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Evaluation of the Effect of Mercerized White Chicken Feather Fibres on the Mechanical Properties of High Density Polyethylene Based Composites

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chicken feather fibres, reinforcement, mechanical properties, high density polyethylene, composites.

A B S T R A C T

Despite the effectiveness and advantages of natural fibres as reinforcement in the production of composite materials, it has been observed that natural fibres have highaffinityfor moisture absorption and this can weaken the properties of the developed composites. So, there is need to modify the properties of the fibres so as to reduce the rate of absorption of moisture that pose advert effect on the mechanical properties when they are incorporated into materials for composite production. In this research, white chicken fibres from chicken feathers were mercerized and utilized to reinforce high density polyethylene HDPE for structural applications. The white chicken fibres were extracted from chicken feathers by trimming after which they were mercerized with 0.1 M NaOH solution. The mercerized and unmercerized fibres were analyzed to ascertain their crystallinity index and morphology by using X-Ray diffraction (XRD) and scanning electron microscopy (SEM), respectively. The composites were developed by varying the fibres in a predetermined proportion of;2, 4, 6, 8 and 10 wt% with the HDPE matrix. Compression moulding process was used to produce the composite samples. The developed composite samples were characterized to ascertain their tensile and flexural properties in accordance with ASTM D3038M-08 and ASTM D7264M-07 standards, respectively. The morphology of the developed composites wasalso analyzed and it revealed that mercerization of the chicken feather fibres are potential means of enhancing the properties of their corresponding composites. From the results, it was observed that addition of 2 % white chicken feather fibre treated with sodium hydroxide (WFTNa2) gave the best values of 21.03 and 23.58 MPa for tensile and flexural strength at peak, respectively while WFTNa10 gave the best flexural modulus value of 190.50 MPa. The composite samples from the mercerized chicken fibre displayed the best mechanical properties compared to the neat sample.

1. Introduction

The volume and number of applications of composite materials has grown steadily, penetrating and conquering new market relentlessly (Turukmaneet al., 2016).Since the past few decades, research and engineering interest has been deviating from traditional monolithic materials to fibres reinforced polymer-based composites because of their unique advantages of high strength to weight ratio, non-corrosive property and high fracture toughness. Polymer matrix compositesthat are made up of high strength fibres such as carbon, glass and aramid, and low strength polymeric matrix, which have presently dominated the aerospace but has limitations such as (i) non-renewable, (ii) non-recyclable, (iii) high energy consumption in the manufacturing process, (iv) health risk when inhaled and (v) non-biodegradable (Hoi-yanet al., 2009). Due to these disadvantages posed by the use of the aforementioned synthetic fibres, has created an avenue for the use of natural fibres for composites productions.

Despite the effectiveness and advantages of natural fibres from plants as reinforcement in the production of composite materials, it has been observed that natural fibres from plants have the limitation of high rate of absorption of moisture and this can weaken the properties of the composite that it will be used to reinforce.These problems, however, can be alleviated bysuitable compatibilisers and coupling agents (Prasad *et al.*,2016), but there is need to divert attention into the use of other source of natural fibres such as chicken feather fibres (CFF) for the development of composites.

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Chicken Feather Fibres which is a natural fibre from animals is usually regarded as a waste, thereby, contributing to environmental pollution due to their disposal problems. There are two major methods of chicken feather disposal; either by burning or burying. Both methods have negative impact on the environment. Recent studies on chicken feathers show that these wastes can be a potential reinforcement in composite development. The use of CFF in composite development offers more effective and efficient way to solve environmental concerns compared to the traditional disposal methods (Oladele *et al.,* 2014). Some of the advantages of the CFF are excellent acoustic properties, non-abrasive behaviour and excellent hydrophobic properties (Barone and Gregoire, 2006). The CFF has the lowest densityvalue compared to all other natural and synthetic fibres.

Martinez *et al.,* (2007) found that CFF keratin bio-fibres allows an even distribution within and adherence to polymers due to their hydrophobic nature and they reported that CFF reinforced composites have good thermal stability and low energy dissipation. Chicken feathers are waste products of the poultry industries and billions of kilograms of waste feathers are generated yearly by poultry processing plants thereby creating a serious solid waste problem (Schmidt, 1998; Parkinson, 1998). The aim of this research is to utilize both mercerized and untreated white CFF to reinforce high density polyethylene for structural applications.

2. Materials and Methods

The chicken feather fibres used were extracted from chicken feathers that were purchased from a poultry in Akure, south-western Nigeria while the HDPE pellets which was used as thematrix were purchased from Eurochemical in Lagos State, Nigeria.

2.1 Extraction of Avian Fibres

The chicken feathers were separated from unwanted materials with hand, washed and sun dried for 10 days. The dried chicken feathers were trimmed using pair of scissors to remove the avian fibres (barbs) from the rachis part of the feathers. Figure 1 (a) and (b) shows the chicken feathe r and the extracted fibres.

2.1.1 Mercerization of the Avian Fibres

In this research, the trimmed avian fibres were divided into two parts from where one part was treated with 0.1 M NaOH solution. The treatment was carried out in shaker water bath that is set to a temperature of 50 ^{o}C and maintained for 4 hours. After which the treated fibres were washed with tap water and later rinsed with distilled water to obtain neutral status followed by sun drying for 10 days (Okoro *et al.*, 2016).

2.1.2 X-Ray Diffraction Analysis of the fibres

Untreated and treated brown avian fibres were chopped into fine particles and compressed into disks using a cylindrical steel mould (Ø = 15 mm) with an applied pressure of 32 MPa. A Philips X'Pert diffractometer fitted with a ceramic X-ray diffraction tube was used to assess the influence of the alkaline treatment on fibres crystallinity. The diffraction intensity of Cu Kα radiation (wavelength of 0.1542 nm) was recorded between 5^{0} and 40^{0}(2θangle range)at 40 kV and 40 mA.

Table 1. Formulation of the avian fibres reinforced HDPE composite from its constituent.

Matrix (wt.%)	Reinforcement (wt.%)	Composites mixture (wt.%)
HDPE	White fibre	Total constituents
100	-	100
98	2	100
96	4	100
94	6	100
92	8	100
90	10	100

2.1.3 Production of the Composite Samples

The untreated and mercerized fibres were varied from 2, 4, 6, 8 and 10 wt% and used to reinforce the HDPE applying compression moulding technique to produce the composite samples. Table 1 shows the formulation of the composites from its constituents. During production, each mixture is placed in the preheated compression moulding machine which was set to a

(a) (b)

Figure 1.(a) White chicken feather and, (b)Extracted white chicken feather

temperature of 135 °C and left for 7 minutes so as to flow in the mould. The samples were formed into the flexural and tensile moulds, respectively and were allowed to cool before they were stripped from the moulds. The flexural mould used has a dimension of 250 x 200 x 3 mm while the tensile mould is 200 x 150 x 3 mm.

The designations based on this formulation as shown in the following Figures are;

Neat - denotes the neat sample which contains only HDPE without any reinforcement.

WFU - denotes the composite samples that contain HDPE and untreated white chicken fibres. WFTNa - denotes the composite samples that contain HDPE and NaOH treated white chicken fibres.

3. Results and Discussion

The results of the ultimate tensile strength of the composites and the neat sample are as presented in Figure 2. It is observed from the plots that some samples from the developed composites performed better than the neat sample. This showed that the use of these CFF as reinforcement could be a potential mode of enhancement for HDPE. The best in this regards was sample denoted as WFTNa2 (2 wt % of NaOH treated white fibre) with a value of 21.03 MPa followed by sample denoted as WFTNa4 (4wt % of NaOH treated white fibre) with a value of 19.10 MPa. Analysis of the results showed that the treated avian fibres reinforced samples gave the best results compared with the untreated fibres samples and the neat sample that has a value of 17.61 MPa which culminated to about 19 % enhancement. The results depict a reduction trend as the ultimate tensile strength tends to decrease as the fibre content increases from 2-10 wt %.

The flexural strength at the composites produced was presented in Figure 3. It was observed from the results that, most of the developed composites possess better flexural strength at peak than the neat sample. From the results, it was obvious that, samples reinforced with NaOH treated white fibre gave the best results in all the fibre content when compared with the untreated fibres.

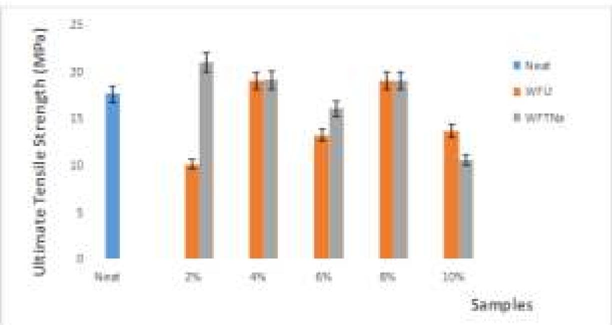


Figure 2. Ultimate tensile strength of the composites and the neat sample

The flexural strength at the composites produced was presented in Figure 3. It was observed from the results that, most of the developed composites possess better flexural strength at peak than the neat sample. From the results, it was obvious that, samples reinforced with NaOH treated white fibre gave the best results in all the fibre content when compared with the untreated fibres reinforced samples. However, sample denoted as WFTNa2 possessed the most superior flexural strength at peak with a value of 23.58 MPa followed by sample denoted as WFTNa8 with a value of 19.72 MPa which are greater than the flexural strength value of the neat sample which has a value of 12.55 MPa. This analysis is an indication that the flexural strength at peak of the developed composite was enhanced by the reinforcement by about 88 %.

Figure 4 shows the specific flexural strength of the developed composite. This property indicated the strength-to-weight ratio of the composite which measure the tenacity of the developed composite. From Figure 4, it was observed that samples WFTNa2 containing 2 wt% of treated white chicken feather fibre possessed the highest specific strength value of 25.22 MPa/gcm^3 followed by WFTNa8 with a specific strength value of 22.56 MPa/g/cm^3 which are greater than the specific strength value of the neat sample which is 13.52 MPa/g/cm^3. This analysis also indicates that the specific flexural strength of the avian reinforced composite sample was enhanced by over 86%.

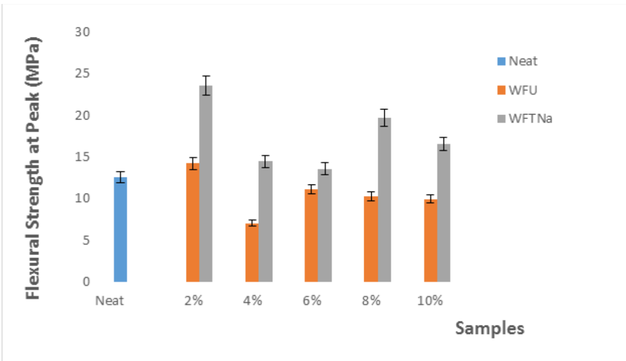


Figure 3. Variation of flexural strength at peak of the developed composite and the neat samples

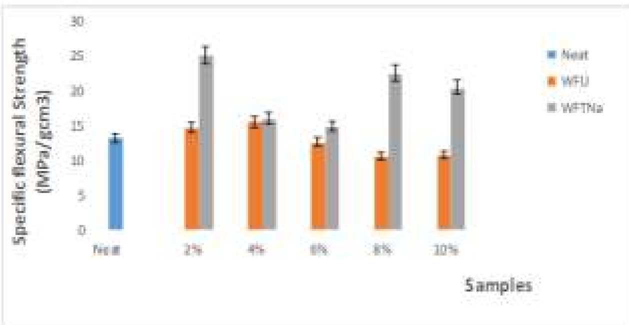


Figure 4. Variation of specific flexural strength of the developed samples

Figure 5 shows the flexural modulus of the developed composites which is a measure of the stiffness of the composite samples when they are subjected to flexural loading. It was observed that the flexural modulus of the developed composites tends to increaseas with increase in the reinforcement content. Also, it was noticed that the treated fibre reinforced samples show the best flexural modulus properties.

However sample denoted as WFTNa10 which contains 10 wt% of the treated chicken feather fibre shows the most superior flexural modulus with a value of 190.50 MPa followed by sample denoted as WFTNa6which contains 6 wt% of the treated chicken feather fibrewith a flexural modulus value of 145.32 MPa which are greater than the flexural modulus of the neat sample which has a value of 73.40 MPa. Considering these results, it implies that the flexural modulus was enhanced by over 100 %. Going by these results, it was observed that the flexural modulus of the materials were better enhanced compared to the tensile properties.

The fibres crystallinity index (Ic) of the treated and untreated avian samples was calculated using equation (1) as opined by Ouajai and Shanks, (2005) and the results are summarized in Table 2.

$$Ic = \frac{Ik - Iam}{Ik} \times 100 \quad (1)$$

Where; Ik- is the maximum intensity of diffra and 25 ction of the peak at a 2 θangle of between 15θ and 25θ and am- is the intensity of diffraction of the amorphous material, which is taken at a 2 θ angle between 13θ and 18θ where the intensity is at a minimum (Roncero et al., 2005).

It can be seen fromTable 2that the crystallinity index of avian fibres was improved by alkali treatment. This is thought to be due to better packing and stress relaxation of polypeptide chains as a result of the removal of other amorphous constituents (lipid 1% and water 8%) from the fibres since it possesses 91 % keratin (Ouajai and Shanks 2005; Lederer, 2005). It can also be seen that fibres treated with NaOH has higher crystallinity index. Other well-defined peaks present on the X-ray diffractograms are at $2\theta = 8.5^0$ and$2\theta = 45^0$respectively.

When the crystalline content is high, these two peaks are more pronounced, and when the fibres contain large amounts of amorphous material (such as lipid and water), these two peaks are smeared and appear as one broad peak. The peaks for NaOH treated fibres are better defined than those of the untreated fibres, suggesting that the NaOH treatment was responsible for the removal of a greater amount of amorphous content from the fibres.

From Figure 7 (a) and (b) which show the SEM images of untreated white CFF and NaOH treated CFF, it was seen that the micro-fibrils are twisted to form helix that is responsible for the good tensile strength of the fibre. It is also seen from the images that the barbs are having branches known as barbules, which can enhance the resilience properties of the CFF. The cleave lines or striations along the fibres give rise to a certain surface roughness, which can contribute to interfacial strength and in addition to the high length to diameter ratio reached by the fibre. These features of the fibres make it a potential reinforcing material for polymer based composites development.

Table 2. Crystallinity index of untreated and NaOH treated white CFF

Index I_c (%)	I_{am} (2??= 14.11^0)	I_k (2??= 19.63^0)	Crystallinity
Untreated white fibres	42.2	1304	96.8
NaOH treated white fibres	0.5	926.7	99.9

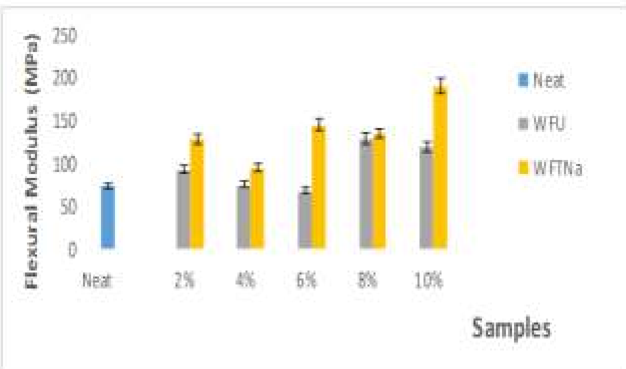


Figure 5. Variation offlexural modulus of the developed samples

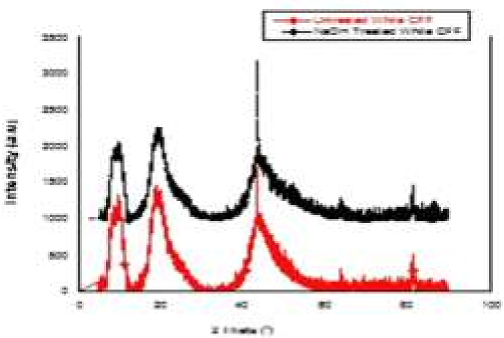
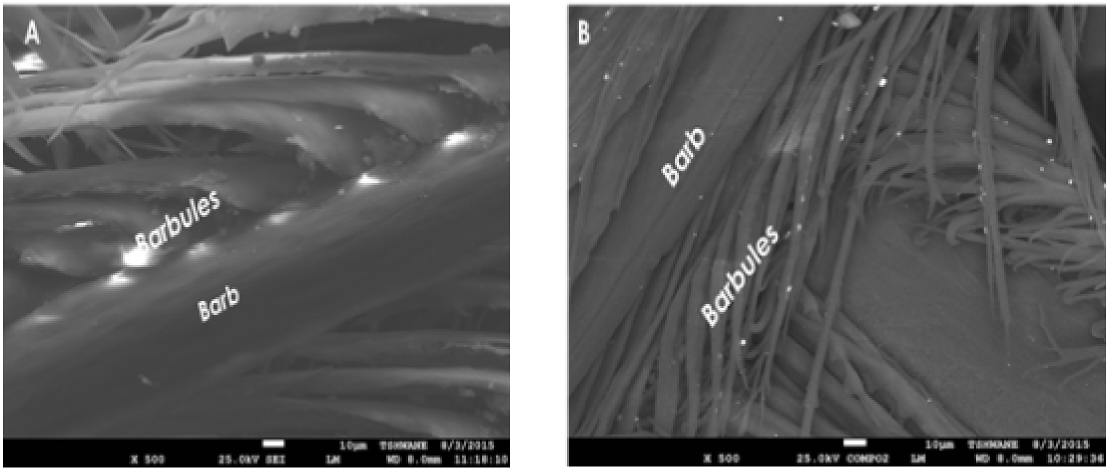


Figure 6. XRD result of untreated white CFF and with NaOH

Figure 8(a-c) present SEM images of fractured surfaces of the neat, Untreated CFF reinforced composite and the NaOH treated reinforced CFF sample.Figure 8(a) shows the SEM image of the neat sample which does not contain any fibre as reinforcement. Figures 8 (b) and (c) confirmed that the avian fibres are well dispersed into the HDPE matrix that was as a result of good compactibility between the matrix and the fibre materials, which reflects a proper interface. In order to improve physical and mechanical properties, a good impregnation and dispersion of the reinforcement is essential to transfer the load between both phases.



(a) (b)

Figure 7. SEM image of untreated white CFF (A) and NaOH treated white CFF (B).

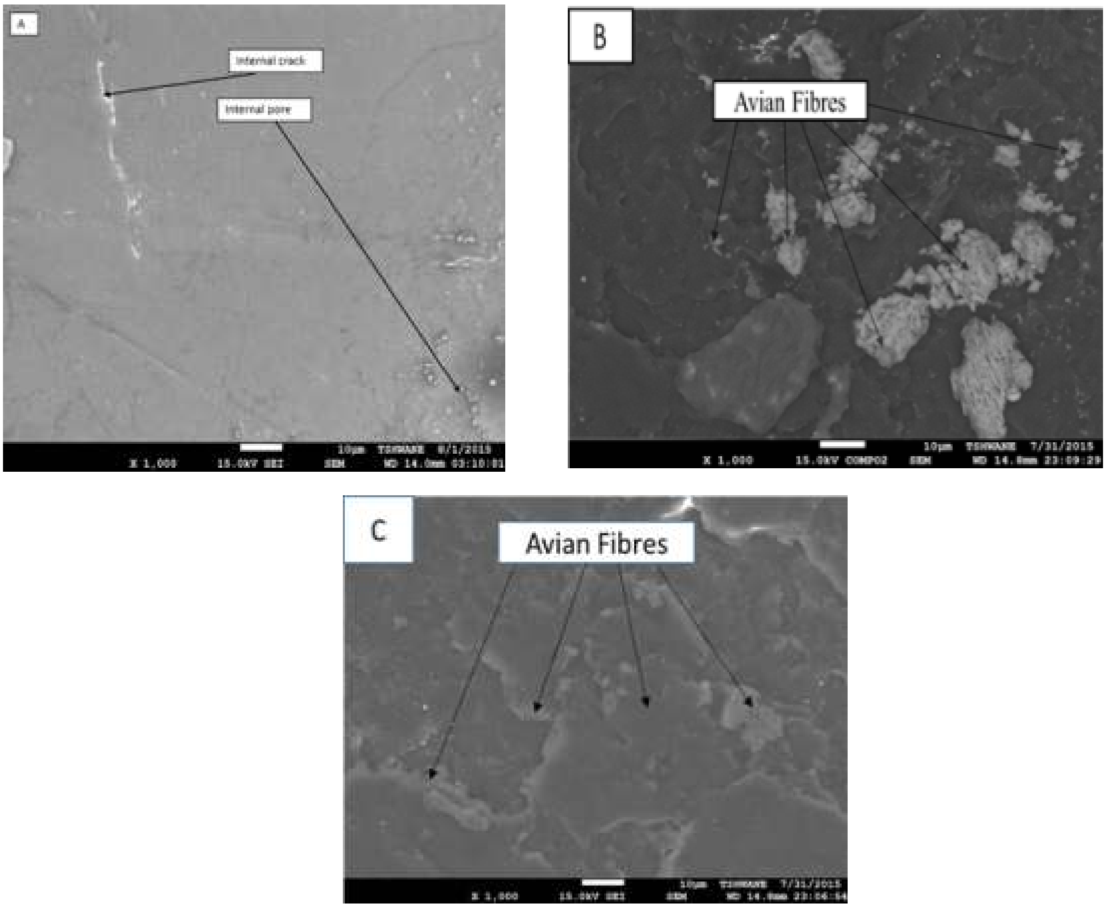


Figure 8. SEM image of the neat sample (A), (B); HDPE reinforced with 10 wt % untreated white CFF and C; HDPE reinforced with 10 wt % NaOH treated white CFF

4. Conclusion

This research was carried to assess the possibility of using avian fibres which are waste materials as an alternative to synthetic fibres for the enhancement of some mechanical properties of high density polyethylene. It was observed that the white CFF possessed better percentage crystallinity index value after treatment with NaOH. From the results, it was observed that the developed composites possessed better properties in most of the properties considered compared with the unreinforced high density polyethylene that served as the neat sample. However, composite sample that was developed from NaOH treated CFF(WFTNa2) possessed the best mechanical properties with respect to tensile, flexural and specific strengths.

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