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The Effect of Surface Treatment of Pineapple Leaf Fibre on the Properties of High Density Polyethylene Composites

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Abstract

The effect of surface treatment of pineapple leaf fibre (PALF) on some mechanical and end-use properties of high density polyethylene (HDPE) composites were studied at filler contents 0, 2, 4, 6, 8, and 10 wt.%. The ground PALF used in this study was sieved to 75 µm mesh size and treated with 10 % NaOH solution. HDPE filled with untreated or treated PALF were prepared by injection moulding technique. The mechanical and end-use properties of PALF/HDPE composites investigated were tensile strength, tensile modulus, abrasion resistance, elongation at break and hardness. Results showed that the tensile strength, tensile modulus, abrasion resistance and hardness of the composites increased with increases in filler content for all the filler contents investigated. The tensile strength of the untreated PALF/HDPE composites was 19.25 Mpa, 20.50 Mpa and 25.10 Mpa at 0 wt.%, 2 wt.% and 10 wt.% respectively while that of the NaOH treated composites was 25.00 Mpa and 29.50 Mpa at 2 wt.% and 10 wt.% respectively.. From the results, it was observed that the tensile strength of untreated PALF/HDPE composites was increased by 6.49 % at 2 wt.% filler content, and 30.39 % at 10 wt.% filler content while for NaOH treated PALF/HDPE composites, the tensile strength was increased by 29.87 % at 2 wt.% filler content, and 53.25 % at 10 wt.% filler content. However, the elongation at break of the composites was found to decrease with increases in filler content for all the filler contents investigated both for the treated and untreated PALF/HDPE composites. The study has shown that NaOH treatment of PALF filler enhanced the mechanical and end-use properties of PALF/HDPE composites, an indication that NaOH treatment, like some other methods of filler surface treatment, is an efficient method of improving the interaction/adhesion between the filler and polymer matix which in turn, improves the mechanical and end-use properties of PALF/HDPE composites.

Keywords: Pineapple leaf fibre, composites, injection moulding technique, properties, high density polyethylene, surface treatment.

1. Introduction

A fibre reinforced polymer (FRP) is a composite material that consists of a polymer matrix imbedded with a high-strength fibre such as glass, aramid, and carbon (Klyosov, 2007; Lopresto, Caprino & Leone, 2013). Thermoplastic materials currently dominate as matrices for bio-fibres, the most commonly used thermoplastics for this purpose are polypropylene

(PP), polyethylene (PE), and poly(vinyl chloride) (PVC) while phenolics, epoxy and polyester resins are the most commonly used thermosetting matrices (Mohanty, Misra & Drzal, 2005). Natural fibres that have been recommended for use in the polymer industry as fillers include flax, hemp, jute, sisal, kenaf, coir, kapok, banana, henequen, and pineapple (Sanadi, Caulfield and Rowell, 1994; Chandramohan and Marimuthu, 2011).

The major drawback on the use of natural fibres in making polymer composites is the problem of incompatibility between the hydrophilic natural fibres, and the hydrophobic thermoplastic matrices (Borba, Tedesco and Lenz, 2014). . This has led to certain undesirable composite properties such as tensile strength, flexural strength, and tensile modulus because of poor interfacial adhesion between the natural fibre and the polymer matrix (Rowell, Han and Rowell, 2000). To overcome this problem, fibre surfaces are being modified so as to improve the adhesion between the fibre and matrix (Mohanty, Misra and Drzal, 2000).

The interfacial adhesion between reinforcing fibres and polymer matrices in composites plays an important role in the final mechanical properties of the composites. This is because the stress transfer between the matrix and fibre depends on the resultant reinforcement efficiency (Rowell et al., 2000). Generally, chemical or mechanical treatment of natural fibres is being utilized to increase the adhesion between natural fibres and polymer matrices. The chemical methods of sodium hydroxide, peroxide, and silane treatment have been applied to improve the adhesion properties of natural fibre (Mir, Hasan, Hossain and Hasan, 2013).
While it is necessary to improve the natural fibre/plastic adhesion, most natural fibre surface treatment involve the use of expensive equipment and chemicals (Zafeiropoulos, Williams, Baillie and Matthews, 2002). Some surface fibre treatment methods such as sodium hydroxide, and hydrogen peroxide treatments are simple methods that involve immersing fibres into appropriate solutions under ambient conditions (Dijon, 2002).

The addition of aqueous sodium hydroxide (NaOH) to natural fibre promotes the ionization of the hydroxyl group to the alkoxide (Agrawal, Saxena, Sherma, and Sreekala, 2000). Thus, alkaline processing directly influences the cellulosic fibril, and the extraction of lignin and hemicellulosic compounds (John, Francis, Varughese and Thomas, 2008). Alkali treatment of fibre surfaces also increases the surface roughness resulting in better mechanical interlocking, and the amount of cellulose exposed on the fibre surface. This in turn increases the number of possible reaction sites and allows for better wetting of fibre (Zini and Scandola, 2011).

The present study was aimed at determining the effect of NaOH treatment of pineapple leaf fibre on some mechanical and end-use properties of PALF/HDPE composites.

2. Materials and Methods

2.1. Materials

The high density polyethylene (HDPE) used in this study was obtained from Ceeplast Industries, Aba, Abia state, Nigeria. It has a density of 0.97 g/cm^3, and melt flow index of 9.0 g/10 min. at 170 ^{0}C. The pineapple leaves from where the fibre in powder form was prepared were collected from a pineapple orchard near Imo State Polytechnic, Umuagwo, Imo State, Nigeria. Sodium hydroxide (NaOH) pellets supplied by Rovet Scientific Limited, 1 Wire Road, Benin City, Edo State, Nigeria was used for surface modification of pineapple leaf fibre powder (PALP). The processing equipment used include a sieve of mesh size 75 µm, injection moulding machine (NegriBossi, Italy), Instron testing machine (Instron Ltd., United Kingdom), electronic weighing balance (Contech, India), shredding machine, thermometer, oven, desiccator and grinding machine.

2.2. Preparation of Pineapple Leaf Fibre

Pineapple leaves were cut into smaller sizes and sun-dried for fourteen days. The dried leaves were later oven-dried for 24 hrs at 80 ^oC prior to grinding. A manual grinder was used to grind the chopped dry pineapple leaves into powder. The pineapple leaf powder obtained was sieved with a sieve of particle size, 75 µm.

2.3. Sodium Hydroxide Treatment

35 g of PALF was placed in a 500 cm^3 beaker containing 5 % NaOH at room temperature, and stirred continuously for 18 hrs. At the expiration of 18 hr, the content of the beaker was filtered using a filter paper. The collected PALF was first washed with acetone, and later, distilled water for the removal of absorbed alkali. The water used in washing the PALF was tested with a red litmus paper to ensure that all the alkali had been removed completely from the PALF. A red litmus paper was neutral when dipped in the water, an indication that the alkali had been removed completely from the PALF. The alkali treated PALF was placed in a hot air oven maintained at 70^oC, and later kept in a dessicator for subsequent use.

2.4. Preparation of High Density Polyethylene Composites

PALF/HDPE composites were prepared by thoroughly mixing 200, 198, 196, 194, 192 and 190 g of high density polyethylene with 0, 2, 4, 6, 8 and 10 wt.% of untreated PALF. The process was repeated for the NaOH treated PALF/HDPE composites. The formulated composites were processed at 165^oC, and pressure of 125 N/m^2 using an injection moulding machine.

2.5 Measurement of Mechanical and End - Use Properties of Composites

An Instron testing machine (Lloyds, capacity 1-20 kN) was used in testing some tensile properties such as tensile strength, tensile modulus and elongation at break of the composites using standard method (ASTM D 638). The other mechanical and end-use properties of PALF/HDPE composites that were determined are abrasion resistance (ASTM D 1044) and hardness (ASTM D 2240).

3. Results and Discussion

3.1. Mechanical Properties

The mechanical and end-use properties of PALF/HDPE composites have been determined and are discussed below.

3.1.1 Tensile Strength

Figure 3.1 shows the effect of NaOH treated and untreated PALF content on the tensile strength of PALF/HDPE composites. The figure shows that the tensile strength of the untreated and treated PALF/HDPE composites increased with increases in filler contents. Furthermore, the tensile strength of NaOH treated PALF/HDPE composites was observed to be higher than that of the untreated PALF/HDPE composites. For the untreated PALF/HDPE composites, the adhesion between the PALF and HDPE was low when compared to the treated PALF/HDPE composites resulting in low tensile strength (Mohanty et al., 2000).

Generally, the organic PALF is of polar nature whereas HDPE is characterized by non-polar groups. The NaOH treated PALF/HDPE composites exhibited appreciable increases in tensile strength than the untreated PALF/HDPE composites for all the filler contents investigated. This can be attributed to the fact that NaOH treatment removed hemicelluloses, lignin, waxes, and oil from the PALF thereby enhancing its matrix-filler adhesion (Luz, Del' Tio, Rocha, Gonclaves & Del' Arco Jr., 2008). Sodium hydroxide (NaOH) treatment is used to remove the hydrogen bonding in the network structure of the fibres, thereby increasing the fibres surface roughness (Lee, Kim and Yu, 2009). As lignin is removed, the middle lamella joining the ultimate cell is expected to be more plastic as well as homogeneous due to the gradual elimination of microvoids, while the ultimate cells themselves are affected slightly (Li, Tabil and Panigrahi, 2009). In addition to the increase in mechanical properties with alkali treatment, an increase in the composite quality is expected due to the improved fibre-matrix bonding (Luz et al., 2008). It was observed that the variation in the quantity of HDPE has no effect on the tensile strength and the other mechanical and end-use properties of the composites investigated in this study (Lee et al., 2009).

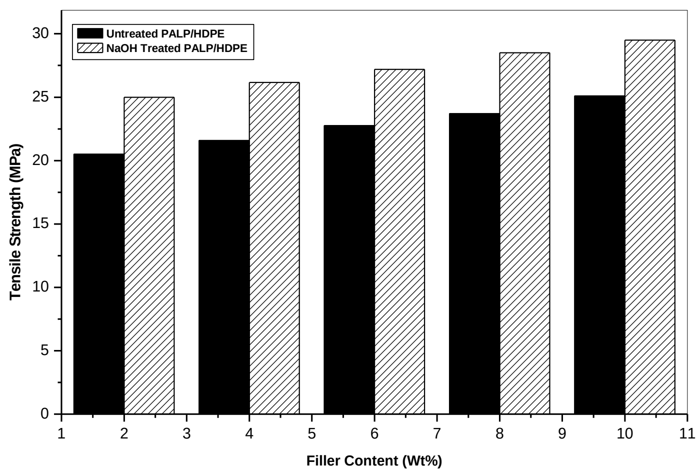

Figure 3.1. Effect of NaOH Treated and Untreated PALF Contents on the Tensile Strength of HDPE Composites.

3.1.2. Tensile Modulus

Figure 3.2 shows the effect of NaOH treated and untreated PALF on the tensile modulus of PALF/HDPE composites. The figure shows that the tensile modulus of NaOH treated PALF/HDPE composites was higher than that of the untreated PALF/HDPE composites for all the filler contents investigated. Thus, NaOH treatment increases the stiffness of pineapple leaf fibre since it modifies the fibre's surface. John, Francis, Varughese & Thomas (2008) who studied flax fibre composites reported that alkaline treatment had a lasting effect on the mechanical behaviour of flax fibres, especially on fibre strength and stiffness (modulus). Also, Van de Weyenberg, Ivens, De Coaster, Kin, Baetens and Vepoes (2003) reported that NaOH treatment of natural fibres enhances both the tensile strength and tensile modulus of the fibres. Therefore, treatment of PALF with NaOH enhances the rigidity (stiffness) of composites thereby making the treated PALF/HDPE composites to exhibit higher tensile modulus than the untreated composites.

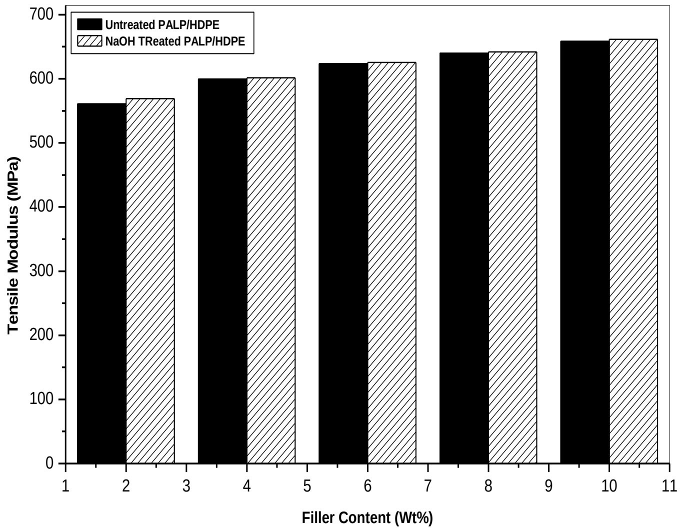

Figure 3.2. Effect of NaOH Treated and Untreated PALF Contents on the Tensile Modulus of HDPE Composites.

3.1.3 Elongation at Break

Figure 3.3 shows the effect of NaOH treated and untreated PALF on the elongation at break of PALF/HDPE composites. From the figure, it can be observed that the elongation at break of the PALF/HDPE composites was decreasing with increases in filler content for all the filler contents investigated both for the untreated and treated composites.

Generally, the elongation at break of NaOH treated PALP/HDPE composites was observed to be lower than that of the untreated composites for all the filler contents investigated. The elongation at break of natural fibre/polymer composites has been found to decrease as the fibre's stiffness increases (Jacob, Thomas and Varughese, 2004). Surface treatment makes fillers to become stiffer than the untreated fillers (Van de Weyenberg et al., 2003). Thus, the incorporation of NaOH treated PALF into HDPE makes the composites to become stiffer (i.e. higher modulus), thereby, further reducing their elongation at break (Sreekala, Kumaran, Joseph, Jacob and Thomas, 2000). This study shows that elongation at break of PALF/HDPE composites decreased as the tensile modulus of PALF/HDPE composites increased.

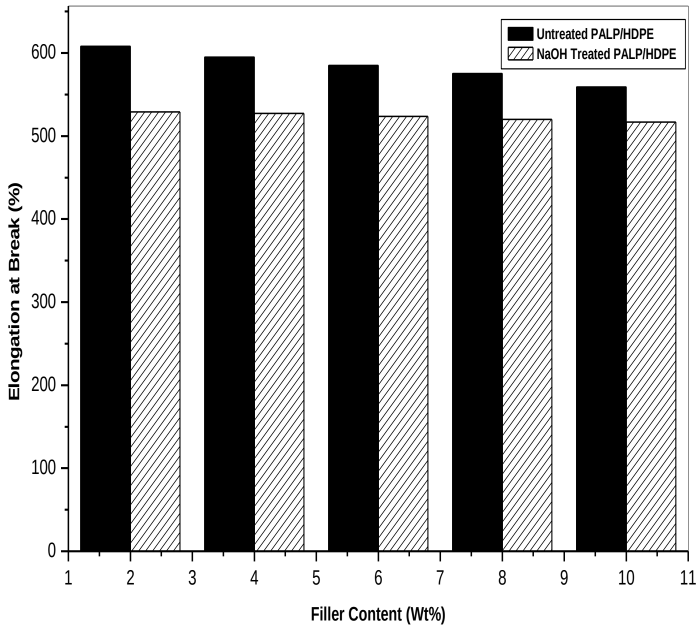

Figure 3.3. Effect of NaOH Treated and Untreated PALF Contents on the Elongation at Break of HDPE Composites.

3.1.4 Abrasion Resistance

Figure 3.4 shows the effect of NaOH treated and untreated PALF on the abrasion resistance of PALF/HDPE composites. The figure shows that the abrasion resistance of PALF/HDPE composites increased with increases in filler content for both the treated and untreated PALF/HDPE composites for all the filler contents investigated. The NaOH treated PALF/HDPE composites were observed to exhibit higher abrasion resistance than the untreated PALF/HDPE composites. Premalal, Ismail and Baharin, 2002) who studied polypropylene composites had reported such increases in the abrasion resistance of composites with increases in filler content. They attributed the observed increase in the abrasion resistance of the composites to the increase in the surface area of filler in contact with the polymer, which decreased the movement of the polymer molecular chains. Therefore, treating the filler (PALF) with NaOH makes the filler stiffer and harder than the untreated filler, thereby increasing the abrasion resistance of the NaOH treated PALF/HDPE composites (Rana, Mandal, Mitra, Jacobson, Rowell and Banarjee, 1998).

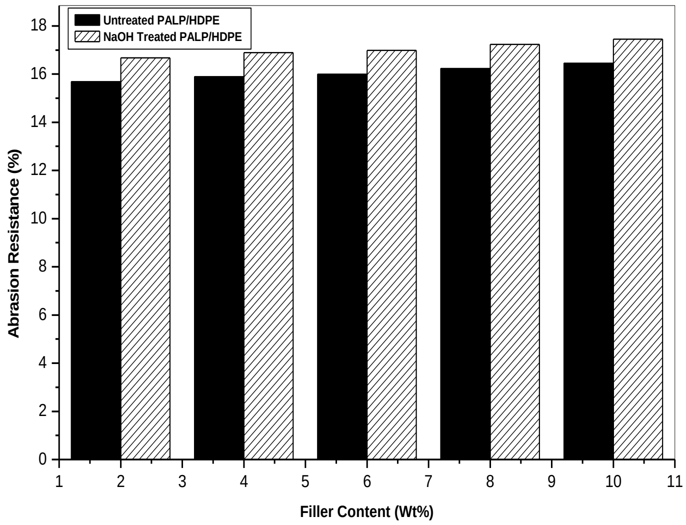

Figure 3.4. Effect of NaOH Treated and Untreated PALF Contents on the Abrasion Resistance of HDPE Composites.

3.1.5 Hardness of Composites

The effect of NaOH treated and untreated PALF on the hardness (Shore D) of PALF/HDPE composites is illustrated in Figure 4.5. The NaOH treated PALF/HDPE composites exhibited higher hardness than the untreated PALF/HDPE composites for the filler contents investigated.

It has been reported that the incorporation of fillers into polymer matrices makes the resulting composites to be harder because fillers are naturally stiffer than polymers (Jacob et al., 2004; Wang, Sain and Cooper, 2007). Therefore, the incorporation of NaOH treated PALF into HDPE ultimately results to harder HDPE composites when compared to the untreated PALF/HDPE composites.

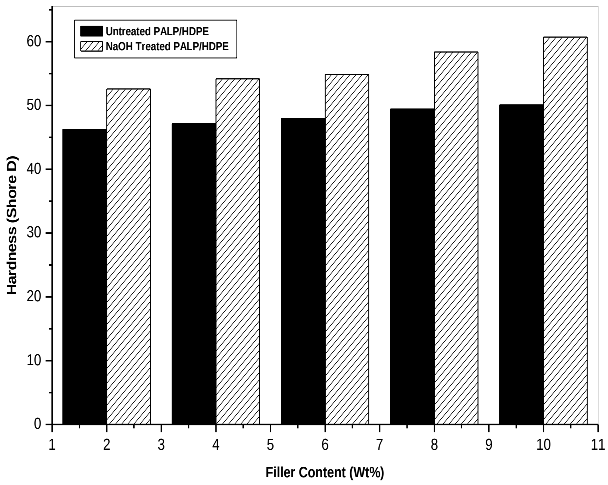

Figure 3.5. Effect of NaOH Treated and Untreated PALF Contents on the Hardness of HDPE Composites.

4. Conclusion

The present study has shown that the tensile strength, tensile modulus, abrasion resistance and hardness of PALF filled HDPE improved significantly by treating PALF with NaOH to enhance its compatibility with HDPE. The elongation at break of the NaOH treated PALF/HDPE composites was lower than that of the untreated PALF/HDPE composites. The present study has equally shown that NaOH treatment is a viable option out of the different surface treatment methods available to the polymer industry to utilize. This is justified by the fact that the NaOH treated PALF/HDPE exhibited better mechanical properties than the untreated PALF/HDPE composites. It is suggested that further researches should be carried out using other fibre surface modification methods in order to avail the industrialists in the polymer industries with more viable options to choose from when the need arises.

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