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Development and Characterization of Fiber Filled with High-Density Polyethylene (HDPE) Plastic Composites

Usman, I[1], Hammajam, A.A[2], Ngawaitu, M.B[3], Ali, M.D[4]
[1,3&4]Department of Mechanical Engineering, Ramat Polytechnic, P.M.B 1070, Maiduguri, Borno State, Nigeria
[2]Department of Mechanical Engineering, University of Maiduguri P.M.B 1069, Maiduguri, Borno State, Nigeria
Corresponding Author: email: dilad2002.ui@gmail.com

Abstract: *In this study, Sugarcane bagasse were treated with Sodium hydroxide (NaOH) 4%wt at room temperature for 24hrs. The process enables removal of fiber surface impurities. However, it was observed that exposing this process beyond 24hrs have a damaging effects on the fibers physical properties. Both the treated and untreated fibers were pulverized to 250µm. The mechanical properties test specimens were prepared through compression mold process and by using ASTM D638, D790, and D256 for tensile, flexural and impact test respectively. It was reveals that tensile modulli and flexural properties increase steadily as a result of fiber treatment, but the impact properties suddenly decrease. Microstructure of the fracture tensile test specimen indicated improvement in matrix-fiber adhesion due to fiber treatment.*

Key words: *surface treatment; composite; fibers; sodium hydroxide, Sugarcane bagasse*

1. Introduction

Globally, environmental conservation has been an issue especially as a result of the perceived ozone depletion resulting in global warming and its attendant consequences. In Engineering design materials production and consumption is coming up against environmental issues in almost every sphere, including species biodiversity, land-use change, climate impacts, and biogeochemical flows. Concerning this, reducing the impact of material use is now an intricate warrant urgent assessment of unforeseen consequences. (Ren, Goda & Noda, 2012)

However, any contribution to environmental protection is always helpful however small it may be. In an attempt to contribute to this noble cause of protecting the environment many researchers have investigated the use of natural fibers as reinforcement in polymeric composite production. Their availability, coupled with low cost, low density,

and biodegradability, make them a suitable alternative to traditional reinforcement fibers such as glass fiber (Boopathi, & Mylsamy. (2012).

Natural fibers in the simple definition are fibers that are not synthetic or manmade. They can be sourced from plants or animals (Ticoalu, 2010). The use of natural fiber from both resources, renewable and non-renewable such as oil palm, sisal, flax, and jute to produce composite materials, has gained considerable attention in the last decades, so far. The plants, which produce cellulose fibers can be classified into bast fibers (jute, flax, ramie, hemp, and kenaf), seed fibers(cotton, coir, and kapok), leaf fibers (sisal, pineapple, and abaca), grass, and reed fibers (rice, corn, and wheat), and core fibers (hemp, kenaf, and jute)as well as all other kinds (wood and roots) (Jayamani, Rahman, & Bakri, 2014.). Even though many studies have been focused on fibers from jute, oil palm, sisal, kenaf, and flax (Ku, Wang, Pattarachaiyakoop, Trada, 2011) give an example of such Natural fiber polymer composites (NFPC) consisting of a polymer matrix embedded with high-strength natural fibers, from jute, oil palm, sisal, kenaf, and flax (Hamajam, Ismarrubie & Sapuan, 2014). But few studies have examined the effect of sugar cane bagasse fiber.

In this study, characterization of polymeric composite will be investigated based on different fiber compositions of Sugarcane bagasse.

2. Experimental

2.1 Materials

The raw materials for the present investigation, (see figure 1). Sugar cane bagasse was collected from sites around Maiduguri, Borno State, Nigeria. Thermoplastic high density polyethylene (HDPE Titavene HD5218EA) Properties; density of 0.960 g/cm^3 and melt flow index of 8.2 g/10 min (190 ˚C, 2.16 kg) was used as the polymer matrix.

2.2 Alkaline treatment

Chemical treatment of Sugarcane bagasse fibers; to improve the fibers/matrix adhesion, the surface of Sugarcane bagasse fibers was subjected to one chemical treatment to bleach and clean the surface of fiber. Sugarcane fibers were first washed with water and then kept for 24 h in a 40g/mol sodium hydroxide aqueous solution. The resulting fibers are then removed from the NaOH solution and treated with normal water several times (100 ml) to neutralize the remaining hydroxide. These fibers were finally dried for 72 h. The chemical treatment on natural fibers by sodium hydroxide (NaOH) also known as alkalization is mostly being used to modify the cellulosic molecular structure. It changes the orientation of highly packed crystalline cellulose order and forming an amorphous region (Burgueño, R., et al, 2005). This provides more access to penetrate chemicals. Cellulose micro molecules are separated at large distances and the spaces are filled by water molecules. Alkali sensitive hydroxyl (OH) groups present among the molecules are broken down, which then react with water molecules (HAOH) and move out from the fiber structure similar process was employed by (Chiachio, Chiachio, & Rus, 2012) . Table 1 shows the chemical composition of fiber responsible for surface cover.

Table 1 Chemical composition of Sugar cane bagasse

Composition	Content (%)
Cellulose	25 - 35
Hemicelluloses	17 - 20
Lignin	0.8
Protein	2.3

Figure 1 Sugar**cane bagasse fiber before Alkalinazation**

Figure 2 Alkalinazation of Sugarcane bagasse fiber

Figure 3 Sugar cane bagasse fiber chemically treated bagasse fiber chemically treated with NaOH

Figure 4 pulverized Sugar cane with NaOH

2.3 Fiber pulverizations.

Both the treated and untreated Sugar cane bagasse fibers were pulverized into 250 µm by using Fritsch Pulverisette P15/P16 mill. The pulverized samples were subjected to 105 °C temperature for 24 hrs in an industrial oven in order to remove moisture before blending with the high density polyethylene. Thus, table 2 depicts composite formulation. The table of formulation was used throughout the project.

Table2 Composite Formulation for the Studies

SB (wt %)	HDPE (wt %)
10	90
20	80
30	70
40	60

2.4 Composites fabrications.

Sugarcane bagasse (SB) and high density polyethylene (HDPE) were compounded by melt blending techniques, followed by compression molding process. Internal mixer (Brabender GmbH) was used in the blending process at processing temperature of 170 ˚C, for a period of 10 min, and rotating speed of 50 rpm. Labquip scientific 40 ton compression molding machine was used in hot pressing the test specimens. 15 cm × 15 cm × 0.3 cm steel mold was used for the compression process. The samples were pre–heated for 3 min at 170 ˚C. Venting time was set to 3 min and final press temperature of 170 ˚C for 3 min. Finally, the samples were cold pressed for 5 min at room temperature. SB/HDPE composites was formed from the three sample sizes with 0 %, 10 %, 20 %, 30 %, and 40 % weight of fiber loading. Table 3 shows melt blend technique set up.

Table3. Brabender twin rotor internal mixer condition

Condition	**Polymer matrix (HDPE)**
Temperature (^oC)	170
Time (min)	10
Rotor Speed (rpm)	50
Sample weight; $\rho v = \rho \pi r^2 h$ (g)	37

2.5 Mechanical properties.

The tensile properties were tested according to ASTM D638 by using Instron 3365 machine. Specimens for the tensile tests were specified according to type V ASTM standard test samples. Tensile testing was carried out at 5 mm/min with load cell of 5 kN. While the flexural and impact properties were tested by using Instron 3365 according to D790, ASTM Standard D790, and Instron 9050 according to D256 ISO 180A, ASTM Standard D256 respectively.

3 Results and discussion

3.1 Effect of surface treatment of natural fibers

Figure 1 depicts the Sugar cane bagasse untreated containing impurities on the surface covers. These impurities can affect interfacial adhesion between fiber and matrix in the composites. After the treatment for 24hrs in NaOH solution, it was observed that the impurities were removed as a result of surface cleaning effects of the NaOH as can be seen

in figure 2. Consequently, figure 3 shows the treated fibers and close fiber texture observation reveal degradation. Thus, allowing this process beyond 24hrs in NaOH solution has damaging effects on the fibers. Therefore, for easy wettibility of the fibers, it was pulverized into 250µm and this can eliminate fiber dimensional instability hence provides better surface area for fiber-matrix interactions.

2.2 Effect of fiber treatment on tensile strength

From figure 5 below it shows the tensile strength of the composite. The complicated interactions between the fiber and matrix were displayed. There was substantial increase in strength at 10 % fiber loading compare to net matrix. There was strength decrease slightly from 20 % fiber loadings below 10% fiber loading by 28.8 %. The fluctuation indicates the characteristics of adhesion and decreases in tensile strength of the composites.

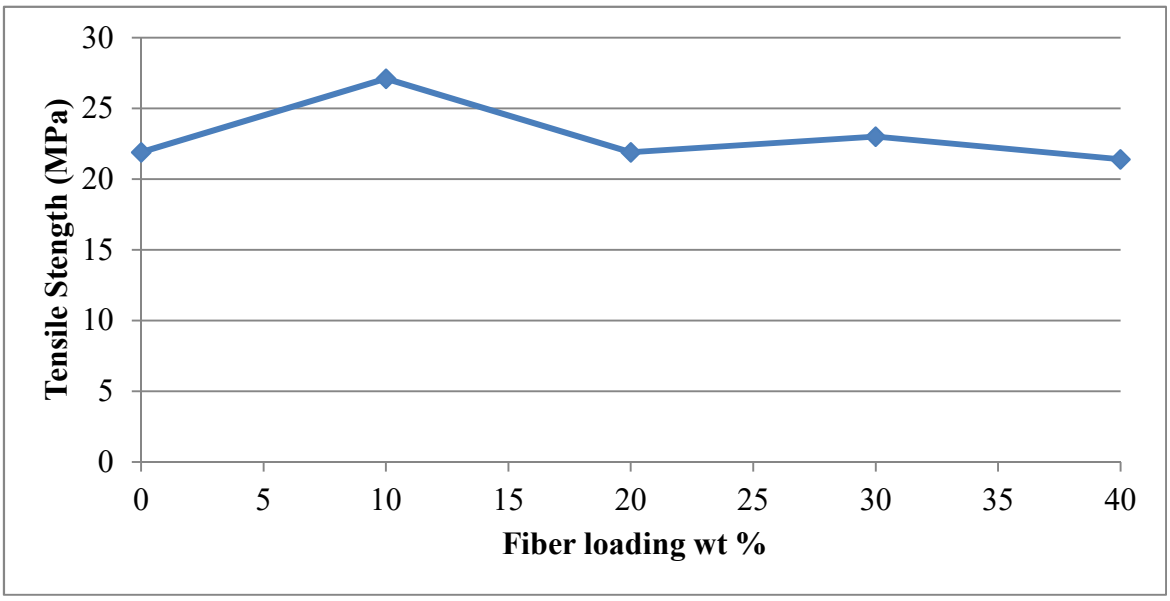

Fig5 Tensile strength of SB/HDPE composites at various fiber loadings

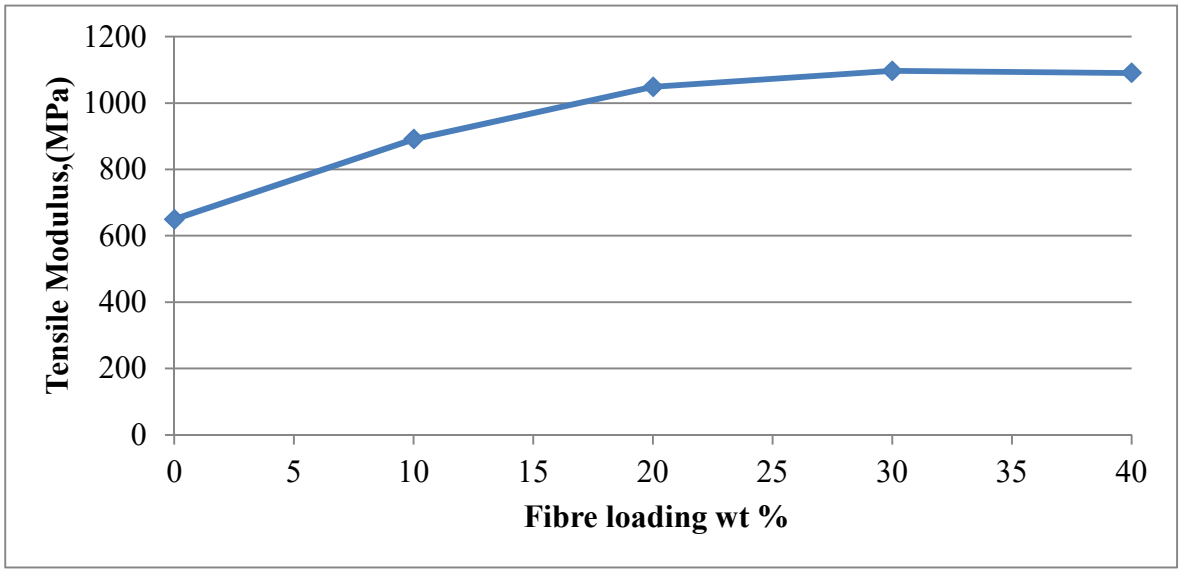

Fig 6 Tensile modulus of SB/HDPE composites at various fiber loadings

3.3 Effect of fiber treatment on tensile modulus.

Figure 6 above shows the tensile modulli of the composites. The modulli increases for all the fiber loadings compare to 100% matrix. The maximum value of the tensile modulus was 1103.6 MPa at 40% fiber loadings. It can be deduced that increase in fiber beyond 40% can increase the rigidity of the composites. Homogeneity between fiber and matrix has little effects on the rigidity of this composite.

3.5 Effect of fiber treatment on flexural strength

It was observed that flexural strength increased with increasing loading of Sugar cane bagasse powder. Thus, is only possible if there is stress transfer from matrix to fiber through a fairly strong interfacial bond. The bond cleavage that lead to failure is not obtained in bending test as the maximum strain applied is only 5 %. It could be inferred that 5 % strain was insufficient to cause a failure. Hence, in the case of flexural strength, interfacial interaction between Sugar cane bagasse fibers and HDPE matrix had only served to transfer stress. As observed from the graph, the flexural strength of composites increases at 40 % fiber loading. Hence it is presume that increase in fiber loading above 40 % may lead to also improve in strength for composites as expected from this study. This might be because of increased surface area exposed for interaction as a result of fiber chemical treatment that provides a better adhesion between the matrix and the fiber as similar trend reported by (Fiore, Bella & Valenza, 2015). Thus increase the strength by using further small size of Sugar cane bagasse fiber could be expected.

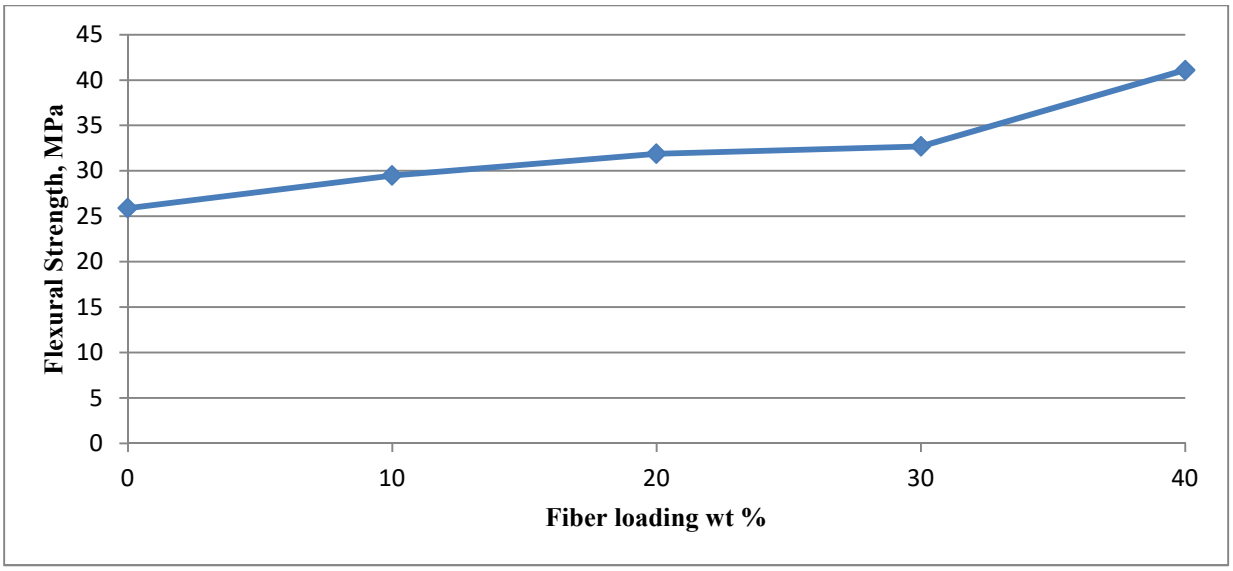

Fig. 7 Flexural strength of SB/HDPE composites at various fiber loadings

3.6 Effect of fiber treatment on flexural modulus.

Flexural modulus was found to increase with increasing Sugarcane bagasse fiber loading as can be observed from Figure 8 as expected from the normal trend. Thus, this could be as a result of the contribution made by fibers to impart its property to the composite. From Figure 8 it was observed that increase in the flexural modulus became pronounced for loadings greater than 10 %. Maximum flexural modulus of about 1988 MPa was achieved at 40 % fiber loading which amounted to about 64 % more than 0 % HDPE. Thus, it is expected that with further increase in fiber loading above 40 %, it presume increase in modulus of composites.

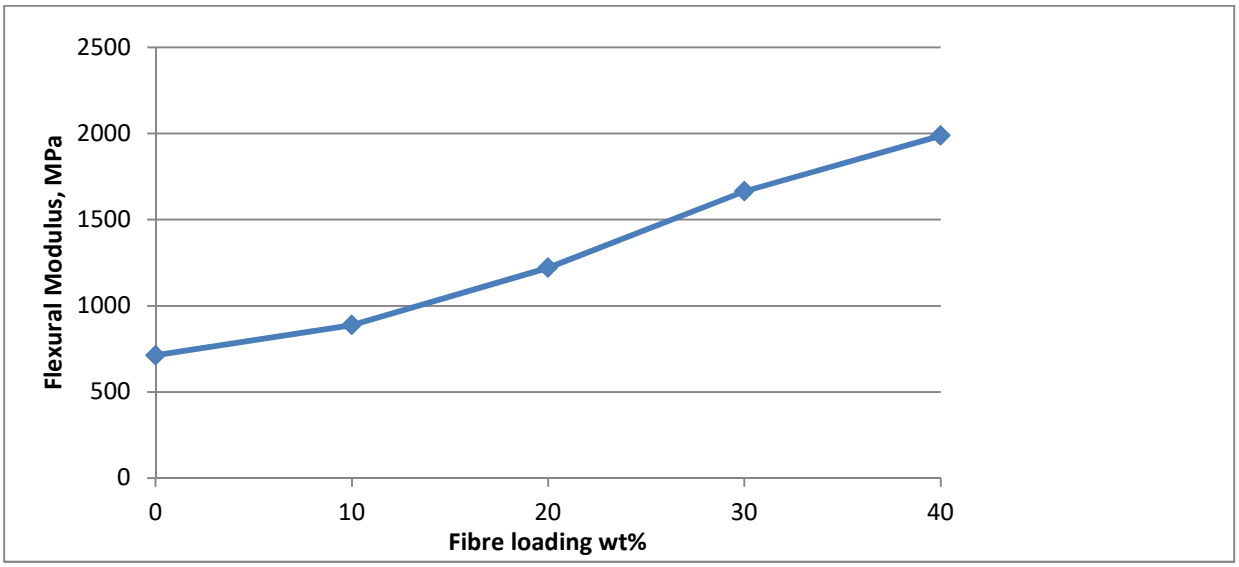

Fig. 8 Flexural modulus of SB/HDPE composites at various fiber loadings

3.7 Effect of fiber treatment on impact strength

Figure 9 shows SB/HDPE composites impact rates revealed that increase in fiber loading resulted in decreased impact strength of the composites considerably. It is probably that this decrease is as a result of increased in fragility of the polymer matrix, because SB fiber concentration increased, so the plastic behavior of polymer matrix decreases, similar results were observed by (Bouafif, Koubaa, Perre & Cloutier, 2009).

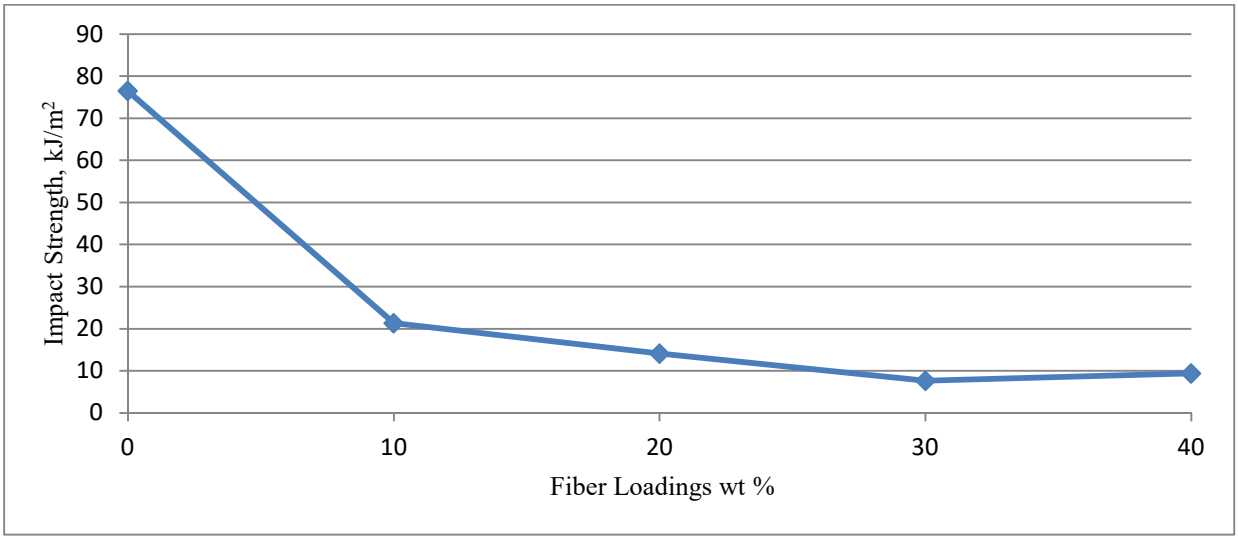

Fig. 9 Impact strength of SB/HDPE composites at various fiber loadings

4. Conclusions.

From this study, it was observed that increasing fiber loadings lead to decrease in the tensile strength of composite. The plasticity of the polyethylene decrease with increase Sugarcane bagasse fiber. Therefore, the elongation at break decreases. However, the flexural strength and modulus increase as fiber loading increase. This shows that composites properties are brittle after the increase in fiber. It was also observed that increasing fiber loadings lead to increase tensile modulus of the SB/HDPE composites with respect to fiber sizes. These problems were enhanced by fiber surface modifications and treatment. Therefore, it is concluded that SB fiber treatment have significant influence on the mechanical properties of the composites.

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