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COMPARATIVE INVESTIGATION OF THE INFLUENCE OF MERCERIZATION TREATMENT ON WHITE AND YELLOW MAIZE CORNCOBS REINFORCED EPOXY COMPOSITES

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Abstract: Agricultural wastes have significant potential in composite developments due to its high strength, environmentally friendly nature, low cost, availability and sustainability. An investigation was performed on the effect of chemical treatment on the reinforcement efficiency of white and yellow maize corncobs reinforced epoxy matrix composites. Epoxy resin composites reinforced with treated alkali solutions of NaOH and KOH as well as untreated yellow and white corncob particles were produced using the open moulding technique. The reinforcement was varied from 2-6 wt.% at intervals of 2 wt.% followed by mechanical and wear properties investigations. The results revealed that chemical treatment with alkali solutions enhanced the mechanical properties of the developed composites. It was observed that the flexural properties were enhanced in 2 wt. % W-NaOH and Y-KOH while tensile properties were enhanced in 2 wt. % Y-KOH corncob reinforced epoxy composites, respectively. However, 6 wt.% U-White corncob reinforced epoxy composite showed the optimum wear resistance.
Keywords: corncob; epoxy; agricultural waste; alkali treatment; mechanical properties; wear resistance

INTRODUCTION

Agricultural waste is the most abundant form of natural fibers [1] and applied in many spheres of modern industries. The utilization of such resources will not only provide sustainable and less expensive material but at the same time will contribute to waste disposal management as well as overcoming environmental problems [2].

Nowadays, natural fibers reinforced composites exhibit the superior mechanical properties than synthetic fiber reinforced polymer composites due to its inherent properties. Natural fiber reinforced composites are renewable, biodegradable, environment friendly and light weight material when compared to the synthetic fiber reinforced composites [3]. Several authors have reported recent progresses in the use of natural fibers (rice husk (RH), bagasse, bread-fruit, coconut shell and coir, etc.) in composites [4].

Corncob is the agricultural waste product obtained from maize which is one of the most important types of cereal crop in Sub-Saharan Africa. When harvested, corn wastes namely corncobs and stovers are either left to dry on the farm after which they are burnt off or found littering the streets of market places. This practice does not help in building an eco-friendly economy. A better approach to this is to convert them to more useful energy products by the use of thermochemical technologies [5].

Corncob contains approximately 39.1% cellulose, 42.1% hemicellulose, 9.1%lignin, 1.7% protein and 1.2% ash [6]. Hemi-cellulose found in natural fibers is believed to be a compatibilizer between cellulose and lignin [7]. The mechanical properties of fibers directly relates to their elemental composition, components, structure and internal defects. The percentage of cellulose influences the structure and properties of fibers such as tensile strength, electrical resistivity, density, modulus, and crystallinity. However, it should not be generalized to all kinds of fibers. Those with higher cellulose content and higher degree of polymerization of cellulose have better mechanical properties [8]. It is important to note that the properties of these fibers have been strongly influenced by their growing environments for example temperature, humidity, soil composition air and many more. All these affect the strength, height and density of the fibers.

Polymeric materials are favored by materials designers due to its light weight, easy forming, resistance to corrosion, resilience and so on. In view of the many advantages polymer has it also has its own disadvantages; its low strength limits its application especially for structural purposes so the need for reinforcement to make it stronger and meet the necessary required specification for structural applications. Polymeric materials are non-biodegradable i.e. they do not decompose on time. Incorporation of corn cob in polymer could have economic advantages and low environment impact [9].

Kiran et al., [10] carried out a study on Mechanical Properties of Corn Cob Particle and E-Glass Fiber Reinforced Hybrid Polymer Composites. From the experimental results, it was observed that the corn cob particles and E-Glass fibers reinforced hybrid epoxy composites exhibited superior properties and thus can be used as an alternate material for synthetic fiber reinforced composite materials. Salmah et al., [11] carried out a research to study the effect of corn cob content and maleic anhydride polypropylene (MAPP) as a compatibilizer on tensile properties and morphology of Polypropylene (PP)/Corn cob (CC) bio composites. It was observed that the tensile strength and elongation at break of PP/CC bio-composites decreased with increasing corn cob loading while modulus of elasticity increased. The compatibilized bio-composites have higher tensile strength and modulus of elasticity compared to the uncompatibilized bio-composites. The incorporation of compatibilizer proved to be effective in enhancing the compatibility of a system comprising of hydrophilic corn cob filler and hydrophobic polypropylene. The morphology study indicates that the interfacial adhesion between corn cob and PP matrix was enhanced with MAPP as compatibilizer.

Natural filler do not well disperse easily in polymer. Due to strong intermolecular hydrogen bonding between natural filler, they tend to agglomerate during compounding process with the matrix polymer. The low compatibility and interfacial adhesion of bio-composites lead to low mechanical properties of final product [12-14]. Therefore, study of ways to improve the interfacial adhesion between natural filler and matrix polymer is very important for the application of composites in industrial application. In recent years, the various methods that have been studied to improve the interfacial adhesion of composites, by modifying the natural filler surface have included the use of compatibilizer such as maleic anhydride-grafted polypropylene (MAPP) [15], addition of silane coupling agent [16], chemical modification on natural filler [17-18], grafting polymer matrix with hydrophilic functional group [12] and plasma treatment on surface of natural filler [19] to the reinforced polymeric composites.

Alkali treatment which is also known as mercerization is one of the most used chemical treatments on natural fibers. It is an effective low cost process to modify the fiber surface by disrupting the internal hydrogen bonding, which increases the surface roughness. Alkali treatment on natural fibers changes the crystallinity, unit cell structure and orientation of fibrils [20]. The treatment removes a certain amount of lignin, wax and oils covering the external surface of the fiber cell wall, partly depolymerizes cellulose and exposes short length crystallites [21]. It also removes hemicellulose and increases the amount of cellulose exposed on the fiber surface, thus increasing the number of possible reaction sites.

The aim of this research is to study the effect of chemical treatment (mercerization) on the reinforcement efficiency of white and yellow corncobs reinforced epoxy matrix composites.

MATERIALS AND EXPERIMENTAL PROCEDURE

» Materials

The materials used for the investigation includes Corncobs as shown in Figures 1 and 2 which serves as the reinforcement, Epoxy and hardener which serves as the matrix phase, Sodium hydroxide (NaOH) and Potassium Hydroxide (KOH) which was used as alkali or mercerizing agents.

Figure 1: White corn cob

Figure 2: Yellow corn cob

EXPERIMENTAL PROCEDURE

» **Reinforcement preparation**

The white and yellow corncobs were obtained from maize sellers in Akure, Ondo State, Nigeria and inclusions present such as dirt and nylons were handpicked. The corncobs were reduced to smaller sizes and divided into three parts each; two parts were treated with 1 molar solutions of NaOH and KOH, respectively in a shaker water bath for 4 hours in order to increase the adhesive nature of the corncob particles by reducing the lignin and hemi-celluloses contents that are present for effective binding of the matrix/fiber interface while the last part was left untreated. The treated and untreated corncobs were dried in air for 10 hours after which they were pulverized separately and screened to obtain particle size of 150 µm undersize.

» **Composite production**

The moulds were properly cleaned and lined with polyvinyl acetate (PVA) in order to enable easy removal of the composite after curing. A mixing ratio of 2:1 (epoxy: hardener) was selected based on the epoxy-hardener manufacturer's instruction. The corncob particulate was varied in predetermined proportions of 2, 4 and 6 wt. %, respectively for each species of corncob. The three moulds used for the fabrication were for tensile, flexural and wear specifications. The samples were left to cure in the mould for 6 hours after which they were removed from the moulds and allow to cure further in air for 27 days as shown in Figure 3.

Figure 3: Composite samples after curing

The following symbols were used to represent the various samples from the corncobs: Y-NaOH – Yellow corncob treated with NaOH; W-NaOH – White corncob treated with NaOH; Y-KOH – Yellow corncob treated with KOH; W-KOH – White corncob treated with KOH; U-Yellow – Untreated Yellow corncob; U-White – Untreated White corncob

» **Property test**

– Measurement of Flexural Properties

Three point bend tests were performed in accordance to ASTM D 790 M to measure flexural properties using Instron Universal testing machine. The samples were of 150 x 50 x 3 mm. Three samples were tested for each weight fraction used and the average values were taken to represent the actual values.

– Measurement of Tensile Properties

Tensile test was carried out in accordance to American Standard Testing and Measurement Method D412 (ASTM D412 1983) on Instron Universal testing machine. Composite samples with 3 mm thick and of gauge length 150 mm were used.

Three identical samples were tested for each weight fraction from where the average values were used as the representative values.

– Measurement of Wear Property

The abrasive wear test was carried out using Taber abrasion testing machine according to ASTM F732. It involves mounting a specimen to a turntable platform that rotates at a fixed speed of 1000 rpm for 20 minutes under the influence of applied specific pressure which is lowered onto the specimen surface.

A rub-wear action (sliding rotation) is produced on the surface of the test piece and the resulting abrasion marks form a pattern of crossed arcs in a circular band. The samples were measured using an analytical weighing balance to take the initial weight of the samples before and after mounting. The difference between the initial and the final values was noted and recorded against each samples. The amount of wear is determined by the weight loss. The average values from each sample were used as the representative values.

RESULTS AND DISCUSSION

The flexural strength at peak of the different composites and the neat sample were as presented in Figure 4.

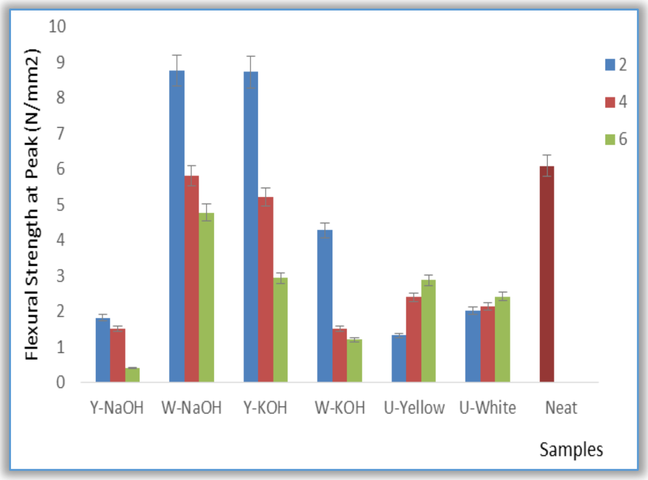

Figure 4: Variation of flexural strength at peak with the developed composites and the neat sample

From the results, it was observed that, flexural strength at peak was highly enhanced in samples with 2 wt. % from chemically treated samples while 6 wt.% was seen to have the best enhancement for the samples with untreated corncobs. However, samples with 2 wt.% for

W-NaOH and Y-KOH possess the maximum flexural strength at peak with values 8.78 and 8.73 N/mm^2, respectively.

It was also observed that samples from the treated white and yellow corncobs showed better flexural strength compared to the untreated ones with the exception of Y-NaOH. This may be due to the surface modification that has taken place as result of the mercerization of the corncobs which might have enhanced the filler properties [22-23].

The flexural modulus of the different composites and the neat sample are presented in Figure 5 where it was observed that 2 wt. % white corn cob treated with NaOH showed the maximum flexural modulus with a value 277.53 N/mm^2. The result showed similar trend to that of flexural strength at peak with the exception of U-Yellow that followed the pattern of the treated corncobs reinforced epoxy composites.

Therefore, next to 2 wt.% W-NaOH sample was 2 wt. % Y-KOH with a value of 266.32N/mm^2. This shows that the treatment of the fibers with these alkali solutions led to increase in flexural properties and that the enhancement occurred at low filler content of 2 wt. %. This may be due to the fact that at high content, there is the tendency for the natural filler material to form clusters and coagulate and, as a result damage of reinforcement surface. Sodium hydroxide (NaOH) treated corncob was seen to be best in the enhancement of the flexural properties.

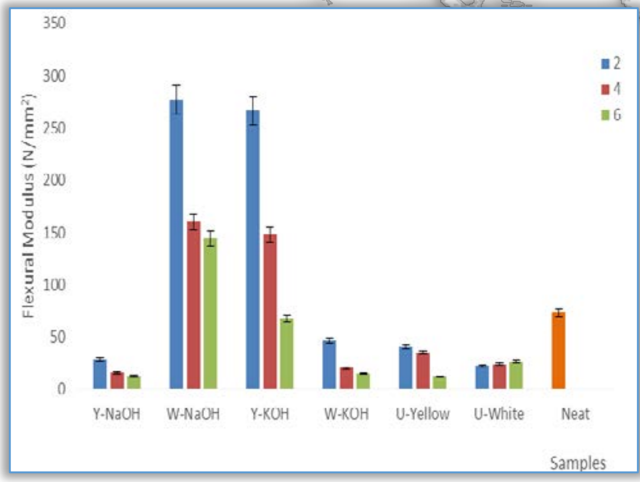

Figure 5: Variation of flexural modulus with the developed composites and the neat sample

Figure 6 shows the variation of tensile strength at peak for the treated and untreated corncobs reinforced epoxy composite and neat samples. From the result, it was observed that the tensile strength at peak was not well enhanced unlike the flexural properties. However, 2 wt. % Y-KOH corncob particles reinforced epoxy showed enhancement in tensile strength at peak with a value of 9.56 N/mm^2**.** This implies that treatment of the yellow corncob with KOH increased the adhesion between the corncob and the epoxy thereby, leading to increased tensile strength. This is in accordance with Oladele et al., (2014) [24].

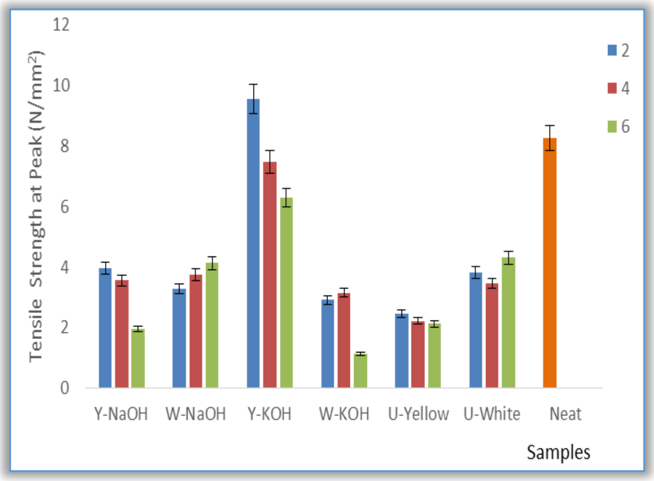

Figure 6: Variation of tensile strength at peak with the developed composites and the neat sample

The results of the variation of tensile modulus with the developed composites and the neat sample were as shown in Figure 7. The results revealed a similar trend to that of tensile strength at peak in Figure 6.

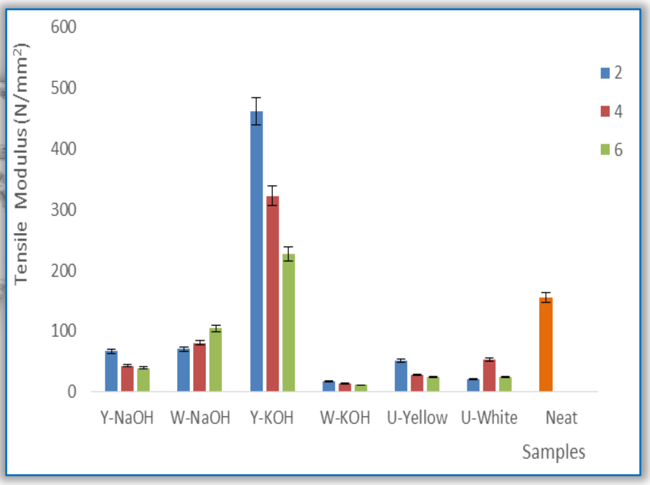

Figure 7: Variation of tensile modulus with the developed composites and the neat sample

However, unlike tensile strength at peak results, all the samples developed from Y-KOH treated corncobs have higher tensile modulus than the neat sample, though; the value reduces as the filler content increases.

From the results, it was observed that 2 wt. % Y-KOH showed maximum enhancement in tensile modulus with a value of 461.61 N/mm^2 followed by 4 wt. % Y-KOH with a value of 322. 38 N/mm^2. This result in agreement with Figure 6 showed that KOH treated corncob was the best in the enhancement of the tensile properties.

Figure 8 shows the variation of wear resistance with their respective composites and the neat sample. From the results, it was observed that all with the exception of sample from 2 wt. % W-NaOH possess better wear resistance than the neat sample.

Also, the wear resistances were seen to increase as the filler content increases in all the developed composites. It was again detected that untreated white corncob reinforced epoxy composites possess the optimum wear resistance compared to others. The best was obtained from 6 wt.% U-White corncob reinforced epoxy composites with a value of 0.00605 g. The high wear resistance obtained with the untreated corncob may be due to the presence of the entire filler constituent as a natural composite.

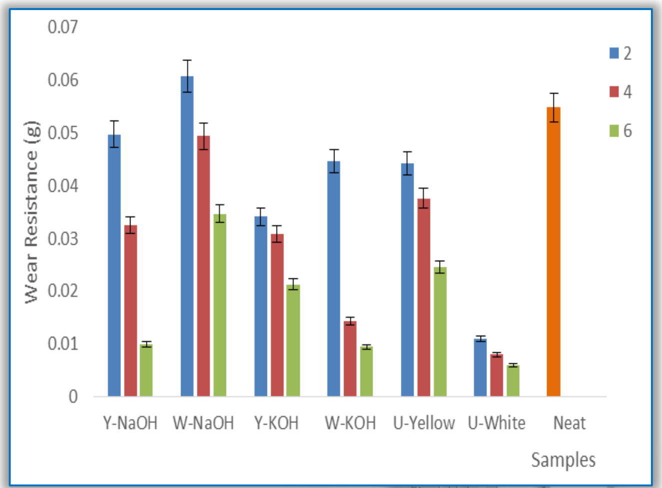

Figure 8: Variation of wear resistance with the developed composites and the neat sample

CONCLUSION

The results of this investigation revealed that:

- » Flexural properties of the developed composites were enhanced after treating the corncobs with NaOH and KOH, respectively. White corncob treated with NaOH was observed to be the best in this respect followed by yellow corncob treated with KOH both at 2 wt. % filler content.
- » The tensile properties were enhanced in the composite sample containing 2 wt. % of Y-KOH treated corncob. This showed that only KOH treatment aid the enhancement of the tensile properties.
- » The wear resistance was enhanced by untreated white corncob that was reinforced with 6 wt.% which showed that higher filler content was responsible for good wear resistance.
- » Low filler content was responsible for high enhancement of the mechanical properties for the developed composites due to constant emergence of 2 wt. % filler content as the sample with optimum performance in all the mechanical properties examined.

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