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Effect of UV-Light on the Mechanical and Morphological Properties of Waste Cow Leather – HDPE Composite

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Abstract

The potential of solid tannery vegetable re-tanned (VT)) waste as filler in high-density polyethylene (HDPE) were studied by examination of the effect of ultraviolet (UV) light on tensile properties and morphology of tensile fractured surface of the composites produced before and after a hundred days of natural weathering. The composites were prepared by two roll melt mixing, and pressed into shapes using compression moulding technique. Fabricated samples of various VT waste contents from 10 to 60% were pressed. Mechanical tests were conducted on the composite samples in accordance with ASTM specifications. The tensile strength decreased from 39.456 to 6.977MPa within 31days of exposure. With additives the composites tensile strength decreased from 5.888 to 5.69 MPa after 3days and remain constant with further exposure. Additives in HDPE/waste leather composite help to stabilize the composite against photo degradations. Ductile fracture surface of composite was the mode of tensile deformation before exposure to UV-light but after exposure to UV-light, a brittle fracture surface, showing wearing a way of the matrix (HDPE) on the surface exposed to sun, alignment of fibre and how they are loosely fallen off, the manner of dispersion, area of agglomerate, places of high concentration of both additives or fibre as well as places that were well dispersed were seen on SEM micrographs. Result suggests that composite of HDPE/VT can be decomposed under the influence of UV-light.

Keywords; Morphology, Natural weathering, Waste cow leather, Composite, HDPE, Properties

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Introduction

The current era is in search of materials, products, and processes that are compatible with the environment (Mohanty *et al*., 2005). For a few decades, efforts are ongoing on the utilization of natural fibres due to their biodegradability and availability in/or as alternative to synthetic polymer. The persistence of synthetic polymer after its service life is a major concern to scientists and manufacturers at large (Musa *et al*., 2017). The suitability of a developed material by a scientist is one that meets the needs of the present without compromising the needs of the future generations. Studies on composites of polymer (both synthetic and natural fiber) have already been established with a record of accomplishment in literatures (Mohanty *et al*., 2005; Jinchun *et al*., 2013; Shamsun *et al*., 2013). This work is aimed at using waste cow leather as filler in synthetic polymer, then exposed the composite to open air in order to know the effect of UV-light on the mechanical properties of the composite, hence proffer solutions to end-of-life of the composite material from polluting the environment.

The other advantage of natural fibre-reinforced composite is reduction in density of products, acceptable specific strength, toughness, and stiffness; and low capital investment due to low cost (Nahar *et al*., 2012).

One difficulty that had prevented a more extended utilization of natural fibre is the lack of good adhesion to most polymeric matrices. Surface treatment with suitable additives or compatibilizer is an effective method to improve fiber – matrix adhesion in natural fibre composites. Several methods have been provided by researchers on how to enhance adhesion in literatures (John and Richard, 2005; Jerzy and Elizbieta, 2012; Espana *et al*., 2013).

Most plastics by themselves are not suitable for load-bearing applications due to their lack of sufficient strength, stiffness and dimensional stability. On the other hand, fibres possess high strength and stiffness but are difficult to use in load bearing applications by themselves because of their fibrous structure. Combination of the two, in fibre reinforced composites, the fibre serve as reinforcement by giving strength and stiffness to the structure while the plastic serves as the matrix to hold the fibres in place so that suitable structural component can be made.

The feasibility study on the conversion of waste plastics into a degradable composite according to Nahar *et al* (2012) is grouped in two major classes which are, a completely biodegradable system and biofragmentable system that is not completely biodegradable. The biofragmentable polymers are blend materials composed of a completely degradable component and a component capable of biodegradation. The presence of moisture in the air causes deterioration on sample when exposed to winter heat (temperatures).

Materials and Methods

Vegetable ('Bagaruwa' *Acacia nilotica*) tanned waste (obtained from Nigerian Institute of Leather and Science Technology (NILEST) Zaria) was selected, cleaned, sun and oven dried at 50^0C then ground to 0.5 mm particle size using an Arthur Thomas Wiley laboratory Mill (model 4), Philadelphia, PA USA. The ground sample was preserved in clean dried thermoplastic transparent bucket with lid as the bulk sample. The high-density polyethylene (HDPE), manufactured from Indorama Petrochemical Company Port-harcourt, Nigeria, a commercial grade was purchased while the additives used were of analytical grade.

The formulation for the different composition of matrix and cow leather wastes used for the research are shown on Table 1 and Table 2 respectively.

Compounding

The formulations on Table 1 (PW01-PW07) were picked one after the other and compounded using Carvers Two Roll Mill (Model 5183) at a processing temperature of 180^0C within 9 minutes. The method of Musa *et al* (2014) was used in compounding. The temperature and processing time was same for all formulations on Table 1 and Table 2, respectively.

Compression Moulding

Each compounded formulation, 1.5g in weight, was measured out and pressed at a compression temperature and pressure of 180-185ºC and 3×10^3 N/m² within 3 minutes preheating and 5 minutes pressed, respectively, 10 samples were pressed into thin film of 1.0 mm thick. All composites were produced in accordance with ASTM D638.

Table 1: Composite formulation of the different composition of HDPE/waste cow leather

	Composites						
Samples (wt %)	**PW01**	**PW02**	**PW03**	**PW04**	**PW05**	**PW06**	**PW07**
HDPE	100	90	80	70	60	50	40
Vegetable re-tanned waste	0	10	20	30	40	50	60

Table 2: Composite formulation of the different composition HDPE/waste cow leather with additives

	Composite with additives (A) or (B)						
Samples (wt %)	**PW01**	**PW02**	**PW03**	**PW04**	**PW05**	**PW06**	**PW07**
HDPE	100	90	80	70	60	50	40
Vegetable re-tanned waste	0	10	20	30	40	50	60

Where A= 0.5g trimethylquinoline (TMQ), 3.5g$Mg(OH)_2$, 0.3g TiO_2, 10g natural rubber (NR), 2g ethylene vinyl-acetate copolymer (EVA) and 2ml of acrylic acid) while B = 0.5g trimethylquinoline (TMQ), 3.5gMg $(OH)_2$, 0.3g TiO_2 and10g natural rubber (NR)), respectively).

Photolysis

Natural weathering of the composite was evaluated by exposing the test samples outside in the open air in accordance with ASTM D1435 standard at the Federal University of Kashere Observatory Station, Gombe State during Harmattan season (September to January). Samples were mounted between two cardboard papers in which holes of approximate dimensions were made, 90 mm × 1000 mm wide. Each sample was placed over a hole on one side of the cardboard paper while another cardboard paper with a hole of equal dimension was placed on top. The cardboard papers were labelled according to the composition of the prepared composite. A masking tape was used to hold the two cardboards together (Kolawole and Olugbemi, 1985; Turu *et al*., 2014). The system was then placed under the open air at exposure time of 1, 3, 7, 31 and 100 days respectively. Composites were picked periodically and their tensile strength was tested.

Morphology

The morphology of the composite was studied by using a JSM-5600 LV (Jeol, Tokyo, Japan) scanning electron microscope (SEM). The fracture surface of composites after tensile test were mounted on a metal stub and sputter-coated with gold in order to make the composite conductive before analysis. Morphologies of the composites before and after modification with additives were studied. The scanned images were taken at accelerating voltage of 2.0 and15.0 kV.

Results and Discussion

The effect of UV-light on the tensile strength of HDPE90/Vegetable tanned waste10 is represented in Figure 1. From the Figure, the tensile strength decreased with increasing time of exposure to UV-light. The tensile strength decreased from 39.456 to 6.977MPa within 31days of exposure, implying loss in strength. Thomas *et al* (2004) and Shaoxu *et al* (2006) reported in their research work that exposure of fibre reinforced plastic to UV-light produces changes in mechanical properties and visual observation of samples coloration with time. This implies that the exposure of fibre reinforce composite to UV-light resulted in the loss of matrix on the surface exposed to UV-light of the material leading to the inability of the matrix to effectively transfer stress between its components, justifying the lost of tensile properties as observed in Figure 1.

Figure 2, illustrates the stability of the composite to photo oxidation for a hundred days when additives (type A and B) were mixed with the fibre and waste tanned leather during the developmental stage as stabilizers. The result of Figure 2 was seen to response in a similar manner to UV-light as those of Figure 1 but the rate of decrease in tensile strength was much lower and remains almost constant after 7 days for both type A and B additives used, respectively. The composite (type A) tensile strength decreased from 5.888 to 5.69 MPa after 3days and increased to 6.2, 6.6 and 6.977 MPa in 7, 31 and 100 days, respectively. While type B tensile strength decreased gradually from 14.5 to 8.4 MPa from the first day to the last day (100). Composite type A was more stable under UV-light to type B. The reduction in tensile properties can be said to be due to the loss wearing a way of matrix at surface directly exposed to the sun, thereby preventing effective transfer of stress between the two component interfaces. In addition, the result in Figure 2 for both type of HDPE90/Vegetable tanned waste10 after 3 days of exposure, increased with exposure time, implying a situation had developed gradually within the surface of composite to prevent any further loss in tensile property with further increased in the time of exposure to UV-light. James *et al* (2008) had similar observation on their research work and gave an explanation, that a photo induce molecular cross linking might had taken place. This may likely be the cause of the slight increase in tensile strength in composite type A in Figure 2 from 5.69 to 6.98 MPa.

Figure 3 describes the effect of waste content with additives on the tensile strength of HDPE/VT (A & B) after a hundred days of exposure to UV-light. From the result, tensile strength increased with increasing waste content to a maximum and decreased with further increased in waste content, suggesting that the more waste the better the stability to UV-light and better adhesion to some point. The maximum tensile strength occurs for both type A and type B at 20 and 40 wt% waste content, which had values 13.6 and 12.0 MPa, respectively. The best composition in the formulation was 80: 20 of HDPE to vegetable tanned cow waste composite with a type A additive, while for type B additives, was obtained at 60: 40 of HDPE to vegetable tanned cow waste composite. The result in Figure 3 agrees with Mohanty (2005) which says, ‘in polymer matrix composites, there appears to be an optimum level of fiber-matrix adhesion, which can provide the best composite properties’.

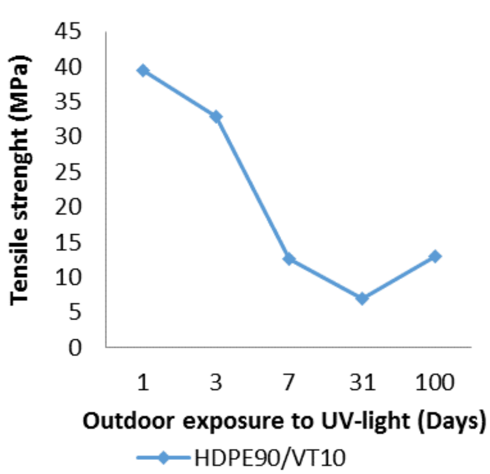

Figure 1: Effect UV-light on the tensile strength of HDPE90/VT10 composites without additives.

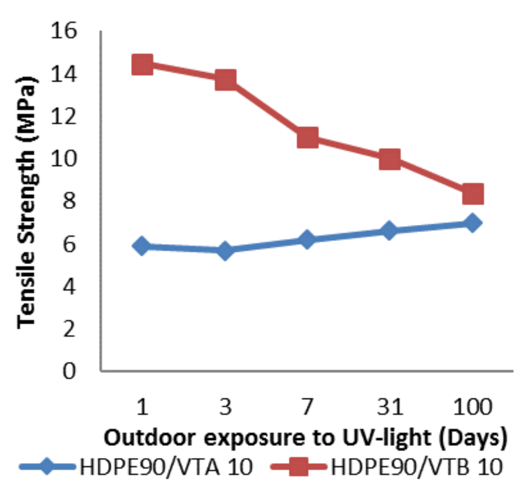

Figure 2: Effect of UV-light on the tensile strength of HDPE90/VT10 composite with additive A and B, respectively.

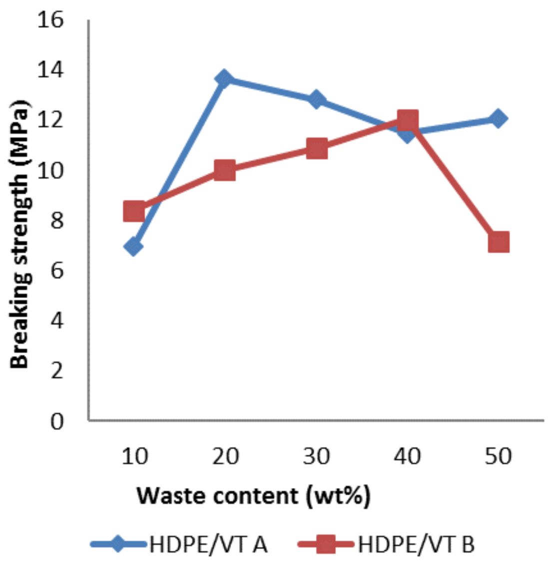

Figure 3: Effect of waste content on the tensile strength of HDPE/VT with additives (type A and B, respectively) after three month of outdoor exposure to UV-light.

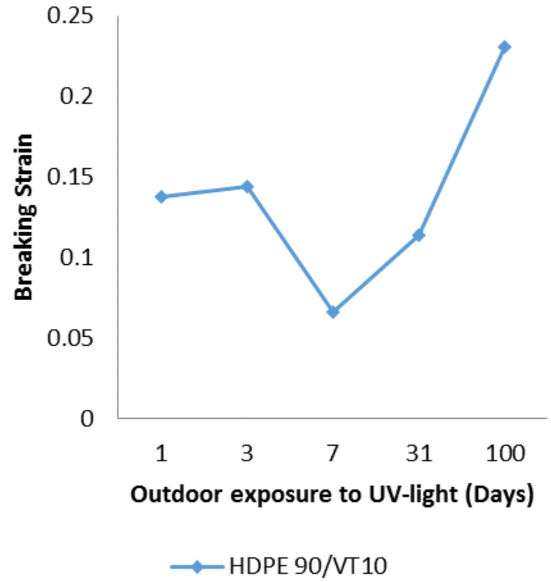

Figure 4: Effect of outdoor exposure to UV-light on the breaking strain of HDPE90/VT10 composite without additive.

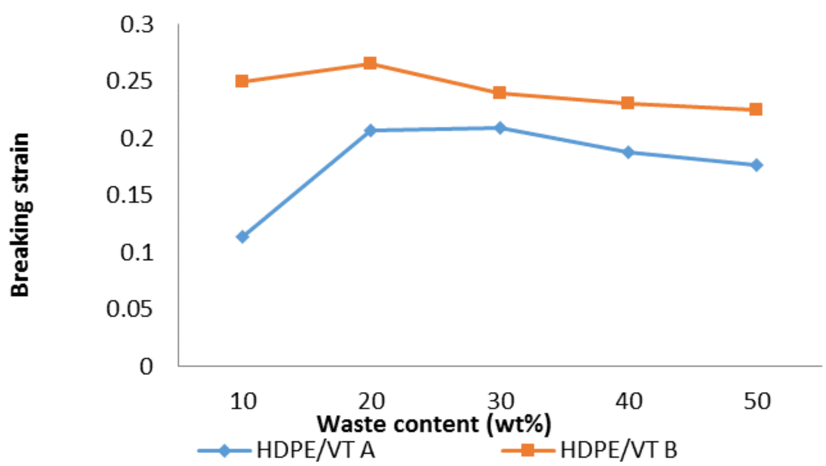

Figure 5: Effect of waste content on the breaking strain of HDPE90/VT10 composites with additives A and B, respectively after three Month outdoor exposure to UV-light.

Figures 4 and 5 describe the effect of UV-light to the tensile strain of HDPE90/vegetable tanned waste 10 and HDPE/VT composite with additives A and B, respectively with increased in waste content. From the result of Figure 4, breaking strain decreased with increasing exposure time up to the 7th day then increased with further time of exposure. It means, ductility of the composites decreased with exposure time. Lundin *et al* (2004) and James *et al* (2008) described the response of natural fibre reinforced polymer to normal environmental ageing; that a rapid degradation happens within the first 0-400h, and continuous within 400-2000h then level up. The elongation at break of HDPE/VT (A and B) in Figure 5 was seen to agree with the report.

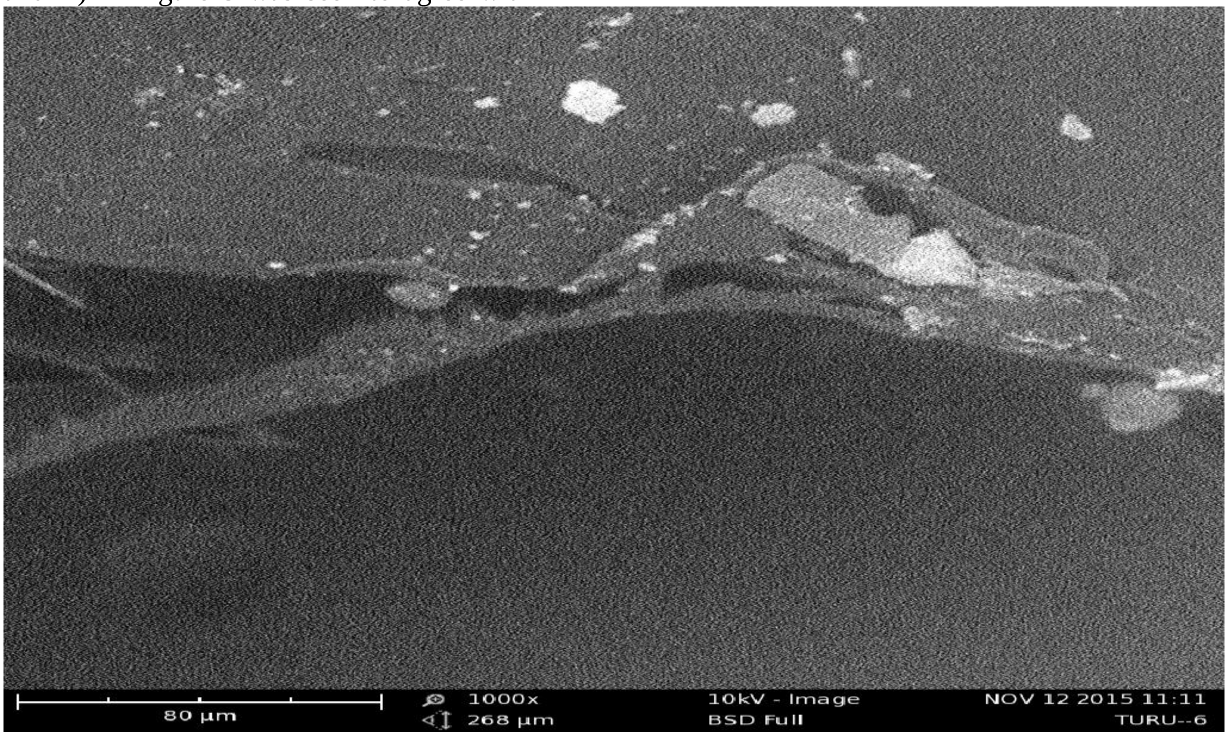

Figure 6: SEM micrograph of tensile fracture surface of HDPE90/vegetable tanned10 (HDPE90/VT10) composite with additives before exposure to UV-light.

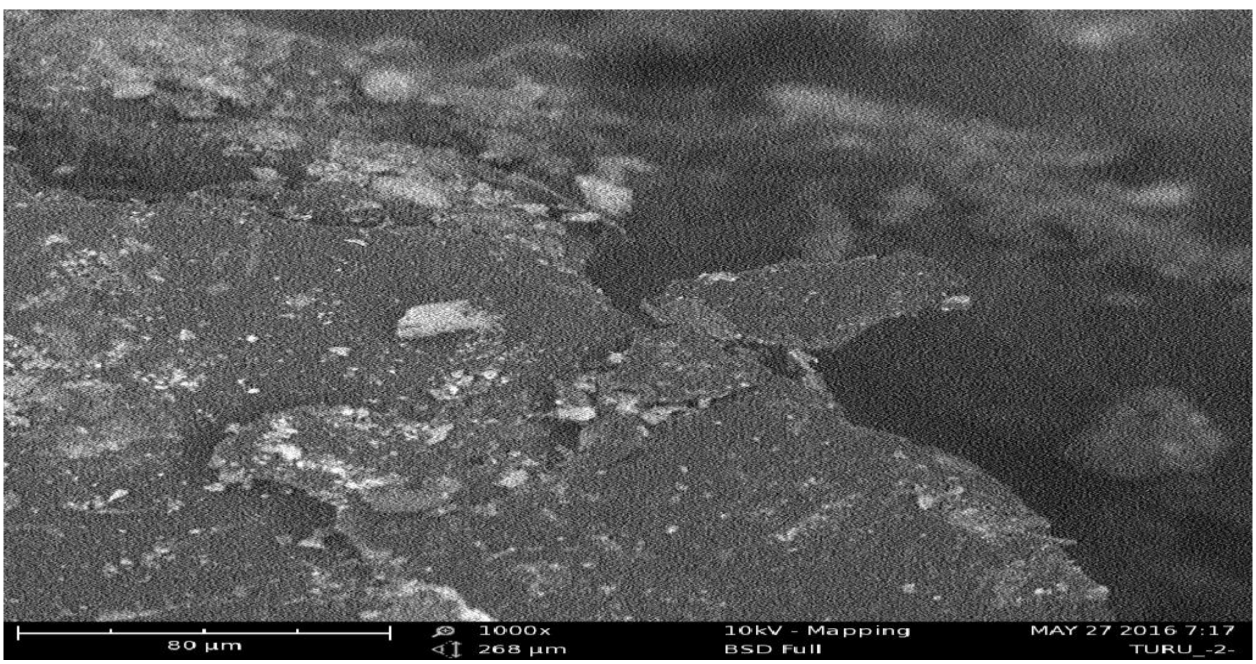

Figure 7: Effect of natural weathering on the SEM micrograph fractured surface of HDPE/vegetable-tanned composite after 100 days of exposure UV-light

Figure 6 shows the SEM micrograph of tensile fracture surface of HDPE90/vegetable tanned10 composite before exposure to UV-light. The micrograph of Figure 6 depicts a good fibre-matrix interaction, seen by links network resisting deformation. According to Mohit (2015), link network indicates good dispersion and compatible fibre-matrix interface. It also means strong bonding at the fibre- matrix interface, (Rajendran *et al* 2016). The micrographs, in addition, shows white patches, holes and presence of various structures like fibrils. The white patches were inorganic substances added as additives while the presence of some holes were due to removal of the fibre (fibre pull-out) while, the presence of various structures like fibrils, suggests a poor interaction between fibre and matrix at such regions. The mode of failure in Figure 6 include tearing of the surface of composite along highly concentrated additives. Ambrósio *et al* **(**2011) reported that accumulation of fibre in a place leads to poor adherence. Concentration of particles or fibre, acts as a flaw which could change the mode of fracture from being ductile to brittle as was seen in Figure 6.

Figure 7 showed the effect of UV-light on the SEM micrograph of the composite fractured surface of HDPE/vegetable-tanned with additives after 100 days of exposure. A pronounced brittle deformation of the composite was seen all over the surface. Wearing a way of the matrix (HDPE) on the surface exposed to sun was clearly seen, thereby showing alignment of fibre and how they are loosely falling off, making it easier for decomposition. The manner of dispersion, area of agglomerate, places of high concentration of both additives and fibre as well as places that were well dispersed were equally seen. The composite are seen to break out into fragments. The result in Figure 7 showed a brittle deformation, implying the absence of the wetted surface area of contact between interface that keeps the material (ductile) mechanically bonded together. The exposed fibre being a natural material can decompose in the present of moisture and other element of nature.

Conclusion

The effect of ultraviolet (UV)-light on the tensile property of composite made of high-density polyethylene (HDPE) mixed with waste from vegetable (*Accasia nolitica*) re-tanned cow leather was studied and found that the tensile properties decreased with exposure time. The rate of deformation was slower with composite having additives. The rate of deformation was seen to level up 3-days. SEM micrograph after exposure to UV-light showed the disappearance of the matrix revealing the fibre alignment to the presence of moisture in the air and/or micro-organism that can cause deterioration on sample. Composite fabricated can fall under the class of biofragmentable system.

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