



Mechanical, Morphological Properties and Chemical Resistance of Filled Rattan Wastes Powder Epoxy Composites

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PAPER INFO

Paper history:

Received 11 August 2020

Accepted in revised form 16 November 2020

Keywords:

Epoxy composite
Flexural strength
Morphology
Rattan wastes
Tensile strength

ABSTRACT

Fibre content effects on mechanical, surface morphology and chemical resistance of epoxy/rattan fibre composite was investigated. By analysis of scanning electron microscopy (SEM), mechanical and chemical examinations. SEM shows the rattan fibre had improved facial adhesion and a fairly uniform distribution of fibre in the matrix. Similar result were observed for flexural and tensile strengths with gradual increase in strengths with filler loading. Mechanical properties improved with increasing fibre loading, peaking at 25 wt % content. The best tensile and impact strength was obtained at 25 wt % filler with a value of 19.271 MPa and 18.876 J/m. There was a 4.48 % increase in hardness obtained at 15 wt %, 6.55 % increase in hardness at 20 wt %, while 7.46 % increase in hardness was obtained at 25 wt % representing the highest hardness for individual fibre wt % considered. The flexural strength obtained for the samples presented increased as fibre content increased, while the best flexural strength result of 27.542 MPa was observed at 25 wt % fibre. The rattan - epoxy composite's weight reduced greatly after testing in 10% HCl, NaOCl, and NaOH solution. Theresult for immersing in H₂O₂ solution showed negligible effects and hence, a small reduction in weight loss.

doi: 10.5829/ijee.2020.11.04.10

INTRODUCTION

The usage of natural fibre filled composites is increasing everyday due to their high strength, low weight, ease of fabrication, eco-friendliness and wide material applications. Fibre-reinforced composite materials use lignocelluloses fillers to mechanically improve the strength, toughness and durability of polymer composites. The degree to which strength, toughness and durability are enhanced in the reinforced polymer depends on the mechanical properties of the lignocelluloses fillers and the polymer matrix, their volumes, fibre size and orientation within the polymer [1, 2]. Natural fibres such as wood flour, henequen, sisal, coconut coirs, banana and pineapple leaves and many others are renewable, non-toxic, and can be recycled or biodegraded easily to reduce the carbon footprint [3–5]. A great variety of lignocelluloses Fibres obtained from plants have been investigated and effectively employed in varying engineering composites in recent years [6]. Despite the advantage of lignocelluloses fibres, their use as reinforcement agents, have some shortfalls like poor wettability, incompatibility with some polymeric materials and the high water absorption of the fibres due

to its hydrophilic nature. Its applications and exposure to aqueous media (alkali, acid, and solvents) has also made it important to examine its chemical resistance with the aim of improving its properties for specific end-uses. The chemical treatment of natural fibres using typical sodium hydroxide treatment [7, 8] and other treatments [9, 10] methods are essential to modify chemically the surface of the fibre for improving these shortfalls, improve surface roughness and interfacial adhesion to matrices [11].

Rattan cane (*Calamus deeratus*) has drawn great attention and are often equated with synthetic glass fibres because of its similar tensile strength which can ranges from 464 to 603 MPa, depending on the species [12]. Rattan fibres have bending modulus (846.7–4057 MPa) and bending strength (31.05–91.0 MPa), compressive modulus (831.61–1571.18 MPa), compressive strength (17.81–33.6 MPa) and impact toughness (177.27–193.82 MPa) [13], which results in their relatively high variability in structural composition and load-bearing part. Notwithstanding the traditional use of rattan fibres as cane furniture/handicraft weaving materials [14], more new applications concentrate on high value-added utilization as superior substitutes to glass fibres in composites and carbon-based materials for energy

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storage [13, 15]. On the other hand, Epoxy LY 556 (bisphenol A diglycidyl ether) resin, are used widely for a variety of applications in every day life [16]. They are also known for their good thermal and mechanical properties, adhesion to different substrates and easy processability. Epoxy LY 556 (bisphenol A diglycidyl ether) resin are made mostly by the condensation of the epichlorohydrin and bisphenol A [13]. Epoxies have many advantages over the other thermosets. They have low shrinkage, high strength and good adhesion to various substrates. They also have good electrical insulation properties, chemical and solvent resistance, as well as low toxicity. Epoxy resins is compactable with many substrates making them very useful in many composites [17]. Its widespread applications offer a variety of non-metallic composite designs in many engineering applications [18]. They are also used in many recreational applications such as, bicycle frames, tennis rackets and other equipments [19, 20].

Many researcher have studied composites reinforced with rattan fibres. Rachchh et al. [21] studied the Mechanical properties of rattan fibre polyester composite and discovered that the addition of varying percentage of fibre improved the mechanical properties at fibre content of 12.5% after which there is decrease in the properties. Ma et al [22] studied the tribological, physical and mechanical properties of the friction materials reinforced by varying the rattan fibre content. Nikmatin et al [23] evaluated the Physical, thermal, and mechanical properties of polypropylene composites filled with rattan nanoparticles. The major drawback of natural fibre composite, which is the bonding between fibre and matrix can be addressed by using finer particle in the nanometer range. Balakrishna et al. [24] noticed that incorporating rattan powder and kaolin fillers in polypropylene raised the composite tensile modulus by 12 % compared with only kaolin fillers. Nikmatin et al. [25] observed that integrating rattan in nanoparticle size into polypropylene improved the composite's thermal properties. Their study, however, was limited to studying the effect of rattan nanoparticle on the thermal resistance properties. Hence, the need to also study the mechanical, morphological properties and chemical resistance of filled rattan wastes powder epoxy composites.

MATERIAL AND METHOD

Materials

The resin used in this study is Epoxy LY 556 (bisphenol A diglycidyl ether) [26]. HY-951 Hardener NN – bis 2 aminoethylene 1, 2-diamine. Sodium hydroxide (NaOH) was used; Distilled water and processing oil were obtained from Rovet Chemicals, Lagos State, Nigeria. The raw material for the present study, Rattan Cane was obtained from Ogube-Ihuba, Okigwe, Imo Nigeria and the foil paper was obtained from Pascal Scientific, Lagos.

The chemical solution was prepared by dissolving 5 g NaOH in 100 ml distill. This process led to a 5 wt. % homogeneous NaOH solution as reported by [27, 28].

Composite preparation

The Rattan Cane fibre were soaked for 4 hours, then washed with water to eliminate impurities and the bark peeled. They were then oven dried at 70 °C for 6 hours to remove all moisture. They were then cut to a length of to 2-4 mm. The fibres were pre-treated using 5 % NaOH solution for four hours. After pre-treatment, the fibres were washed with distilled water until all untreated NaOH solution was removed. They were then dried in the sun and in the oven at 80 °C for 4 hours. The fibres were bow milled for to obtain particle sizes of 70 µm prior to compounding. The rattan cane particles which act as the filler, in the company of the hardener was then mixed with the epoxy in a container. The mixtures were thoroughly mixed by mechanical agitation for about 10 minutes in order to ensure homogeneity. The mixture were poured into a mould and placed into the compression moulding machine at 130 °C and allowed for about 5 – 10 minutes to cure. The composites were removed from the machine and put into the cooling part for about 5 minutes and allowed to cure completely. Hardener was then added. Proper stirring was done to ensure uniform mixture. Fibre content was varied from 5-30 wt. % at increments of 5 wt. % and the composition were used in a ratio of 2:1 as shown in the Table 1. The moulded samples were cut into square shapes (15cm x 15cm) from which the specimen(s) for all the tests were taken.

Characterization

FT-IR was used to evaluate the changes in the vibrational frequencies of the functional groups in untreated and alkali treated rattan cane fibre. Spectra measurements were taken between 4000 – 650 cm⁻¹ of the electromagnetic spectrum at a resolution of 4 cm⁻¹ using an FTIR Agilent technology Spectrometer. For this purpose, approximately, 0.1g each of the rattan cane samples was separately prepared by thoroughly mixing

TABLE 1. Composition of epoxy/ hardener /rattan cane composite

Filler (Wt.%)	Epoxy (Wt.%)	Hardener (Wt.%)
00	66.66	33.34
05	63.33	31.67
10	60.00	30.00
15	56.67	28.33
20	53.33	26.67
25	50.67	25.33
30	46.67	23.33

with nujol in the quartz disc. FT-IR spectra of the samples were then determined by placing the disc on the part of the spectrometer. The FTIR spectra of fibre were recorded in the range of 4000 to 600 cm⁻¹ at a resolution of 4 cm⁻¹ using an FTIR Agilent technology Spectrometer.

Morphology

The morphology of the samples was studied using Scanning Electron Microscope model Phenon Prox. Manufactured by Phenonworld Eindhoven, the Netherlands at an accelerating voltage of 5.0kV and magnification of 1000. Test samples were first sputter-coated with gold in order to prevent electrical discharge in the course of examination with the microscope. The coating thickness was 5nm. The samples were successively placed on a slab secured with a double adhesive, introduced into the column of the SEM and viewed through an installed Navcam camera after adjusting to SEM model.

Tensile test

The tensile strength of the composites were determined/conducted on mould samples by cutting the samples into dumb-bell shapes according to ASTM D 638M using Mosanto Tensometer (type w) S/no 9875. To do this, each sample was placed between the grips of the universal testing machine in such a way that the long axis of the sample aligned with the instrument grips creating an imaginary line that joined the points at which the grips attached to the machine. The grips were uniformly and firmly tightened to forestall slippage of the sample during the test. The tensile strength of the sample was obtained and expressed in N/mm². Using the same instrument, the tensile modulus, elongation at break (E) and modulus of elasticity (MOE) were obtained from the stress-strain curves.

Flexural test

The flexural strength tests for the samples were carried out using Testometric Universal Testing machine (UTM) (WITHLAB WL2100) according to ASTM D790M. The test speed was 5mm/min while the load cell capacity and support span were 200 N and 25 mm respectively. The test was carried out at 23 ± 2 °C and relative humidity of 50 ± 5 %.

Impact test

The impact resistance test was conducted using a RESIL Impactor (6957 Piezino Turin, Italy) based on ASTM D0256. After centrally notching individual impact specimen samples of 10 mm x 10 mm x 5 mm dimension to a depth of 3mm in order to create a stress concentration area for fracture initiation, the samples were loaded onto the sample beam support of the Resil impactor. A vertical load from a fast-moving hammer having a potential energy of 150 J was thereafter made to drop at the sample

centre until it broke. The reading on the dial gauge on the machine displayed the impact energy absorbed by the sample under investigation. Impact resistance tests were carried out in duplicates and the average of the readings that indicated 3% accuracy was recorded as the impact energy value.

Hardness test

The samples hardness was measured using Asker Shore (Durometer Hardness type) in accordance with ASTM D 2240. The test which was carried out under a relative humidity of 50 ± 5 % at 23 ± 2°C was conducted on 5 replicate samples of each composite and the average values reported. For this purpose, the sample was placed on a horizontal hard surface. The Durometer was held in a vertical position with the point of indentor at least 12 mm from the sample edge. The presser foot was rapidly applied to the sample with the foot kept parallel to the sample. Hardness test was carried out at different positions (at least; 6 mm apart) of the test sample and the hardness at each position was read from the Durometer instrument display screen and noted. The average value of the hardness was calculated and the recorded as the sample hardness.

Chemical resistance test

ASTM D 543-95 standard was used in carrying out the Chemical resistance tests. The four standard chemical reagents selected were: 10% HCl, NaOH, NaOCl, and H₂O₂ solution. Five specimens were prepared and dried in an oven for 24 hours at 40 °C for each composite. The dried specimen were weighed to a precision of about 1mg and placed in four chemicals at room temperature for 7, 14, 56 and 90 days days respectively at different concentration and formulations. At the expiration of the stipulated time/days, the samples were removed with forceps from the chemicals and dried in an oven for 24 hours at 40°C. The changes in weighth of the specimens were calculated using the oven dried weight before and after immersion in the various solutions. The weight loss in each sample at any step due to the effect of the chemicals, signified as the degree of chemical resistance was estimated from its calculated weight before and after immersion in the various chemicals using the model below:

$$\% \text{ W.C.R.} = (\text{WB} - \text{WA}) \quad (1)$$

where W.C.R. is weight of the sample after chemical treatment while WB and WA are the weights before and after immersion in the various chemicals.

RESULTS AND DISCUSSION

Characterization

Figures 1 and 2 show the results of the infra-red analysiscarried out. Untreated rattan fibre spectrum as

shown in Figure 1 indicate that OH-stretching vibration of cellulosic structure have a peak intensity of 3302.4 cm^{-1} showing the presence of O–H and H–bonded stretch of the alcohols and phenols compounds. This peak intensity was observed to have shifted after the sodium hydroxide treatment to 3377.0 cm^{-1} . The peak that is seen at a frequency of 2970.0 cm^{-1} showed there is a presence of C–H stretching vibration of cellulose/hemicellulose which changed to 2922.2 cm^{-1} after the sodium hydroxide treatment was carried out [29]. The C=O linkage of hemicellulose in the raw rattan fibre is exhibited by the band of 1699.7 cm^{-1} which becomes 1707.1 cm^{-1} after carrying out chemical treatment on it. The peak at 1602.8 cm^{-1} and 1509 cm^{-1} of untreated rattan fibre indicate the presence of C=C aromatic stretching vibration which can be attributed to the presence of lignin which peaks at 1606.5 cm^{-1} after sodium hydroxide treatment. The peak which had appeared at a frequency of 1360.5 cm^{-1} shows that there is the presence of C–H of alkanes. The peak which appeared at frequency of 1230 cm^{-1} implies that there is also a presence of C–H, ($-\text{CH}_2\text{X}$) stretch of alkyl halides. The peak which can be seen at a frequency of 1028.7 cm^{-1} proves the presence of C–N stretch of aliphatic amines in the sample.

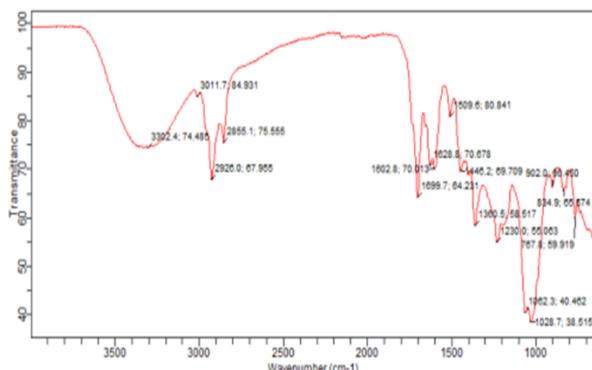


Figure 1. FT-IR crystallography of the untreated rattan cane fibre

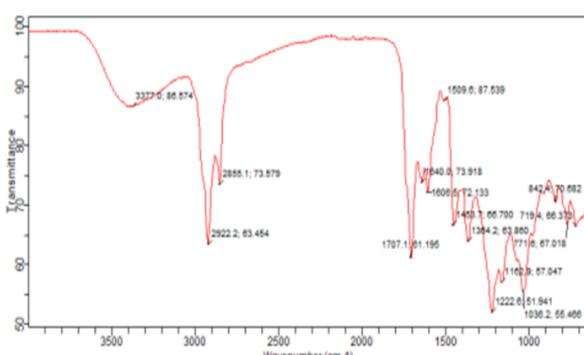


Figure 2. FT-IR crystallography of the treated rattan cane fibre

Morphology

The SEM micrographs as illustrated in Figures 3, 4 and 5 show the rattan fibres effects on the composites. It was observed that the micrograph showed various level of adhesion. In Figure 4 (a and b), it can be seen that the samples showed a smoother adhesion compared to the samples in Figure 5 (b). It is very clear that the fibre weight of 10 to 25 wt % increases the effective surface area that is available for wetting in the epoxy. The low strength can be attributed to the voids arising from fibre debonding and it pull-out at the lower fibre contents of 5 to 10 wt %. Agglomeration of the fibre was observed at higher fibre contents of 20 to 30 wt%. At 30 wt %, unstable interfacial adhesion between fiber/filler and matrix were observed as shown in Figure 5 (b). The presence of pits and global marks after the chemical treatment is helpful for increasing the effective surface area for bonding. The roughness of the fibre surface increases and consequently improve the mechanical bonding with the polymer matrix. The surface roughness of treated rattan fiber resulting in more mechanical interlocking between fibers with matrix confirms with that reported by Sun et al. [30]. In addition, the colour of the composites is ash black/brown due to removal of lignin [31]. The hardness properties that increases with increase in the fibre content may be due to the fibre being spread during mechanical agitation, going in between the epoxy molecular chains, and destroying the hydrogen bonding between the intermolecular chains/branches of the matrix.

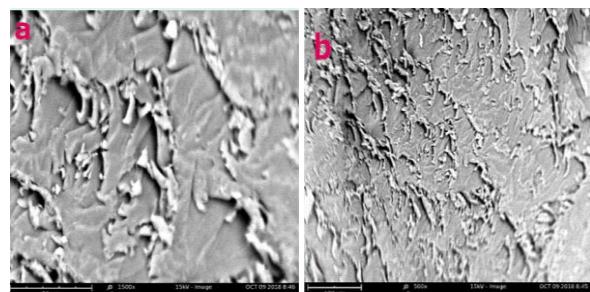


Figure 3. SEM micrographs of epoxy resin based composites reinforced with (a) 0 wt % rattan fibre (b) 10 wt % rattan fibre

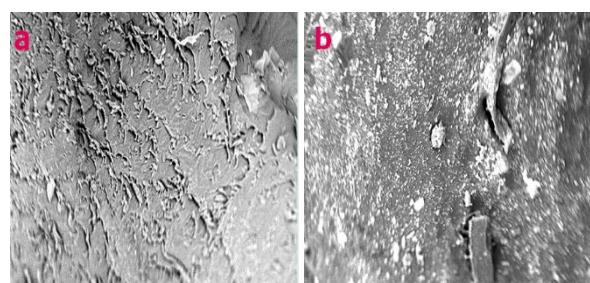


Figure 4. SEM micrographs of epoxy resin based composites reinforced (a) 15 wt % rattan fibre (b) 20 wt % rattan fibre

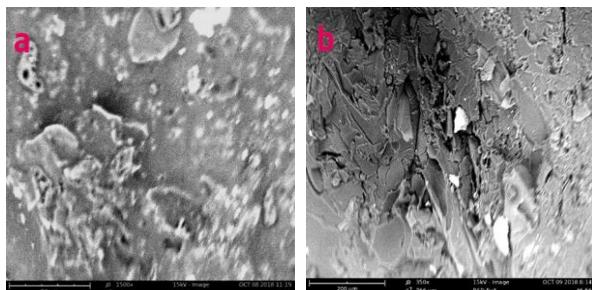


Figure 5. SEM micrographs of epoxy resin based composites reinforced (a) 25 wt % rattan fibre and (b) 30 wt % rattan fibre

Mechanical properties

Tensile strength

The result of the tensile strength test is shown in Figure 6 (a) where it was seen that 25 wt. % reinforcement from composites gave optimum value. The gradual increase in tensile strength with filler loading is noticed before it starts decreased at 30 wt %. The increase in tensile strength is as a result of surface area of the plant fibre having better polymer filler interaction as the filler content increases which is in agreement with some studies. Study on the palm kernel shell fibre/particulate cassava peel hybrid reinforced epoxy composites showed that fibre size and fibre content influence the mechanical properties of the composites [32]. The factors that affect the reinforcing potentials of fillers include filler dispersions, surface area reactivity, bonding capacity (quality) particle size between the filler and the polymer matrix. This property will help to promote the profitable utilization of rattan cane as an alternate to the synthetic materials that are mostly used as fillers in epoxy and other materials. The tensile strength properties of the composites indicates that they can be used for applications where light weight and medium strength properties is required [33].

Young modulus

The Young modulus result is presented in Figure 6 (b).

The trend is Similar to that of the tensile strength. The 25 wt. % composite sample showed the best modulus with a value of 2171 MPa followed by the 20 wt. % composite sample. At 25 wt. % fibre loading, Young's modulus value of the composite is 48 % higher than that of neat epoxy resin. The tensile modulus of the neat epoxy matrix (1469.85 MPa) increased to a maximum of 2170.92 MPa on the 25 wt. % fibres. Good dispersion of the rattan fibre particles in the epoxy matrix as well as to the good interfacial adhesion between the rattan fibre particles and the epoxy matrix contributed to the improvement in Young's modulus. Beyond 25 wt. % rattan fibre particles addition, the young modulus value of the composites decreased. This may have been resulted from lower degree of dispersion. Poorly dispersed aggregates of rattan particles can lead to reduction in the Young's modulus value by splitting up under load. Moreover; addition of more than 25 wt. % rattan particles may also lower the cross-link density. Hence, composite resin may become less stiff and polymer chains can move more easily. Consequently, this leads to a decrease in Young's modulus value. The surface modification due to the chemical treatment contributed to the Young's modulus value by exposing the cellulose rough surface. This was in agreement with the submissions of Oladele et al. [32] and Obiukwu et al. [34].

Flexural strength

The flexural strength results is shown in Figure 7 (a). All the composites possess better flexural strengths than the neat epoxy matrix. The trend was similar to that observed in Young modulus of Figure 6 (b) where all the samples had better property than the pure epoxy matrix. Despite, an improvement in the flexural strength, an initial increase from 5 to 25 wt. % was followed by rapid decline from 25 to 30 for the samples. 25 wt.% treated rattan/epoxy reinforced composite possess the best result with a value of about 27.54 MPa followed by the 20 wt.% sample with a value of about 26.65 MPa while the worst

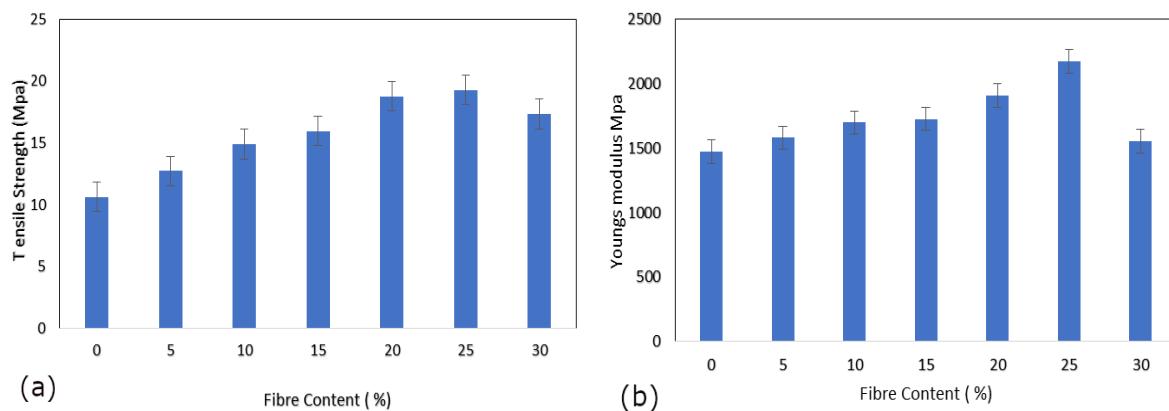


Figure 6. (a) Tensile strength, (b) Young modulus of the composites

result was the neat epoxy matrix with a value of 15.16 MPa. The percentage improvements were 82 % and 76 %, respectively which implies an improvement over the tensile properties as obtained in figures 4a and 4b. Ebu et al. [35] reported increase in the flexural strength of PP-mica composites with increments in the mica content of the composite in the effect of mica reinforcement on the mechanical properties of PP. Ghali et al. [36], Zhang et al. [37] and Oladele et al. [38], respectively reported similar enhanced flexural properties. After, investigating the mechanical, thermal, morphology and decay properties of hazel nut husk filled polymer composites, Tufan et al. [39] discovered that the addition of a coupling agent significantly improved the values of the flexural and tensile moduli as well as that of the elongation at break. It is probable that the large amount of rattan fibre in the 30 wt. % composites overwhelmed the binding capacity of the epoxy matrix. This depreciated the degree of adhesion between the epoxy and the rattan filler and subsequently resulted in the depreciation and failure of the flexural strength property.

Flexural modulus

Figure 7 (b) shows the behavior of flexural modulus with rattan fibre loading. It was observed that the flexural modulus of the epoxy/rattan composites increased continuously with increasing rattan fibre content. Maximum improvement was achieved at 25 % rattan fibre content. The flexural modulus is shown to be 5.08 GPa at 25 wt %. At 30 wt%, modulus reduction takes place. Conversely, significant moduli decline was observed at the fibre content of 5, 10 and 15 wt %, and this trend was considerably noticed at 5 wt%. The low sensitivity of tensile modulus of the composites to the adhesion between rattan fibre reinforcements and epoxy matrices can be attributed its tensile strength as observed by Dong et al. [40].

Elongation at break

The elongations at break for composites is shown in Figure 8. It generally decreased as the fibre loading

increased from 5 to 30 wt %. It is noteworthy that rattan cane fibres meets the minimum elongation requirement of 12 % specification when compared with other natural fibres like jute, sisal and bamboo, with relatively small elongation values at 4 -10 %, 1.16 –1.5% and 3–7% [41, 42] respectively. The elongation at break in good agreement with PP/treated coir composites [43].

Impact strength

Figure 9 (a) shows results of impact strength for the produced composites. Impact Strength is a property of material that describes amount of energy it can absorb before it fracture. The result as shown indicates that the neat epoxy sample have impact strength of 11.23 J/mm and the impact strength improved as the amount of rattan cane fibre was increased with the 25 % wt % composite demonstrating the largest impact resistance. The effect of impact strength increased by increase in fibre loading due to proper interfacial bonding and alignment between the matrix and the filler. However, the drop in impact strength (from 25 to 30 wt%) could be due to inadequate circulation of epoxy matrix around each ratta fibre, leading to poor fibre-matrix interaction which resulted in reduction in the amount of impact energy absorbed per unit area. This is agreed by the findings of Zhang et al. [44].

Hardness test

Hardness results for the fabricated composites as shown on the Figure 9 (b). Hardness property of material describes its ability to resist indentation. The control sample has hardness of 90.88 Shore A. From the result it was observed that there was an increase in hardness from 90.88 to 97.69 Shore A on the investigated composite. The hardness tends to increase with increasing fibre loading respectively but was affected as the filler loading exceeds 30 wt % filler loading as shown by the investigations. It showed that the composites demonstrated enhanced stiffness, rigidity and firmness as the filler content continued to increase. The behaviour could be linked to the increased adhesion between the

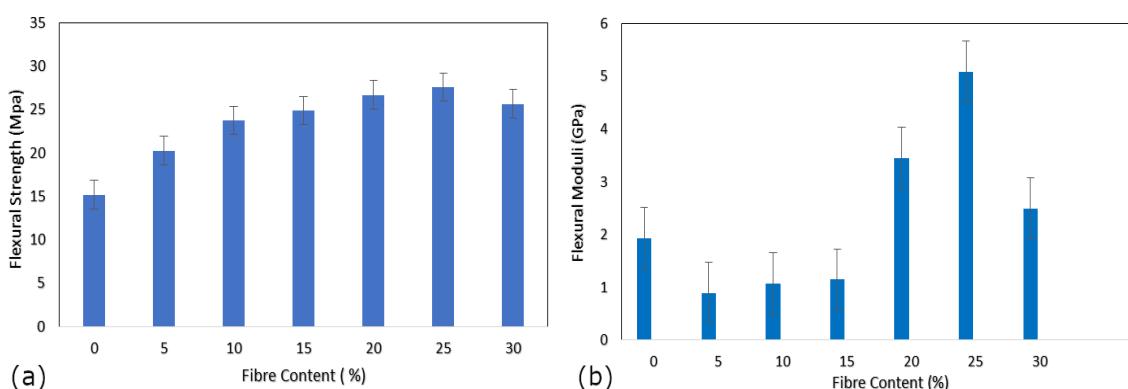


Figure 7. (a) Flexural strength, (b) Flexural modulus of the composites

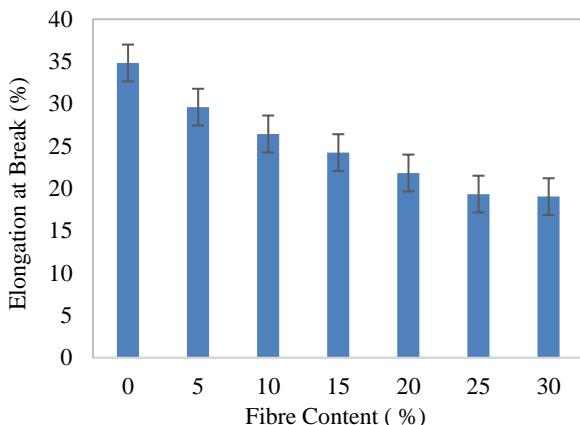


Figure 8. Percent elongation of the composites

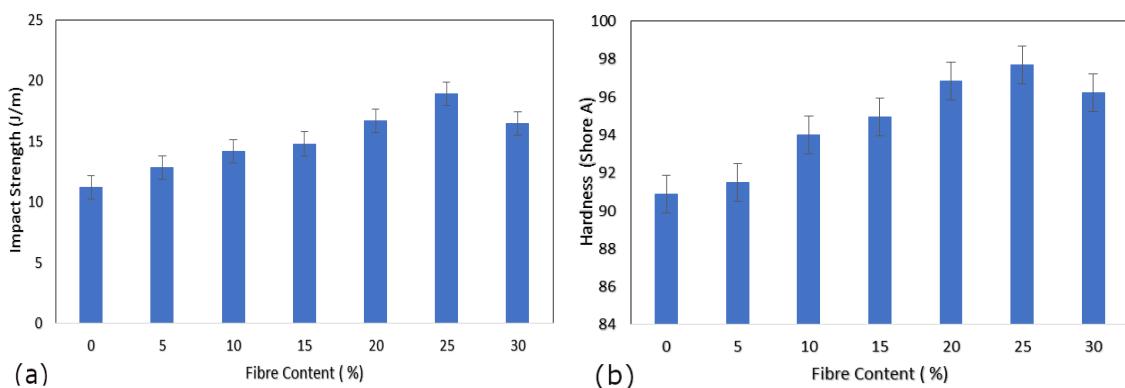


Figure 9. (a) Impact resistance of the composites, (b) Hardness of the composites

The concentration of the chemicals used were as follow; 10% each of HCl, NaOH, H₂O₂ and bleach solution (NaOCl). The weights of the rattan cane filled epoxy composites were adversely affected on treatment with HCl, followed by bleach solution NaOH, and then 10% NaOCl. The other chemicals H₂O₂ solution exhibited small decreases in weights of the composites. Rattan cane fibres are rich in cellulose and hemi-cellulose [47] and celluloses are of low acid resistance. Therefore, the considerable decrease in the weights of composites can be attributed to the degradation of cellulose. Bleach solution (NaOCl) contains OCl⁻ ion which is found in chemicals mostly used in pulp bleaching and paper production [48]. OCl⁻ which is highly reactive degrades the structure of lignin through breakage of the chemical bonds. This breakage manifests in weight losses on exposure to NaOCl solution with the resultant decrease in the weights of the composites. The effect of NaOH on the other hand may be associated to its reaction with cellulose present in the fibres, which have the tendency to undergo oxidative degradation with the resultant decrease weights of the composites. The present study shows that all composites manifested much reduction in

epoxy and the rattan fibre. The hardness properties of the composite with increased percentage filler loading could also be related to the fact that Rattan Cane fibre stiffens the polymer core making it more resistant to indentation. Ganiu Agbabiaka et al. [45] discovered that the hardness properties of reinforced PP composites was improved with increased treated sponge fibre loading on reinforced PP composites. The study is also in agreement with some other works [46].

Chemical Resistance Properties

The investigations on the effects of the some selected chemicals (HCl, NaOH, H₂O₂ and NaOCl) on the weights of the composites are as illustrated in Figures 10.

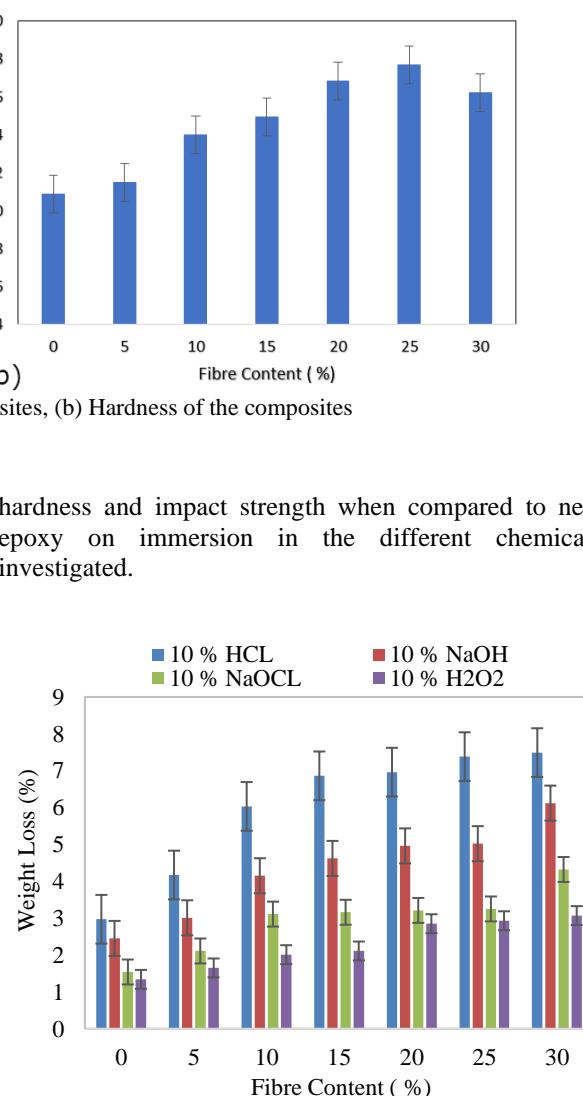


Figure 10. Weigh loss of rattan (*Calamus deeratus*) fibre filled epoxy composites and control after immersion in different chemical media

CONCLUSIONS

Mechanical and chemical resistance of Rattan (*Calamus deeratus*) fibre Filled Epoxy Composites with alkali treatment have been successfully evaluated. From the results obtained, rattan (*Calamus deeratus*) fibres have been found to affect the mechanical and chemical resistance properties of epoxy resins at the fibre contents studied. There is improved adhesion of smaller particle size, which indicates that particle size can affect adhesion and better fibre performance as indicated by SEM micrographs. The decrease in tensile strength for composites after peaking can be associated with the voids due to pull-out of fibre and its debonding at the fibre contents of at 30 wt%, as well as the fibre agglomeration at high fibre contents. This results in low adhesion between the polymer matrix and cellulosic fillers. The tensile/flexural strengths of treated fibre composites were better than those of neat epoxy. The chemical test studied showed that chemicals can attack and degrade the quality of the components and the extent of degradation is in direct relation with the quantity of the fibre, temperature, nature and concentration of the chemical used. HCl, NaOCl and NaOH solutions greatly affected the weight of rattan fibre filled epoxy whereas H₂O₂ had negligible effects, and showed very small weight changes. Reinforcement content with optimum value was 25 wt. % from chemically treated Rattan (*Calamus deeratus*) fibre reinforced composites. Thus the composite can provide potential materials for some engineering application.

REFERENCES

- Coir-Polyester Composite: Effect on fibre surface treatment on mechanical properties of composite, International Plastics Engineering and Technology, 4: 79–86.
- Ray, D., Sarkar, B. K., Rana, A. K., & Bose, N. R., 2001, Effect of alkali treated jute fibres on composite properties, Bulletin of Materials Science, 24(2): 129–135. <https://doi.org/10.1007/BF02710089>
 - Sreekala, M. S., Kumaran, M. G., Joseph, S., Jacob, M., & Thomas, S., 2000, Oil palm fibre reinforced phenol formaldehyde composites: influence of fibre surface modifications on the mechanical performance, Applied Composite Materials, 7(5–6): 295–329. <https://doi.org/10.1023/A:1026534006291>
 - Paul, A., Joseph, K., & Thomas, S., 1997, Effect of surface treatments on the electrical properties of low-density polyethylene composites reinforced with short sisal fibers, Composites Science and Technology, 57(1): 67–79. [https://doi.org/10.1016/S0266-3538\(96\)00109-1](https://doi.org/10.1016/S0266-3538(96)00109-1)
 - Kalia, S., Kaith, B. S., & Kaur, I., 2009, Pretreatments of natural fibers and their application as reinforcing material in polymer composites-a review, Polymer Engineering and Science, 49(7): 1253–1272. <https://doi.org/10.1002/pen.21328>
 - Firdaus, F. E., & Dachyar, M., 2018, Fiber Surface Modification; Characterization of Rattan Fiber Reinforced Composite, International Journal of Engineering & Technology, 7(3.7): 113–116. <https://doi.org/10.14419/ijet.v7i3.7.16250>
 - Shang, L., Jiang, Z., Liu, X., Tian, G., Ma, J., & Shumin, Y., 2016, Effect of Modification with Methyl Methacrylate on the Mechanical Properties of Plectocoma kerrana Rattan, 11(1): 2071–2082. <https://doi.org/10.15376/biores.11.1.2071-2082>
 - Lucas, E., & Dahunsi, B., 2004, Characteristics of three western nigerian rattan species in relation to their utilisation as construction material, Journal of bamboo and Rattan, 3(1): 45–56. <https://doi.org/10.1163/156915904772875635>
 - Francis, B., Thomas, S., Thomas, S. P., Ramaswamy, R., & Lakshmana Rao, V., 2006, Diglycidyl ether of bisphenol-A epoxy resin-polyether sulfone/polyether sulfone ether ketone blends: Phase morphology, fracture toughness and thermo-mechanical properties, Colloid and Polymer Science, 285(1): 83–93. <https://doi.org/10.1007/s00396-006-1537-0>
 - Miracle, D. B., & Donaldson, S. L., 2001, Introduction to Composites, ASM handbook, 21: 3–18. <https://doi.org/10.31399/asm.hb.v21.a0003350>
 - Guo, B., Jia, D., & Cai, C., 2004, Effects of organo-montmorillonite dispersion on thermal stability of epoxy resin nanocomposites, European Polymer Journal, 40(8): 1743–1748. <https://doi.org/10.1016/j.eurpolymj.2004.03.027>
 - Liu, W., Hoa, S. V., & Pugh, M., 2005, Organoclay-modified high performance epoxy nanocomposites, Composites Science and Technology, 65(2): 307–316. <https://doi.org/10.1016/j.compscitech.2004.07.012>
 - Ratna, D., Becker, O., Krishnamurthy, R., Simon, G. P., & Varley, R. J., 2003, Nanocomposites based on a combination of epoxy resin, hyperbranched epoxy and a layered silicate, Polymer, 44(24): 7449–7457. <https://doi.org/10.1016/j.polymer.2003.08.035>
 - Isik, I., Yilmazer, U., & Bayram, G., 2003, Impact modified epoxy/montmorillonite nanocomposites: Synthesis and characterization, Polymer, 44(20): 6371–6377. [https://doi.org/10.1016/S0032-3861\(03\)00634-7](https://doi.org/10.1016/S0032-3861(03)00634-7)
 - Rachchh, N. V., Ujeniya, P. S., & Misra, R. K., 2014, Mechanical Characterisation of Rattan Fibre Polyester Composite, Procedia Materials Science, 6: 1396–1404. <https://doi.org/10.1016/j.mspro.2014.07.119>
 - Ma, Y., Wu, S., Tong, J., Zhao, X., Zhuang, J., Liu, Y., & Qi, H., 2018, Tribological and mechanical behaviours of rattan-fibre-reinforced friction materials under dry sliding conditions,

- Materials Research Express, 5(3): 035101. <https://doi.org/10.1088/2053-1591/aab4a7>
23. Nikmatin, S., Syafiuddin, A., Hong Kueh, A. B., & Maddu, A., 2017, Physical, thermal, and mechanical properties of polypropylene composites filled with rattan nanoparticles, *Journal of Applied Research and Technology*, 15(4): 386–395. <https://doi.org/10.1016/j.jart.2017.03.008>
24. Balakrishna, N. S., Ismail, H., & Othman, N., 2014, Polypropylene/Rattan Powder/Kaolin Hybrid Composites: Processing, Mechanical and Thermal Properties, *Polymer - Plastics Technology and Engineering*, 53(5): 451–458. <https://doi.org/10.1080/03602559.2013.844833>
25. Nikmatin, S., Syafiuddin, A., Beng Hong Kueh, A., & Aris Purwanto, Y., 2015, Effects of nanoparticle filler on thermo-physical properties of rattan powder-filled polypropylene composites, *Jurnal Teknologi*, 77: 2180–3722. Retrieved from www.jurnalteknologi.utm.my
26. Penn, L. S., & Chiao, T. T., 1982, Epoxy Resins, In *Handbook of Composites* (pp. 57–88). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4615-7139-1_5
27. Preet Singh, J. I., Dhawan, V., Singh, S., & Jangid, K., 2017, Study of Effect of Surface Treatment on Mechanical Properties of Natural Fiber Reinforced Composites, In *Materials Today: Proceedings* (Vol. 4), pp. 2793–2799. <https://doi.org/10.1016/j.matpr.2017.02.158>
28. Oushabi, A., Sair, S., Oudrhiri Hassani, F., Abboud, Y., Tanane, O., & El Bouari, A., 2017, The effect of alkali treatment on mechanical, morphological and thermal properties of date palm fibers (DPFs): Study of the interface of DPF-Polyurethane composite, *South African Journal of Chemical Engineering*, 23: 116–123. <https://doi.org/10.1016/j.sajce.2017.04.005>
29. Obiukwu, O. O., & Igboekwe, J. E., 2020, Investigations on the Thermal and Dynamic-Mechanical Properties of Rattan Cane Fibre (*Calamus Deerratus*) Filled Epoxy Composites, *International Journal of Engineering Research & Technology*, 9(2): 416–420. Retrieved from www.ijert.org
30. Sun, Z., Zhang, L., Liang, D., Xiao, W., & Lin, J., 2017, Mechanical and Thermal Properties of PLA Biocomposites Reinforced by Coir Fibers, *International Journal of Polymer Science*, 2017: 1–8. <https://doi.org/10.1155/2017/2178329>
31. Tran, T. P. T., Bénézet, J. C., & Bergeret, A., 2014, Rice and Einkorn wheat husks reinforced poly(lactic acid) (PLA) biocomposites: Effects of alkaline and silane surface treatments of husks, *Industrial Crops and Products*, 58: 111–124. <https://doi.org/10.1016/j.indcrop.2014.04.012>
32. Oladele, I. O., Ibrahim, I. O., Adediran, A. A., Akinwekomi, A. D., Adetula, Y. V., & Olayanju, T. M. A., 2020, Modified palm kernel shell fiber/particulate cassava peel hybrid reinforced epoxy composites, *Results in Materials*, 5: 100053. <https://doi.org/10.1016/j.rinma.2019.100053>
33. Dawit, J. B., Regassa, Y., & Lemu, H. G., 2020, Property characterization of acacia tortilis for natural fiber reinforced polymer composite, *Results in Materials*, 5: 100054. <https://doi.org/10.1016/j.rinma.2019.100054>
34. Obiukwu, O., Opara, I., & Udeani, H., 2016, Study on the mechanical properties of palm kernel fibre reinforced epoxy and poly-vinyl alcohol (PVA) composite material, *International Journal of Engineering and Technologies*, 7: 68–77. Retrieved from <https://doi.org/10.18052/www.scipress.com/IJET.7.68>
35. Erdogan, S., & Huner, U., 2018, Physical and Mechanical Properties of PP Composites based on Different Types of Lignocellulosic Fillers, *Journal Wuhan University of Technology*, Materials Science Edition, 33(6): 1298–1307. <https://doi.org/10.1007/s11595-018-1967-9>
36. Ghali, L., Msahli, S., Zidi, M., & Sakli, F., 2011, Effects of Fiber Weight Ratio, Structure and Fiber Modification onto Flexural Properties of Luffa-Polyester Composites, *Advances in Materials Physics and Chemistry*, 01(03): 78–85. <https://doi.org/10.4236/ampc.2011.13013>
37. Zhang, Q., Yi, W., Li, Z., Wang, L., & Cai, H., 2018, Mechanical Properties of Rice Husk Biochar Reinforced High Density Polyethylene Composites, *Polymers*, 10(286): 1–10. <https://doi.org/10.3390/polym10030286>
38. Oladele, I. O., Ibrahim, I. O., Akinwekomi, A. D., & Talabi, S. I., 2019, Effect of mercerization on the mechanical and thermal response of hybrid bagasse fiber/CaCO₃ reinforced polypropylene composites, *Polymer Testing*, 76: 192–198. <https://doi.org/10.1016/j.polymertesting.2019.03.021>
39. Tufan, M., Akbaş, S., Gülec, T., Taşçıoğlu, C., & Alma, M. H., 2016, Mechanical, thermal, morphological properties and decay resistance of filled hazelnut husk polymer composites, *Maderas: Ciencia y Tecnología*, 17(4): 865–874. <https://doi.org/10.4067/S0718-221X2015005000075>
40. Dong, Y., Ghataura, A., Takagi, H., Haroosh, H. J., Nakagaito, A. N., & Lau, K. T., 2014, Polylactic acid (PLA) biocomposites reinforced with coir fibres: Evaluation of mechanical performance and multifunctional properties, *Composites Part A: Applied Science and Manufacturing*, 63: 76–84. <https://doi.org/10.1016/j.compositesa.2014.04.003>
41. Adewuyi, A. P., Otukoya, A. A., Olaniyi, O. A., & Olafusi, O. S., 2015, Comparative Studies of Steel, Bamboo and Rattan as Reinforcing Bars in Concrete: Tensile and Flexural Characteristics, *Open Journal of Civil Engineering*, 05(02): 228–238. <https://doi.org/10.4236/ojce.2015.52023>
42. Bismarck, A., Mishra, S., & Lampke, T., 2005, Plant fibers as reinforcement for green composites, In *Natural Fibers, Biopolymers, and Biocomposites* (pp. 37–108). CRC Press. <https://doi.org/10.1201/9780203508206.ch2>
43. Gu, H., 2009, Tensile behaviours of the coir fibre and related composites after NaOH treatment, *Materials and Design*, 30(9): 3931–3934. <https://doi.org/10.1016/j.matdes.2009.01.035>
44. Zhang, Q., Li, Y., Cai, H., Lin, X., Yi, W., & Zhang, J., 2019, Properties comparison of high density polyethylene composites filled with three kinds of shell fibers, *Results in Physics*, 12: 1542–1546. <https://doi.org/10.1016/j.rinp.2018.09.054>
45. Ganiu Agbabiaka, O., Oluwole Oladele, I., & Daramola, O. O., 2015, Mechanical and Water Absorption Properties of Alkaline Treated Coconut (*cocosnucifera*) and Sponge (*acanthus montanus*) Fibers Reinforced Polypropylene Composites, *Columbia International Publishing American Journal of Materials Science & Technology*, 4(2): 84–92. <https://doi.org/10.7726/ajmst.2015.1007>
46. Opara, H., Igwe, I., & Ewulonu, C., 2016, Mechanical and Chemical Resistance Properties of High Density Polyethylene Filled with Corncob and Coconut Fiber, *International Research Journal of Pure and Applied Chemistry*, 11(2): 1–10. <https://doi.org/10.9734/irjpac/2016/22902>
47. Krisdianto, K., Jasni, J., & Tutiana, T., 2018, Anatomical Properties of Nine Indigenous Rattan Species of Jambi, Indonesia, *Indonesian Journal of Forestry Research*, 5(2): 147–161. <https://doi.org/10.20886/ijfr.2018.5.2.147-161>
48. Tejas V. Shah, & Dilip V. Vasava, 2019, A glimpse of biodegradable polymers and their biomedical applications, *e-Polymers*, 19(1): 385–410. <https://doi.org/10.1515/epoly-2019-0041>

Persian Abstract

DOI: 10.5829/ijee.2020.11.04.10

چکیده

اثرات محتوای فیبر بر مکانیک، مورفولوژی سطح و مقاومت شیمیایی کامپوزیت فیبر اپوکسی / خیزان بررسی شد. با تجزیه و تحلیل میکروسکوپ الکترونی روبشی (SEM)، بررسی مکانیکی و شیمیایی، تصویر نشان می دهد که الیاف چوب خیزان چسبندگی و توزیع نسبیًّا یکنواخت فیبر در ماتریس را بهبود بخشیده است. نتیجه مشابهی برای مقاومت های خمشی و کششی با افزایش تدریجی مقاومت ها با بارگذاری پرکننده مشاهده شد. خواص مکانیکی با افزایش بارگذاری فیبر، به حد اکثر رساندن محتوای ۲۵ درصد وزنی بهبود یافت. بهترین مقاومت در برابر کشش و ضربه در ۲۵ درصد وزنی ماده پرکننده با مقدار ۱۹/۲۷ Mpa و ۱۸/۷۸۶ J/m بدست آمد. ۴/۴۸ درصد افزایش سختی به دست آمده در ۱۵ درصد وزنی، ۶/۵۵ درصد افزایش سختی در ۲۰ درصد بود، در حالی که ۷/۴۶ درصد افزایش سختی در ۲۵ درصد وزنی بدست آمد که نشان دهنده بالاترین سختی برای فیبرهای اختصاصی درصد وزنی است. مقاومت خمشی به دست آمده برای نمونه های ارائه شده با افزایش میزان فیبر افزایش می باید، در حالی که بهترین نتیجه مقاومت خمشی ۲۷۴/۵۴ مگاپاسکال در ۲۵ درصد وزنی فیبر مشاهده شد. کامپوزیت اپوکسی خیزان پس از آزمایش در محلول ۱۰ درصد HCl، NaOCl و NaOH تا حد زیادی کاهش یافت. نتیجه غوطه ور شدن در محلول H₂O₂ اثرات ناچیزی را در کاهش وزن نشان داد.