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STUDIES OF THE MECHANICAL AND MORPHOLOGICAL PROPERTIES OF ZEBU CATTLE HAIR REINFORCED POLYETHYLENE TEREPHTHALATE WASTE COMPOSITE

***[1]Muktari, S., [2]Kuzmin Anton, [3]Agbogo U.V.,**

[1]Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria, Nigeria.

[2]Department of Mechanization of Agricultural Products Processing, National Research Mordovian State University, Sarank, Russia

[3]Department of Industrial Chemistry, Kaduna State University, Kaduna, Nigeria.

*Corresponding Author: smuktari@abu.edu.ng, +2348090389396

ABSTRACT

Polyethylene terephthalate (PET) plastic wastes were collected and filled with treated and untreated keratin fibres of zebu breed of cattle using melt-mixing and compression moulding technique. The variation of PET to Zebu hairs was made in the ratios: 100_0g; 90_10g; 80_20g; 70_30g; 60_40g and 50_50g. The samples were buried under the ground to investigate the degradation effect soil burial will have on the mechanical properties of the material. After the soil burial, the tensile and flexural properties of the materials were analysed. Scanning electron microscope was used to examine the morphological properties of the tensile fractured properties of the buried materials. Results obtained showed a general decrease in the mechanical properties tested after the soil burial test. The tensile strength of the buried samples decreased steadily with all the filler loadings. At 50_50g filler loading the tensile strength decreased by 33% for composites made with treated fibres and 45% for composites made with untreated fibres. Similar trend was observed with the flexural strength of the buried samples. Soil burial had degradation effect on the composites.

Keywords: PET, Keratin fibres, Soil burial, Mechanical properties, Degradation

INTRODUCTION

Plastic waste pollution is a major environmental problem globally. This is because most of the single use commodity plastics are not biodegradable [1]. Common commodity plastics used for making every day house hold products are: low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polyethylene terephthalate (PET) [2]. Because these house hold plastics are used almost by every home and are inherently not biodegradable, they constitute a large deposit on refuse dumps. These waste plastics find their ways to block our drainage channels. In Nigeria, blockage of the drainage channels has been identified as one of the major causes of flood. The Blockage of the drainage system have been documented as a major cause of flood [3].

In order to reduce the environmental hazards caused by the non-biodegradable plastics, materials scientists have in recent times used waste plastics as the matrix phase also known as the continuous phase for composite production [4]. The use of waste plastics for the continuous phase of composite materials have significantly added value to the danger posing commodity plastics.

A composite also consists of a discontinuous phase also known as the reinforcing phase or the filler [5]. Materials scientists have over time added value to waste agricultural products such as rice husk, ground nut shell, cassava peels, cow hair, human hair, goat hair, sheep hair, horse hair and many more by employing them as the discontinuous phase of composites [6].

However, not much work has been done to investigate what will happen to the composite materials made after their life span. The thought of whether they will be degradable after recycling or they should be recycled into something else comes to mind. In our earlier works [7,8], we produced composite materials with keratin-based fibres and wastes commodity thermoplastics.

This research work investigated the effect soil burial will have on keratin-based fibres/PET thermoplastic composite materials produced using the compression moulding technique.

MATERIALS AND METHODS

Materials

Waste PET plastics were collected from Zaria metropolis, Kaduna, Nigeria.

Keratin-fibres were collected from the zebu breed of cattle.

Equipment

Two-Roll Mill (U.S.A Model 5189), Hydraulic Hot Press (U.S.A Model 3851-0), Instron 1195 universal materials testing machine, Indentec Universal hardness tester-Model no – 8187.5LKV(B).

Composite Preparation

Short hairs of Zebu cattle breed were mixed with PET using the two-roll mill. The mixture was poured in a metallic mould and hot pressed with a hydraulic press. Two sets of composites were prepared with untreated keratin fibres (UKF) and treated keratin fibres (TKF). The treated keratin fibres were treated with

0.2M hydrogen peroxide (H_2O_2). The treatment of the fibres is reported in our earlier works [7,8]. The variation of PET to Zebu hairs was made in the ratios: 100_0g; 90_10g; 80_20g; 70_30g; 60_40g; 50_50g

Soil Burial

The composite samples were buried in a garden to a depth of 10cm for 90 days. The samples were then removed from the soil and cleaned with a dry fabric to remove dust. The samples were oven dried at 70 °C for 24 hr. The mechanical tests were then conducted to determine the effect of soil burial on the mechanical properties of the composites.

RESULTS AND DISCUSSION

Tensile Properties

KEY: TBS – Treated Buried Sample

UBS – Untreated Buried Sample

TUBS – Treated Unburied Sample

UUBS – Untreated Unburied Sample

UBC -Unburied Control

BC – Buried Control

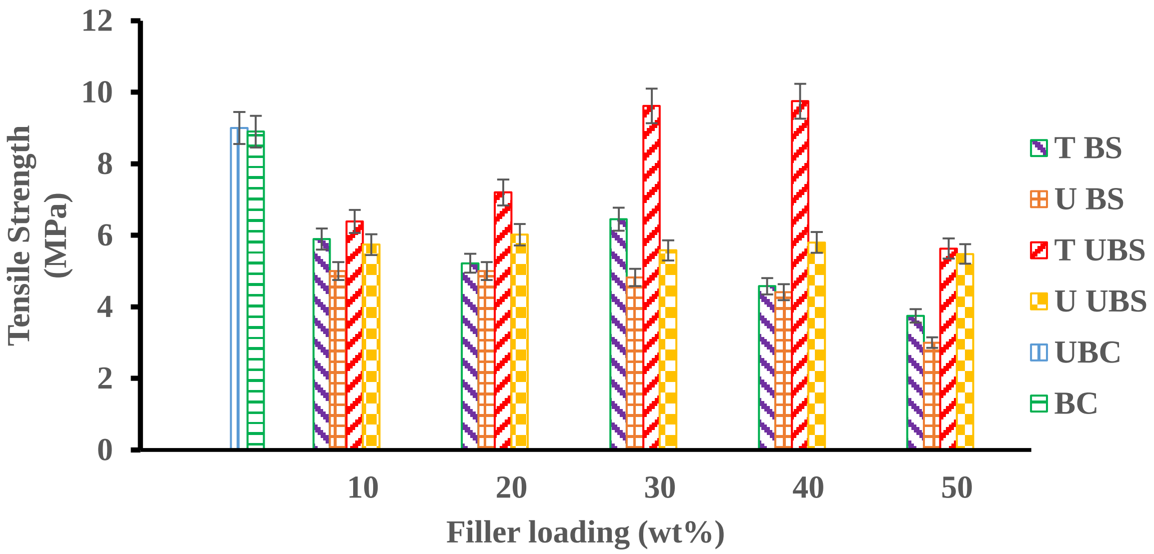

Figure 1: Effect of soil burial on the tensile strength of waste PET/Keratin fibre blends

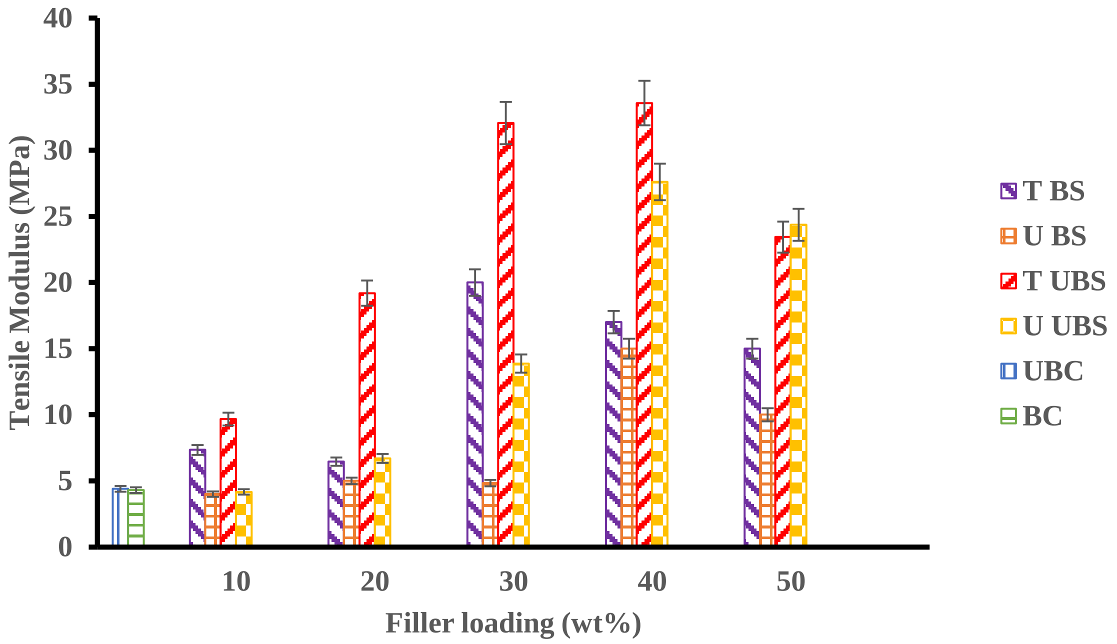

Figure 2: Effect of soil burial on the tensile modulus of waste PET/keratin fibre blends

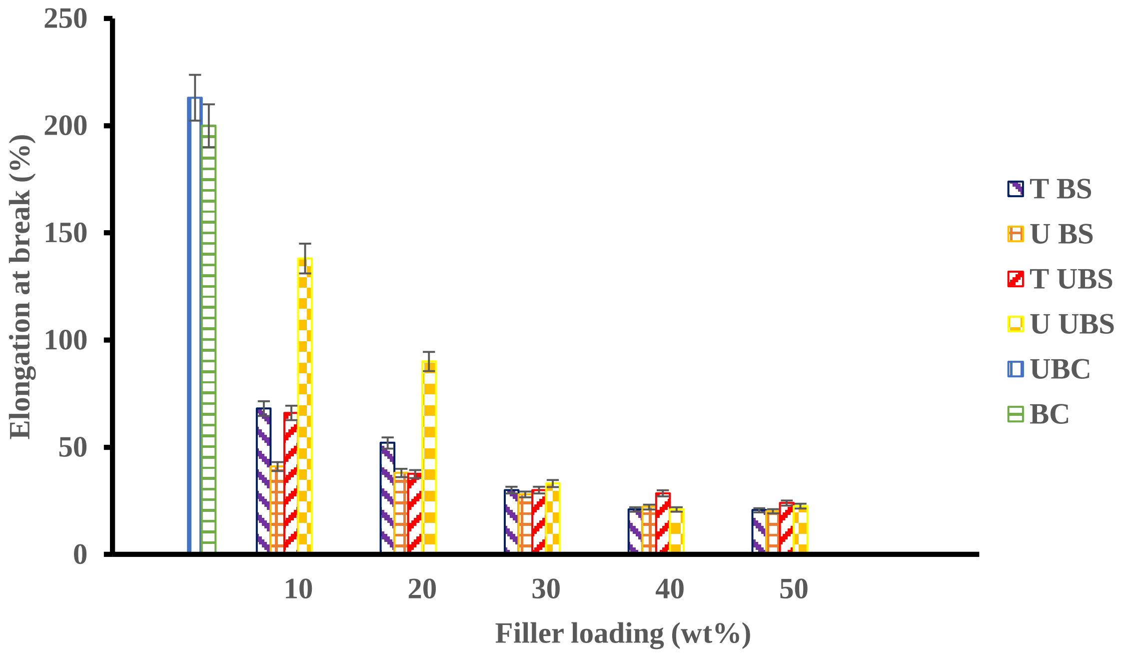

Figure 3: Effect of soil burial on the elongation at break of waste PET/ keratin fibre blends

Figures 1 to 3 show the tensile properties of waste PET/keratin fibre composite that were

buried in the soil and those that were not buried. From the figures, it can be seen that the tensile strength, Young's modulus and elongation at break decreased after 90 days of been buried under the soil. The decrease in the tensile strength, Young's modulus and elongation at break was due to the pit and voids which occurred after the degradation of the reinforcing phase by the action of micro-organisms naturally found under the soil. The pit and voids act as stress concentrator and lead to a decrease in the tensile properties [9]. As the micro-organisms consumed the reinforcing fibres, the blends lost their structural integrity. This process could lead to the deterioration of the tensile properties. The degradation of the blends normally occurs due to the vacation of fibre sites, which are occupied by either microbes or water and thus, leads to extensive degradation of the blends [10]. During the experiment, the water inside the soil diffuses into the polymer sample, causing swelling and enhancing biodegradation. In addition, extra cellular enzymes made by the microbes also attack the resin and may be responsible for the fine cracking and tearing that lower the elongation at break, and can lead to further degradation and lower the tensile properties [11]. The waste PET/TKF composites buried in the soil showed better tensile properties compared to the waste PET/UKF composites even though both composites witnessed a decreasing trend. The treated fibres aided better interfacial adhesion with the matrix that could prevent early degradation. Enhanced interfacial adhesion reduced the volumes of voids which created the stress concentration area in the composites. As a result, the mechanism of degradation was reduced.

Flexural Properties

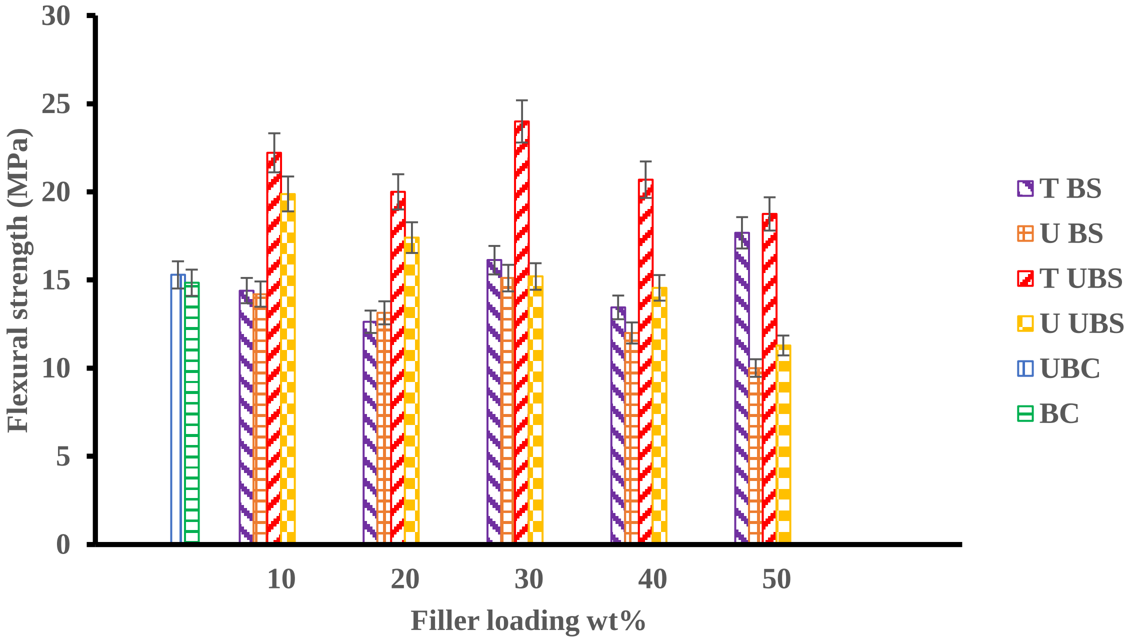

Figure 4: Effect of soil burial on the flexural strength of waste PET/keratin fibre blends

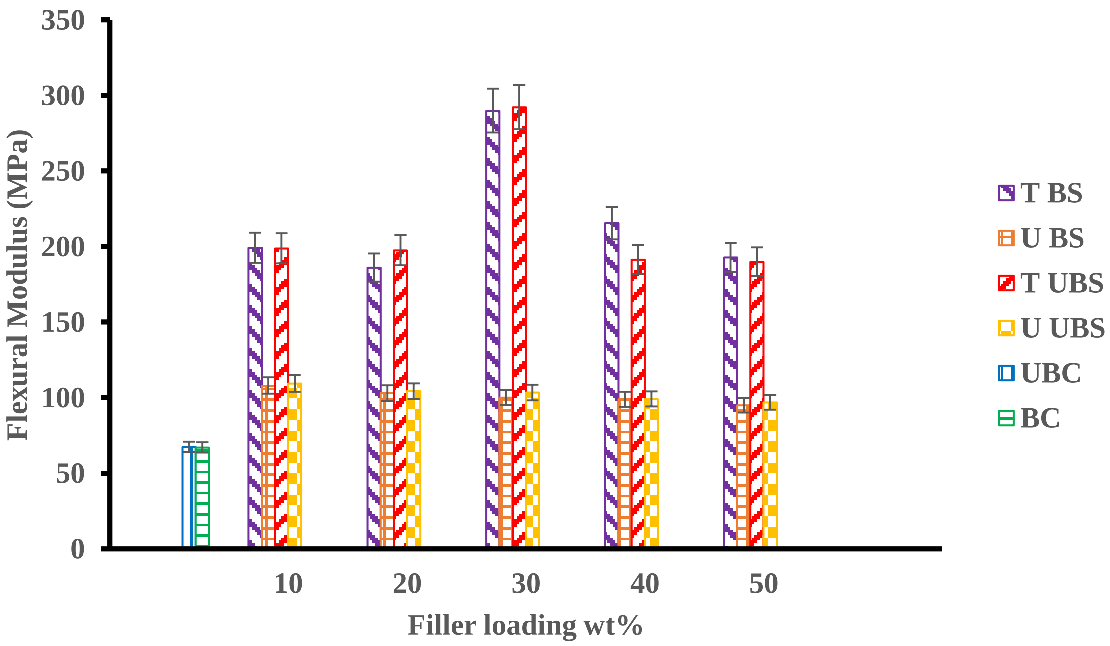

Figure 5: Effect of soil burial on the flexural modulus of waste PET/keratin fibre blends

Figures 4 to 5 show the flexural properties of waste PET/keratin fibre blends that were buried in the soil and those that were not buried. The results revealed a general decrease in the flexural properties of the buried samples compared with their unburied counterparts. The weakening of the Keratin fibres of the buried samples due to attack by microbes, weather, humidity, and temperature under the soil might be responsible for the reduction in the flexural strength.

Hair is keratin i.e. a structural protein found on animal skin (20%) contains cysteine and methionine and could be a source of carbon and nitrogen for the microbes to initiate decomposition and in this way the material's strength changes [12]. Furthermore, the degradability of keratin rest on its wettability. In compost or healthy moist soil, it goes rather quickly, a matter of weeks or months because these are the location of huge numbers of different bacteria, actinomycetes and fungi [13].

Surface Morphology

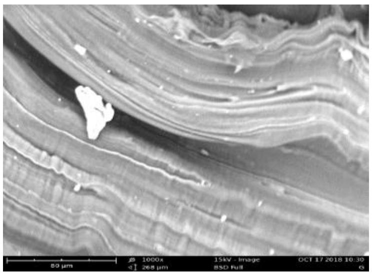

Plate 1: Unburied 0 wt% waste PET sample

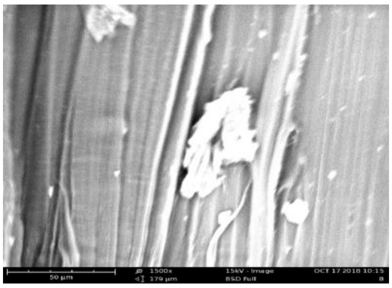

Plate 2: Buried 0 wt% waste PET sample

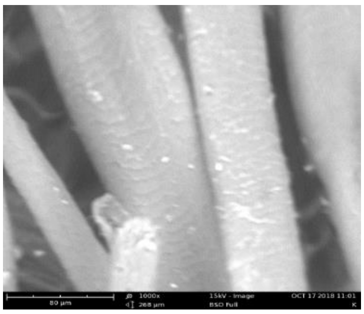

Plate 3: Untreated 30 wt% unburied sample

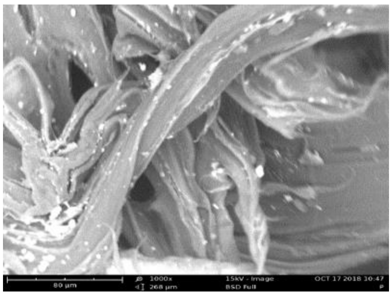

Plate 4: Untreated 30 wt% buried sample

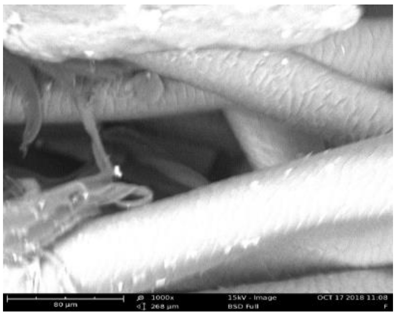

Plate 6: Treated 30 wt% unburied sample

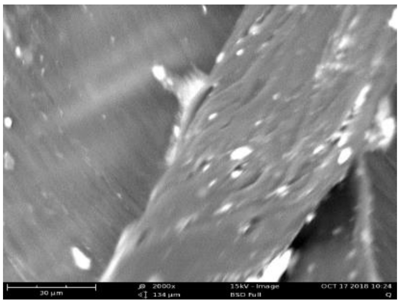

Plate 5: Treated 30 wt% buried sample

Plates 1-6 show the SEM images of tensile fractured surfaces of some of the buried and unburied composites samples. Plate 1 and 2 show a ductile failure for the unfilled waste PET sample. This indicates that soil burial for 90 days had no effect on the degradation of the sample made of only waste PET. This explains why the tensile and flexural properties of the 0 wt% sample before and after burial had no significant difference. Micrographs of all the soil buried composites show a rougher surface with the presence of voids and holes. The presence of voids and holes are due to the removal of the keratin fibres by microorganism in the soil. However, the sample filled with the surface treated keratin fibres had less voids and holes after burial. This is due to the strong interfacial adhesion between the matrix and the surface treated fibres. A major feature of keratin fibres is the presence of scales on their surface [14]. Surface treatment of the keratin fibres further exposed the scales as can clearly be seen in Plate 6. The scales enhance mechanical anchorage with the matrix. The stronger bond between the matrix and the fibres allowed for less water and microbial penetration into the composites causing less degradation effect to the composites. This further proves the higher mechanical properties of the samples filled with treated keratin fibres compared to those filled with untreated keratin fibres after the soil burial test.

According to Kim *et al*. [15], the presence of holes in bio-composite surfaces may be attributed to the attack by the microorganism under soil environment. It can be identified as a surface degradation of the composites [16].

CONCLUSION

The tensile and flexural properties of waste PET/Keratin fibre blends made by compression moulding technique will witness a decrease if the material is buried under the soil. This is because degradation causing microorganisms naturally available under the soil are capable of penetrating micro cracks inherently present on the surface of composites made using the compression moulding technique. The micro-organisms attack and feed on the keratin fibres which serve as the reinforcing phase of the composites thereby creating vacuums for stress concentration and subsequent decline in the strength of the material.

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