Effects of Hydrogen Peroxide Treated Pineapple Leaf Powder on Mechanical Properties of High Density Polyethylene Composites

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ABSTRACT

The effects of hydrogen peroxide (H₂O₂) treated pineapple leaf powder (PALP) on the mechanical properties of high density polyethylene (HDPE) composites were studied. HDPE and PALP (untreated, and treated) composites were prepared by injection moulding technique. The filler (PALP) contents investigated were 2, 4, 6, 8, and 10 wt %. Results showed that the tensile strength, tensile modulus, flexural strength, abrasion resistance, and hardness of the composites increased with increases in filler content for all the filler contents investigated, while the elongation at break (EB) for PALP/HDPE composites was found to decrease with increases in filler content for all the filler contents investigated. It was observed from the results that H₂O₂ treated PALP/HDPE composites exhibited better mechanical properties than the untreated PALP/HDPE composites for all filler contents investigated. The present study has shown that surface treatment of PALP with H₂O₂ has proved to be an efficient alternative in bringing about an improved adhesion/compatibility between PALP and HDPE, thereby improving the mechanical properties of the composites.

Keywords: High density polyethylene, pineapple leaf powder, injection moulding techniques, surface treatment, mechanical properties

INTRODUCTION

Natural fibre-reinforced thermoplastic composites form a new class of materials which seem to have good potential in the future as a substitute for wood based material in many applications [1]. However, lack of good interfacial adhesion and poor resistance to moisture absorption makes the use of natural fibre-reinforced composites less attractive. Various fibre surface treatments like mercerization, isocyanate treatment, acrylation, latex coating, permanagante treatment, acetylation, silane treatment and peroxide treatment have been carried out which may result in improving composite properties [2-3]. Research on a cost effective modification of natural fibres is necessary since the main attraction for today’s market of bio composites is the competitive cost of natural fibre. Interfaces play an important role in the physical and mechanical properties of composites. Natural fibres are amenable to modification as they contain hydroxyl groups from cellulose and lignin present in the fibres.

The hydroxyl groups may be involved in the hydrogen bonding within the cellulose molecules thereby reducing the reactivity towards the matrix. Chemical modifications may activate these groups or can introduce new moieties that can effectively interlock with the matrix [4-5]. Simple chemical treatments can be applied to the fibres with the aim of changing surface tension and polarity of fibre surfaces. Mir et al [6] investigated the mechanical properties of coir based polymer composites. The composites were prepared using coir fibre treated with varying pre-treatment conditions. The results showed increase in the mechanical and modulus of rupture properties of coir based polymer composites and these were as a result of chemical composition modification, and surface modification of the fibres. Li et al [7] studied flax fibre reinforced linear low density polyethylene (LLDPE) and HDPE bio composites processed by extrusion, and injection moulding processes. Five surface modification methods (alkali, silane, potassium permanganate, acrylic acid, and sodium chlorite treatments) were employed to improve the interfacial bonding between fibres and matrix. It was found that the biocomposite tensile strengths were increased after fibre surface modifications.
The aim of this paper is to investigate the effect of \( \text{H}_2\text{O}_2 \) treatment of pineapple leaf powder on the mechanical properties of pineapple leaf powder filled high density polyethylene. This was necessitated by the fact that sodium hydroxide treatment having performed when it was used to modify PALP surface in our previous research work, it was recommended that other types of surface treatments should be investigated to ascertain whether they will also perform. This, we believe, will give viable options to whoever wants to chemically modify natural fibres/fillers in polymer industry.

**MATERIALS AND METHODS**

**Materials**

High density polyethylene (HDPE) and pineapple leaf powder were used in this study. 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/cm³, and melt flow index of 9.0 g/10 min. at 170 °C. The pineapple leaves from where the powder was prepared were collected from a pineapple orchard near Umuagwo Polytechnic, Owerri, Imo State, Nigeria. Hydrogen Peroxide (\( \text{H}_2\text{O}_2 \)) was the major chemical used. The processing equipment used includes Mesh sieve (0.3 mm), injection moulding machine (Negri Bossi, Italy), instron machine (Instron ltd., United Kingdom), electronic weighing balance (Contech, India), shredding machine, thermometer, oven, desiccator, grinding machine, personal protective equipments (PPEs).

**Pineapple Leaf Powder Preparation**

Pineapple leaves collected from Umuagwo, Imo State, Nigeria were cut into smaller sizes and sun-dried for fourteen days. The dried leaves were later oven-dried for 24 hrs at 80°C prior to grinding. A manual grinder was used to grind the chopped dry pineapple leaves into powder. The pineapple leaf powder (PALP) obtained was sieved with a sieve grid of 0.3 mm (75 μm).

**Hydrogen Peroxide Treatment**

35g of PALP was placed in a 500 cm³ beaker containing 320cm³ hydrogen peroxide, and 1g of NaOH at 85°C, and stirred for 1 hour. At the expiration of 1hr, the content of the beaker was filtered; the PALP was washed with distilled water, and dried in an oven at 50°C to a constant weight. Later, the PALP was kept in a desiccator for subsequent use.

**Preparation of High Density Polyethylene Composites**

High Density Polyethylene composites of the pineapple leaf powder (PALP) were prepared by thoroughly mixing 200 g, 198 g, 196 g, 194 g, 192 g and 190 g of high density polyethylene with 0, 2, 4, 6, 8 and 10 wt % filler contents of the untreated PALP respectively. The process was repeated for the \( \text{H}_2\text{O}_2 \) treated PALP. The formulated blend compositions were each processed at the same temperature (165°C) using an injection moulding machine.

**Measurement of Mechanical Properties**

Tensile properties of the composites were determined by using an Instron Testing Machine (Lloyds, capacity 1-20 kN) according to standard method (ASTM D638). The tensile properties of PALP/HDPE composites that were determined are: (i) tensile strength, (ii) elongation at break, and (iii) tensile modulus. Other properties of the composites that were determined are: (i) abrasion resistance (ASTM D1044), (ii) hardness (ASTM D2240), and flexural strength (ASTM D790).

**RESULTS AND DISCUSSIONS**

**Mechanical Properties**

**Effect of \( \text{H}_2\text{O}_2 \) Treated PALP Content on Tensile Strength of Composites**

The effect of filler surface treatment (\( \text{H}_2\text{O}_2 \)) on the tensile strength of PALP/HDPE composites is shown in Fig.1. It can be observed that the \( \text{H}_2\text{O}_2 \) treated PALP/HDPE composites showed appreciable increases in tensile strength than the untreated PALP/HDPE composites for all the filler contents investigated. It has been reported that \( \text{H}_2\text{O}_2 \) treatment of fibres reduces the fibre diameter and increase the aspect ratio [8]. The report showed that \( \text{H}_2\text{O}_2 \) treatment helped in the removal of lignin and hemicellulose which affect the tensile characteristics of the fibres. When the hemicellulose is removed, the interfibrillar region is expected to be less dense and rigid, thereby making the fibrils more capable of rearranging themselves along the direction of tensile deformation [8]. This treatment also removes certain amounts of lignin, wax and oils covering the external surface of the fibre’s cell wall, depolymerises the native cellulose structure and exposes the short length crystallites [7-9]. The tensile strength of the untreated PALP/HDPE composites was found to increase by 6.49% at 2 wt% filler content (least filler content), and 30.39% at 10 wt% filler content (maximum filler content). For the \( \text{H}_2\text{O}_2 \) treated PALP/HDPE composites, the tensile strength was increased by 21.66% at 2 wt% filler content, and 42.85% at 10 wt% filler content.

**Effect of \( \text{H}_2\text{O}_2 \) Treated PALP Content on Tensile Modulus of Composites**

It can be observed from Fig. 2 that the tensile modulus of PALP/HDPE composites increases with increase in filler content for both the untreated, and treated PALP/HDPE composites. Generally, incorporation of natural fillers into a
polymer brings about increase in the tensile modulus of the polymer composite. The \( \text{H}_2\text{O}_2 \) treated PALP/HDPE composites was observed to be higher than that of the untreated PALP/HDPE composites for all the filler contents investigated. Valadez-Gonzalez et al [10] in their studies reported that \( \text{H}_2\text{O}_2 \) treatment of fibre has two effects on the fibre: (i) it increases fibre surface roughness resulting in better mechanical interlocking, and (ii) it increases the amount of cellulose exposed on the fibre surface, thus increasing the number of possible reaction sites in the fibre. It was also observed that \( \text{H}_2\text{O}_2 \) increases the stiffness of fibre as it modifies the fibre’s surface. According to other authors [11], \( \text{H}_2\text{O}_2 \) treatment of natural fibres enhances both the tensile strength and tensile modulus of the fibres.

**Effect of \( \text{H}_2\text{O}_2 \) Treated PALP Content on Elongation at Break of Composites**

Jacob et al [12] in their studies reported that the addition of stiff fibre into a polymer matrix interrupted the polymer (HDPE) segments mobility and thus, making the polymer to become brittle. This makes the elongation at break of the composites to decrease with increases in filler content. From Fig. 3, the elongation at break of \( \text{H}_2\text{O}_2 \) treated PALP/HDPE composites was observed to be lower than that of the untreated composites for all the filler contents investigated. Generally, surface treatment makes fillers to become stiffer than the untreated fillers, thereby, further
reducing their elongation at break [11-13]. The elongation at break of untreated PALP/HDPE composites was found to decrease by 2.40% at 2 wt% filler content, and 10.24% at 10 wt% filler content; while the elongation at break of H$_2$O$_2$ treated PALP/HDPE composites decreased by 14.91% at 2 wt% filler content, and 16.69% at 10 wt% filler content.

**Effect of H$_2$O$_2$ Treated PALP Content on Abrasion Resistance of Composites**

Fig. 4 shows that the abrasion resistance of PALP/HDPE composites increases with increase in filler content for both the untreated, and treated PALP/HDPE composites. The abrasion resistance of the H$_2$O$_2$ treated composites was observed to be higher than that of the untreated composites. This may be attributed to the fact that in addition to the H$_2$O$_2$ treatment making the filler (PALP) harder and stiffer than the untreated, the H$_2$O$_2$ may also hinder polymer chains mobility thereby making the polymer (HDPE) to become hard and stiff which will, in turn, further increase the abrasion resistance of the H$_2$O$_2$ PALP/HDPE composites [14].
Effect of H$_2$O$_2$ Treated PALP Content on the Hardness of Composites

It can be observed from Fig. 5 that the hardness (Shore D) of H$_2$O$_2$ treated PALP/HDPE composites was higher than that of untreated PALP/HDPE composites for all the filler contents investigated. It has been reported that the higher the tensile modulus of fibre, the higher will be the hardness of natural fibre/polymer composites [15-16]. This may also be attributed to the fact that in addition to the H$_2$O$_2$ treatment making the filler (PALP) harder and stiffer than the untreated ones, H$_2$O$_2$ may also hinder polymer chains mobility which makes the polymer (HDPE) to become hard and stiff, and this in turn, will further increase the hardness of the PALP/HDPE composites [14].

Effect of H$_2$O$_2$ Treated PALP Content on Flexural Strength of Composites

The effect of H$_2$O$_2$ treated PALP content on the flexural strength of PALP/HDPE composites can be seen from Fig. 6. The flexural strength was seen to increase with increases in filler content for both the untreated, and treated com-
posites. It was also observed that the H$_2$O$_2$ treated PALP/HDPE composites had higher flexural strength than that of the untreated PALP/HDPE composites for all the filler contents investigated. The observed increases in flexural strength of the treated composites may be due to the removal of impurities from the fibre surface after treatment which leads to the better adhesion of the filler with the matrix [17-18].

CONCLUSION

The present study has shown that H$_2$O$_2$ treatment of pineapple leaf powder (PALP) has proved to be a viable and efficient method of surface treatment of fibre which helps to improve the interfacial bonding between the fibre and matrix, thereby enhancing the mechanical properties of composites. This can be justified from the results of the mechanical properties carried out in this study which showed that the H$_2$O$_2$ treated PALP/HDPE composites generally exhibited better tensile strength, tensile modulus, flexural strength, abrasion resistance, and hardness than the untreated PALP/HDPE composites for all the filler contents investigated; while the elongation at break values of the H$_2$O$_2$ treated PALP/HDPE composites was lower than that of untreated PALP/HDPE composites for all the filler contents investigated. It is recommended that other types of filler surface treatments should be investigated for the processing of HDPE composites so as to identify the method with the best promising result.

REFERENCES


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