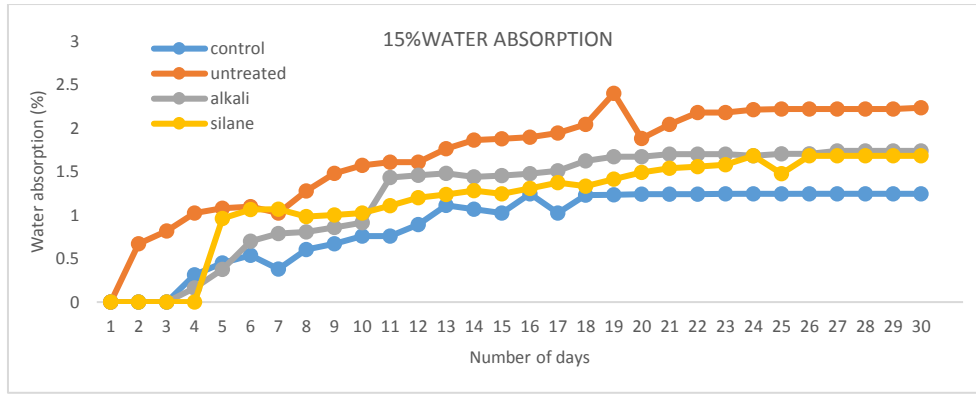


Figure 6. Water absorption (%) profile of 15wt% SCBP\EPOXY nano composites

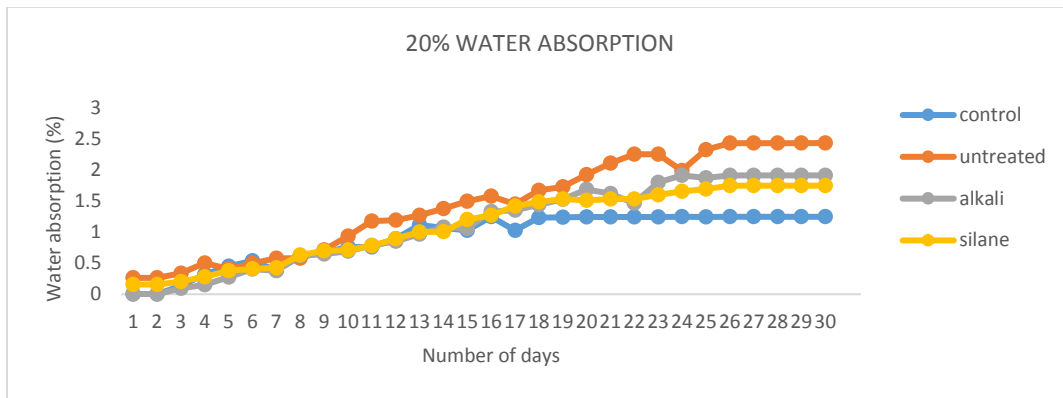


Figure 7. Water absorption (%) profile of 20wt% SCBP\EPOXY nano composites

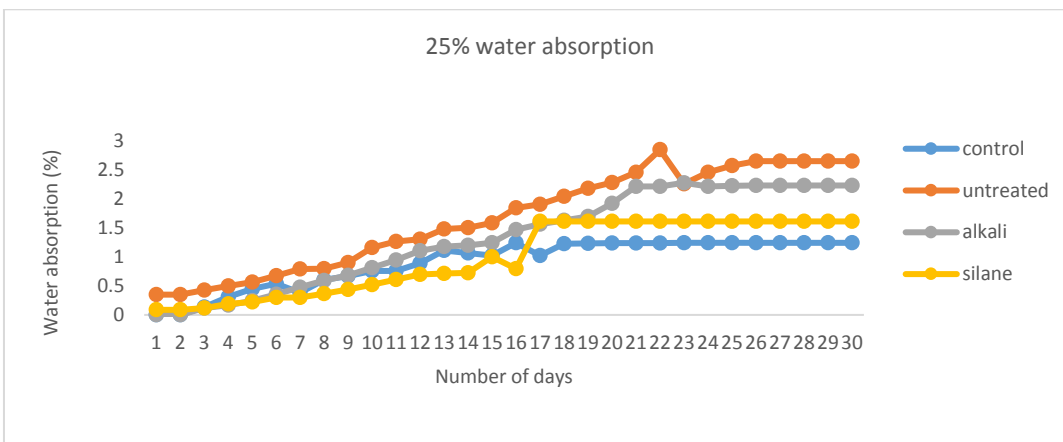


Figure 8. Water absorption (%) profile of 25wt% SCBP\EPOXY nano composites

3.5 Scanning Electron Microscopy (SEM) studies

The SEM micrographs depict the morphological features of SCBP/Epoxy resin nano composites as shown in plates 1 to 4. For the neat epoxy resin composite in plate 1, a homogenous feature is observed which is due to the fact that there was no fiber addition. The untreated SCBP/Epoxy resin nano composites show there is indeed an interfacial interaction between the fiber and the matrix. However, there are voids and pores present in the structure which maybe caused due to air trap during fabrication. A small crack is also present which may be caused during cutting of the composite for analysis. The alkali treated SCBP/Epoxy resin matrix shows better interfacial interaction between the fiber and the matrix than the untreated one as shown in plate 2. This is due to less voids and micropores which are observed as compared to the untreated SCBP/Epoxy nano composites. This will lead to insignificant water absorption as compared to the untreated composite and stress transfer between the fiber and the matrix will be inefficient. The SEM studies of silane treated SCBP/Epoxy nano composite was shown in plate 4, lesser air pores and voids are present as compared to both the untreated and the

alkali treated SCBP/Epoxy nano composite. However, a crack can be seen which may be caused during cutting of the composites. The silane treated composite will not degrade as quickly as the untreated and the alkali treated composites since it has better interfacial bonding between the fiber and epoxy resin matrix.

Plate 1. SEM micrograph of neat epoxy resin nano composite.

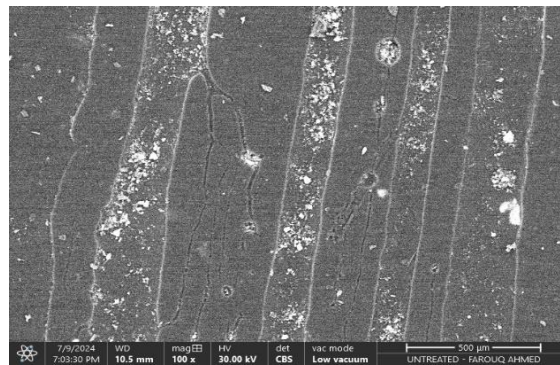


Plate 2. SEM micrograph of untreated SCBP/EPOXY resin nano composite

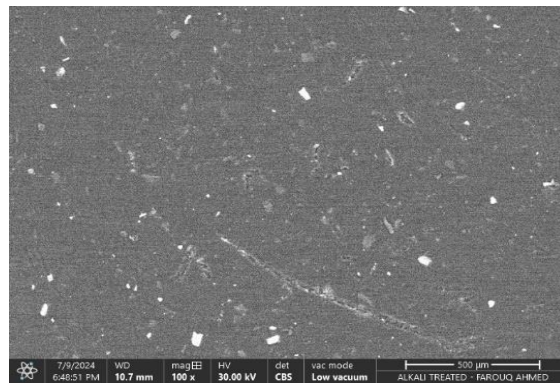


Plate 3. SEM micrograph of alkali treated SCBP/EPOXY resin nano composite

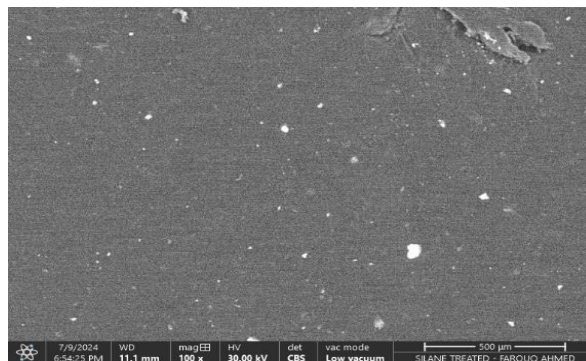


Plate 4. SEM micrograph of silane treated SCBP/EPOXY resin nano composite

4 CONCLUSIONS

The physical and mechanical properties of SCBP/Epoxy resin nano composites for the untreated, Alkali and Silane treatment at different formulations was carried out successfully and the following conclusions were made. The alkali treated SCBP composites have the highest density than the silane and untreated composites. Increase in SCBP content leads to decrease in the density of the composite. The untreated SCBP/Epoxy nano composites have higher water uptake than both the alkali and silane treated composites. And the water absorption increases as the fiber loading increase. The SEM micrograph of SCBP/Epoxy resin nano composite shows the presence of few voids on the surface of the composites. Both alkali and silane treated SCBP/Epoxy nano composites depicts that there is very good compatibility with fewer voids signifying there is better interfacial interaction between the fiber and the matrix in comparison with the untreated SCBP/Epoxy resin nano composite which has several voids and large micropores confirming its larger moisture uptake. Despite its significant importance, silane treatment is very costly and that made it less useful as compared with the alkali treatment of the SCBP/Epoxy nano composite.

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