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HYBRID NATURAL FIBER REINFORCED EPOXY COMPOSITES: THE ROLE OF SUGARCANE AND COW HAIR

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Abstract: Several works have been carried out using natural fibres as reinforcement in polymer matrix for several applications. This research work investigated mechanical and physical properties of varying single and hybrid reinforced composites using cow hair and sugar cane bagasse fibres sourced from both animal and plant waste. Homogenous mixture of the reinforcements and matrix were poured into their respective mould and allowed to cure before removal and allow further curing at ambient temperature within 21 days. The developed composites after curing were evaluated for flexural, hardness and wear in accordance with ASTM standards. The morphology of the fractured surfaces of the composites and the reinforcements were observed using scanning electron microscope. The results shows that both bagasse and cow hair fibers aided the improvement in the selected properties over unreinforced epoxy. Sample with 15 wt% sugarcane bagasse fiber reinforced epoxy composite has 3.11 GPa for flexural modulus while sample with 12 wt.% cow hair fiber and hybrid reinforced sample had 72 HS to emerged as the most improved samples for hardness. Sample with 3wt % cow hair fiber was the best in wear resistance with a value of 0.065 g. Thus, significant enhancement can be attained with the use of animal and plant-based reinforcements in epoxy matrix needed for structural applications in other to advance the use of eco-friendly materials in composite development.

Keywords: Epoxy, cow hair, sugar cane bagasse, SEM, hardness, flexural.

INTRODUCTION

There has been a proliferation of research into the development of natural fibre reinforced polymeric composites with the aim of replacing the more expensive synthetic fibres with the readily available natural fibres which are hitherto wastes and contribute to environmental pollution due to problems with disposal. The interest in using natural fibres in composite development is no doubt due to their light weight, nonabrasive, combustible, nontoxic, low cost and biodegradable properties. However, poor interfacial adhesion, low melting points and poor resistance to moisture absorption, make the use of natural fibre reinforced composites less attractive. Pre-treatments of the fibre can clean and chemically modify the surface, stop the moisture absorption process and increase the surface roughness (Oladele et al., 2018). Composites are made up of one or more discontinuous phase embedded in a continuous phase. The Matrix is usually the continuous phase while the reinforcement is discontinuous the phase which is stronger and harder. Properties of constituent materials is usually determined by the properties of the composite material under consideration. There are other factors that influence in the enhancement of the properties of the composite such as geometry, i.e., shape, size, and distribution of the reinforcement (Mahesha *et al.,* 2019; Vidyashri *et al*., 2019; Yashas Gowda *et al*., 2018. The use of human hair fibre to reinforce polypropylene has a significant improvement in the mechanical properties of the developed composites (Dwivedi *et al*., 2015). It has been observed that low fibre weight fractions enhance mechanical and abrasion properties due to its light weight from its low density while Young's modulus and flexural modulus decrease with an increase in fibre amount in the polymer (Mishra *et al., 2*007). However, unlike vegetable fibres, most animal fibres are biological wastes such as avian feathers and mammalian hairs which are generated across the globe by agro industries in billions of tons per year (Jayathilakan *et al*., 2012). Most of these animal fibres are keratinous materials; that is, they are potential bio-resources for keratin extraction. The Mean spectra values of the principal elements that constitute amino acids in the fibres are in the same range with that of human hair fibres (Oladele, 2017). Also, sugarcane fibre particulates reinforced composites were shown to have better performance, when the wt% of the fibre increase while compared to short fibre reinforced composites and that epoxy matrix in 1 wt% SCB short fibre composite was shown to be more sufficient to cover all the surface of bagasse fibre compared to 5 wt% of SCB short fibre composite. In the research by Ambili *et al*. (2019), the results showed that**,** at higher curing temperature, better flexural, impact and tensile properties were achieved in the polymers with the incorporation of the cow horn as filler.

2. MATERIALS AND METHOD

The materials that used for this research are epoxy resin and hardener both were purchased from Pascal chemical stores. Sugarcane stems were purchased from Shasha market, Akure. Cow hair was obtained from cow sellers at Odo -Eran, market, Akure, Ondo State. The sugar cane bagasse was washed with tap water to remove the juice completely and was sun dried within 5 days. The dried bagasse fiber was cut into 10 mm length. the cow hair was extracted by scraping the hairs from the tails of white cow known as Zebu breed. This was washed properly to remove impurities it was sun dried within 5 days. The dried cow hair was cut into 10 mm length. The composite was developed by using the open mould hand lay-up method by incorporating the fibres into the epoxy matrix from 3 to 15 wt. % CHF/SBF. The epoxy resin and hardener was added in ratio 2:1 and thoroughly mixed to achieve homogeneous mixture. The homogeneous mixtures were introduced into their respective moulds designed for each property to be investigated and allowed to cure and removed from the moulds. The cured samples were allowed to further cure within 21 days.

Figure 1: Sugarcane bagasse:(i). Epoxy resin and hardener (ii). Cow hair (iii). Cow bone (iv). Cow bone particulate

Composites development

The composite was developed by using the open mould hand lay-up method by incorporating the fibres into the epoxy matrix from 3 to 15 wt. % CHF/SBF. The epoxy resin and hardener was added in ratio 2:1 and thoroughly mixed to achieve homogeneous mixture. The homogeneous mixtures were introduced into their respective moulds designed for each property to be investigated and allowed to cure and removed from the moulds. The cured samples were allowed to further cure within 21 days. The sample compositions were as shown in Table 1.

Table 1. Composition of the Developed Composites

Samples (wt.%)	Epoxy resin (%)	Bagasse (%)	Cow hair (%)
Control	100	---	---
3 SBF	97	3	--
6 SBF	94	6	--
9 SBF	91	9	--
12 SBF	88	12	--
15 SBF	85	15	--
3 CHF	97	--	3
6 CHF	94	--	6
9 CHF	91	--	9
12 CHF	88	--	12
15 CHF	85	--	15
3 HYB	97	1.5	1.5
6 HYB	94	3	3
9 HYB	91	4.5	4.5
12 HYB	88	6	6

15 HYB	85	7.5	7.5

Where; CHF-cow hair fiber; SBF-sugarcane bagasse fiber; HYB-hybrid

3. MATERIAL TESTING

The flexural strength of the samples was determined using a three-point blending test. The Universal Tensile Testing Machine Instron series 3369 model was used for the tests. The configuration followed ASTM D790 guidelines. The samples were tested by placing them in a three-point bend fixture with a displacement control rate of 10 mm/min. For each category, three samples were tested, and the average value was used as the representative value.

A Shore D hardness tester was used to test the specimen's hardness. The samples were indented while resting on the tester's stand. By indenting the samples in five different places, five values were obtained, and the average value was used for analysis.

The wear procedure follows the standard CS-10 Calibrase. The wear test was carried out with Taber abrasers, Model ISE AO16. The standard load used was 750 g and a revolution of 76 RPM. A Centre hole of 9 mm was made on the sample to fix the test piece on the machine. The sample was secured to the instrument platform which is a motor driven at a fixed speed and the values was recorded. Each specimen was a flat and round disc of approximately 100 mm^2 and a standard thickness of approximately 6.35 mm. Wear resistance was measured using the weight difference before and after abrasion (weight loss technique). Care was taken to remove loose particles adhering to specimens during testing, especially before weighing.

The morphological characterization of the surface was carried out using JOEL-JSM 7600F. Back-scattered electrons (BSE) are beam electrons that are reflected from the sample by elastic scattering. BSE are often used in analytical SEM along with the spectra made from the characteristic X-rays, because the intensity of the BSE signal is strongly related to atomic number (Z) of the specimen. BSE images can provide information about the distribution of different elements in the sample. For the same reason, BSE imaging can colloidal gold immune-labels of 5 or 10 nm diameter.

4. RESULTS AND DISCUSSION

Figure 2 illustrates the flexural strength of developed composite of single and hybrid reinforced samples with the control sample. It was discovered from the results that as the fiber content increases, the flexural strength increases. However, when compared with the control, there is no enhancement which implies that more reinforcement content is needed to bring about improvement in the flexural strength. The results show that 15 wt. % cow hair fiber reinforced composites had the best overall flexural strength 64.34 MPa among the composite samples.

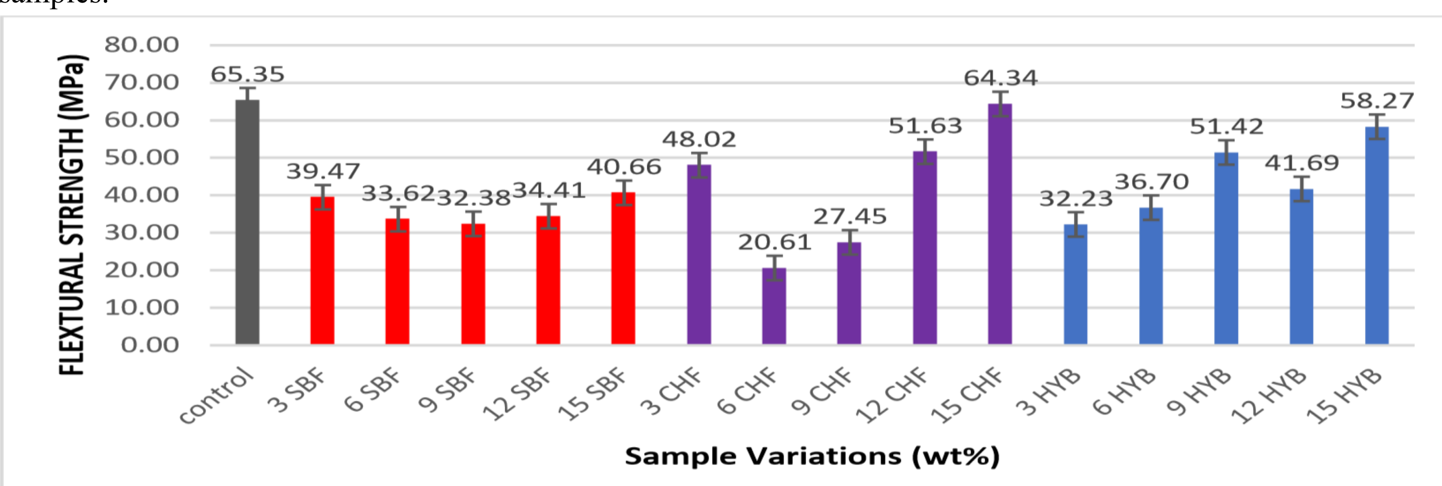


Figure 2. Flexural strength of bagasse and cow hair reinforced epoxy composites and the control

Figure 3 indicate the consideration of flexural modulus for developed single and hybrid reinforced composite and the control sample where similar trends to the results in Figure 2 was noticed. From the results, it was revealed that sample reinforced with 15 wt % sugarcane bagasse fiber had the optimum flexural modulus with a value of of 3.11GPa when compared to the control sample with a value of 2.68GPa which culminated to an improvement of about 16%. This improvement may be due to the fibre stiffness's role in the flexural characteristics.

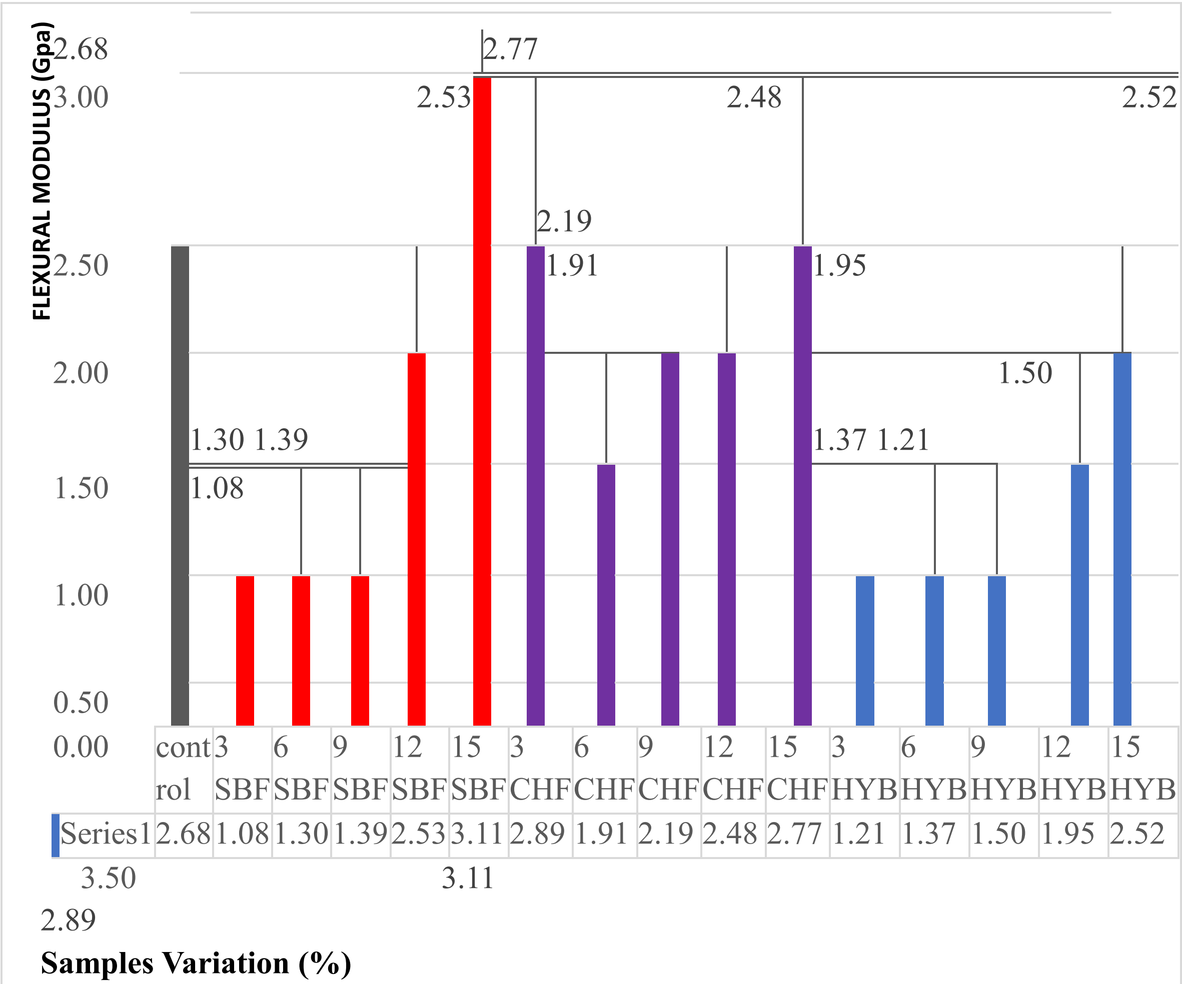


Figure 3. Flexural modulus of bagasse and cow hair reinforced epoxy composites and the control

Figure 4 showed the hardness values of developed samples for single and hybrid fiber-reinforced epoxy composites as well as control samples where it was discovered that the hardness of the developed composites were improved. It was discovered that the hardness of the composites from cow hair and its hybrids increases as the fibre content increases while for bagasse fiber-based composites, no definite order was noticed. From the results, composite samples within the range of 9-12 wt% cow hair fiber and composite sample with 12 wt% hybrid have the same hardness values of 72 HS. This gave a marginal improvement of approximately 3.4% above the control sample that is with a value of 69.6 HS. This enhancement may be due to the fiber's homogeneous distribution inside the matrix and their strong interfacial adherence to the matrix

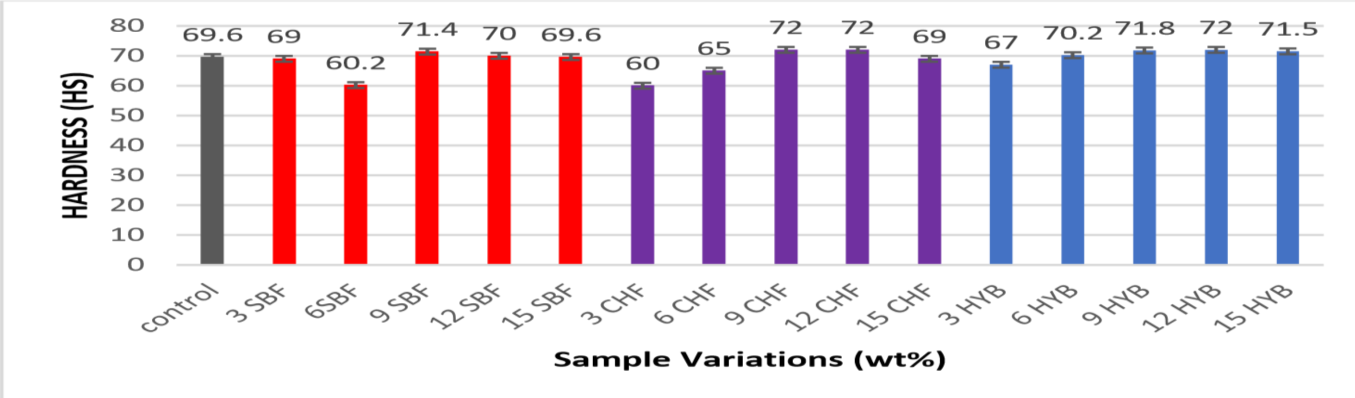


Figure 4. Hardness of bagasse and cow hair reinforced epoxy composites and the control

Figure 5 showed the wear index of developed samples for single and hybrid fiber-reinforced epoxy composites, as well as control samples. It was observed that the wear rate increases as the fiber content increases for single and hybrid composite. However, most of the developed composites possess better wear resistance than the control sample. Composite sample with 3 wt.% cow hair fiber has the least wear value of 0. 065 g to emerge as the sample with the highest wear resistance. The improvement in wear resistance of the composites was supported by the enhancement reported in hardness properties in Figure 5.

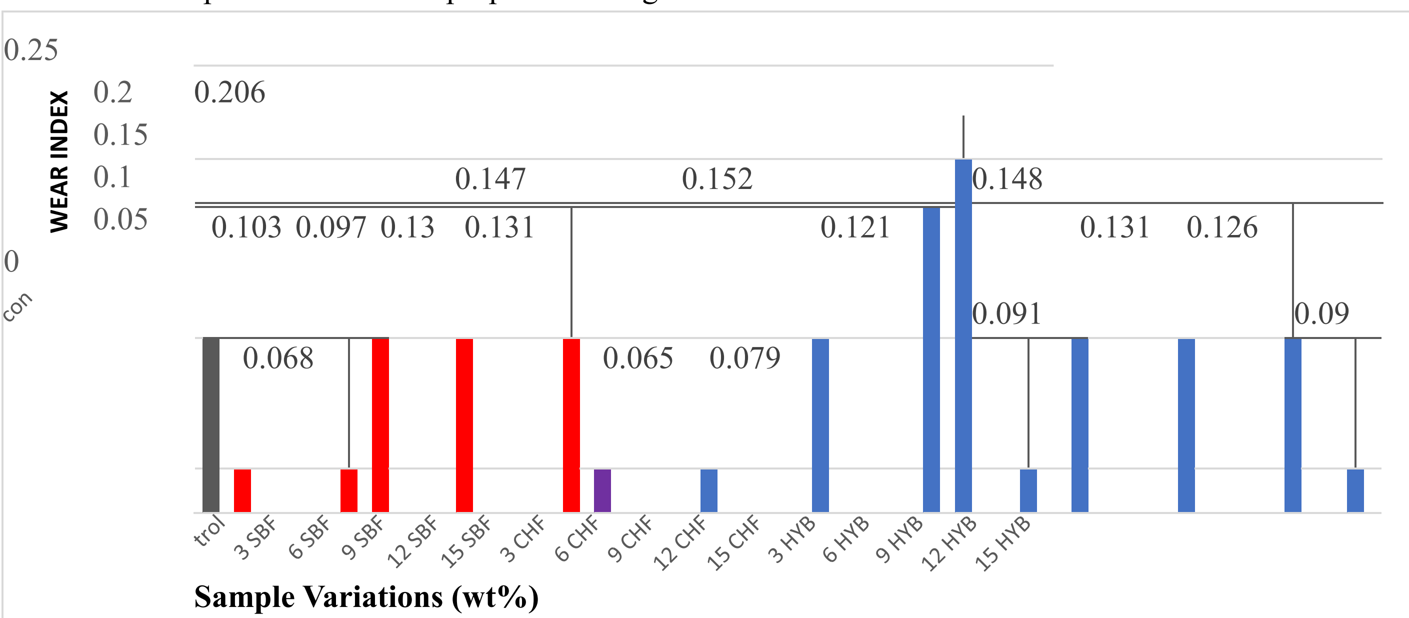
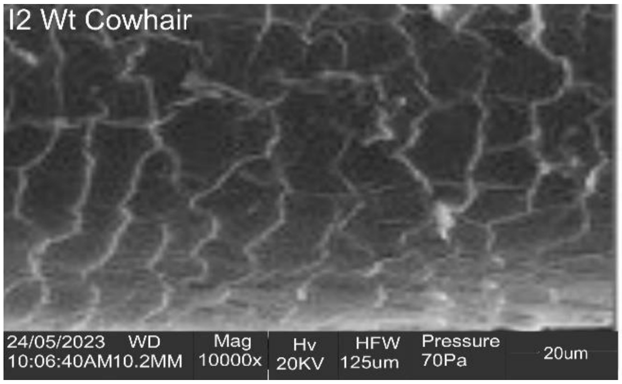


Figure 5. Wear index of bagasse and cow hair reinforced epoxy composites and the control

Scanning electron microscope (SEM) analysis was carried out on the most improved samples from each set of compositions from single and hybrid reinforcements. Plates 1 (a) showed the sample with 12 wt% cow hair fiber reinforced composite where uniform distribution of the fiber in the epoxy was noticed. This could be part of the reasons for the improved hardness and other properties examined. Likewise, Plates 2 (a) showed the sample with 15 wt% sugarcane bagasse fiber reinforced composite where uniform distribution of the fiber in the epoxy was noticed. The fibers were more noticed due to the fact that it was from plant origin compared to the one in Plate 1 (a) that is from animal. The uniform dispersion of the fiber contributed to the improved flexural modulus achieved. Also, Plates 3 (a) showed the sample with 12 wt% cow hair and sugarcane bagasse fibers reinforced composite where uniform distribution of the fiber in the epoxy was noticed. The proper blending of the two reinforcements with the epoxy could be part of the reasons for the improved hardness and other properties examined.

Plates 1-3 (b)s revealed the Energy Disperse X-ray Spectroscopy analysis where the elemental compositions showed that Silicon Si, has highest values of 26.02 for 12 wt% of CHF, 85.60 for 15 wt% of SBF and 52.00 for 12 wt% HYB with other elemental compositions. These elements also aided the improvements obtained from these composites.



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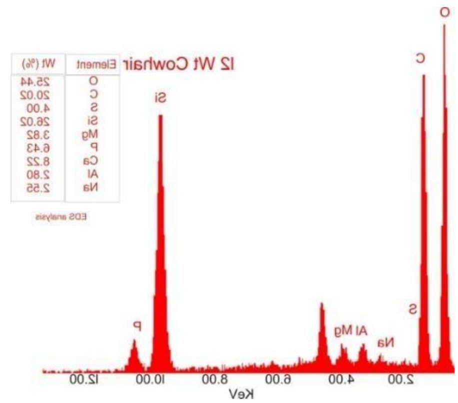
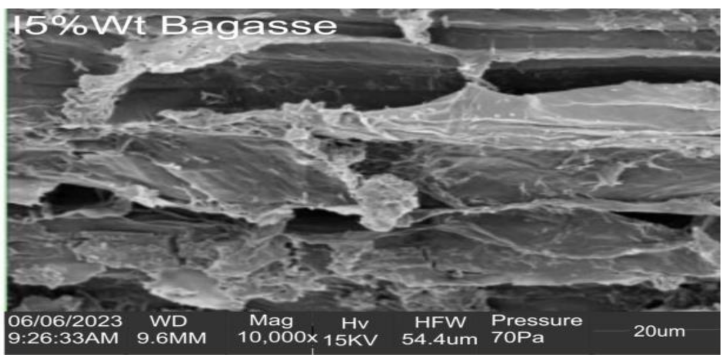


Plate 1 (a) SEM analysis 12wt% CHF **1(b) for 12wt% CHF**



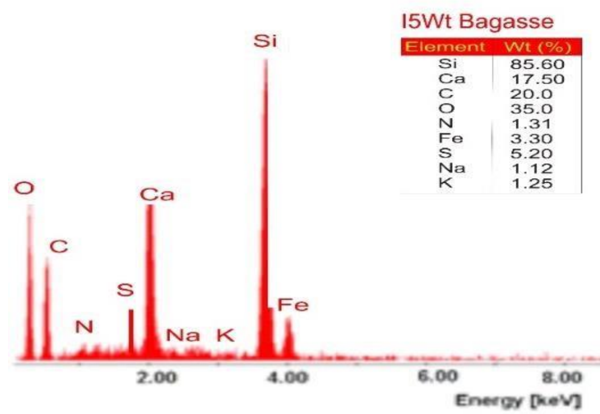
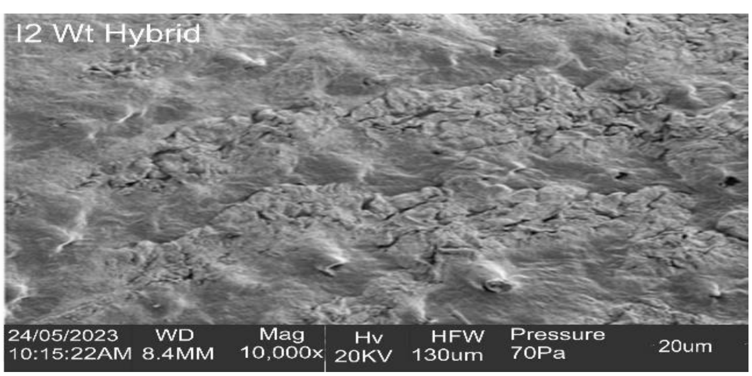


Plate 2(a) SEM analysis 15wt% SBF **2 (b) for 15wt% SBF**



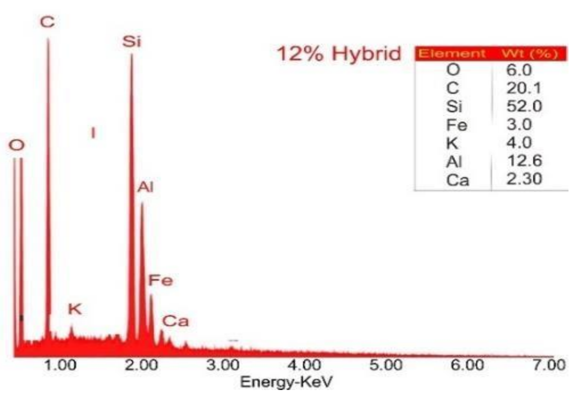


Plate 3(a) SEM analysis 12wt% HBY **3(b) for 12wt% HYB**

5. CONCLUSION

The development of animal and plant based natural fibre reinforced composites from sugarcane bagasse and cow hair with epoxy was successfully examined for structural applications. The evaluation of the selected properties aided the following conclusions from the research;

a. The results shows that both bagasse and cow hair fibers aided the improvement in the selected mechanical properties over unreinforced epoxy where sample with 15 wt% sugarcane bagasse fiber reinforced epoxy composite has 3.11 GPa for flexural modulus while sample with 12 wt.% cow hair fiber and hybrid reinforced sample has 72 HS emerged as the most improved samples for hardness.

b. Sample with 3 wt % cow hair fiber was the best in wear resistance with a value of 0.065 g

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