EXAMINIG THE MECHNICAL AND MORPHOLOGICAL PROPERTIES OF POLY-LACTIC ACID (PLA) /WASTE HIGH-DENSITY POLYETHYLENE (wHDPE) BLENDS FILLED PLANTAIN PEEL (*MUSA PARADISIACA*) PARTICULATES COMPOSITES.

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ABSTRACT

In this study, poly-lactic acid (PLA)/ waste High-Density polyethylene (wHDPE) blends-filled plantain peel particulate composites were fabricated by compression moulding techniques using alkali treated plantain peel with 2 % sodium hydroxide and a particle size of 100 µm with filler loadings ranging from 5 wt.% to 50 wt.%. The mechanical properties of the prepared composites were evaluated. Also, the morphological properties of the composites were studied using scanning electron microscopy (SEM) to examine the tensile fracture surfaces. The results showed that the tensile strength, impact strength and flexural strength of the composites decreased with an increase in filler content. The highest values were recorded for 100 % PLA, tensile strength of 40.66 MPa, impact strength of 1.5 J/m², and flexural strength of 55.60 MPa, than its counterpart of 100 % wHDPE composites which show tensile strength of 24.90 Mpa, impact strength of 1.0 J/m² and flexural strength of 31.98 Mpa. The tensile modulus reached 3.307 GPa for 100 % PLA, flexural modulus at 28271.76 MPa, and hardness reached 54.61 Hv at 50 wt. % filler contents. SEM revealed better filler dispersion at 5 wt. % filler loading to 50 wt. %, where agglomeration and clustering of the plantain peel occurred due to saturation. Plantain peel particulates can effectively be used as filler in PLA / wHDPE blends for applications such as packaging, interiors and others.

Keywords: Poly-Lactic Acid, Waste High Density Polyethylene, Polymer blend, Bio-composites

INTRODUCTION

Plastic waste is a significant environmental concern due to increased usage and improper disposal methods. Recycling via composites, in use with natural fibres, offers a way to reuse waste and reduce pollution (Jacob et al., 2018). Natural fibres are increasingly used in polymer composites for their low density and renewable nature (Yuanjian & Isaac, 2007; Sanjay et al., 2016). Research explores blending PLA with HDPE waste and using natural fillers like plantain peels, which improve mechanical strength and thermal stability (Jones et al., 2020; Smith, 2021).

Aims of the study

This study aims to investigate the mechanical and morphological properties of PLA/waste HDPE blend filled plantain peel particulate composites.

Objectives of the Study

The objectives of this study are to:

i. Source and prepare plantain peel particulates with alkali treatment using 2 wt.% of sodium hydroxides.
ii. Use 100 µm particle size with varying plantain peel particulates loading from 5 wt.% to 50 wt.% in PLA / WHDPE composites.
iii. Prepare the composites with a percentage (%) blend ratio of 3 wt.% PLA and 97 wt.% wHDPE
iv. Evaluate the mechanical properties (Tensile strength, Flexural strength, Hardness and Impact resistance of the resulting composites.
v. Analyze the morphology of the tensile fractured surface of the prepared composites.

MATERIALS AND METHOD

Materials: Polylactic acid, High-Density Polyethylene waste, Plantain Peels, Sodium Hydroxide, Sodium Bicarbonate, Acetic Acid and Distilled Water.

Methods: Materials Collection and Preparation.

Waste Plantain Peels

The plantain peels were cleaned, air-dried for 72 hours, sun-dried for a week, and pulverised to obtain the particles. It was then alkali-treated with 2 % w/v NaOH solution at room temp for 1hr. washed with distilled water, neutralised with 1 % acetic acid, and oven-dried at 60 ℃ for 48hrs. Sieved to 100 µm particle size and used in composite preparation at 5 wt.% -50 wt.% filler loading.

High-Density Polyethylene (wHDPE)

HDPE (waste) were washed thoroughly with sodium bicarbonate, rinsed with distilled water, sun-dried and shredded into particles of smaller sizes using a shredding machine. 97 wt. % was used as % polymer blend, for preparing the composites.

Blends and Composite Formulation

Preliminary tests were carried out with varying blend ratios of HDPE (waste) ranging 97 wt. % - 85 wt. % and PLA from 3 wt. % - 15 wt.%. 97 wt. % wHDPE and 3 wt. % PLA content showed promising results of tensile properties. Hence, 97 wt.% and 3 wt. % was chosen and the wt.% of the varying plantain peel particles loading from 5 wt.% to 50 wt.% was calculated and taken out of the total wt.% of the matrices (according to the rule of mixture) as the % blend for preparing the composites with a particle size of 100 µm. PLA and wHDPE were mixed in a two roll mill machine and compounded with PPP at a nip distance of 0.001-0.004 mm by ASTMD 15-627 at 170 ℃ for 5 minutes, collected and placed in a metal mold of 150 x 150 x 5 (mm), compression molded at 160 ℃ for 5 minutes and cold pressed at room temp for 3 minutes and a pressure of 2.5 Pa was applied. Composites were removed, conditioned and cut into various dimensions for Characterization according to ASTM standards for testing materials.

- Tensile Strength ASTM D638
- Hardness ASTM D2240
- Impact Strength ASTMD 256
- Flexural Strength ASTM D790
- Scanning Electron Microscope (SEM)

Plate 1: Treated Plantain Pericles

Plate 2: Fabricated Cut Samples

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RESULTS AND DISCUSSIONS

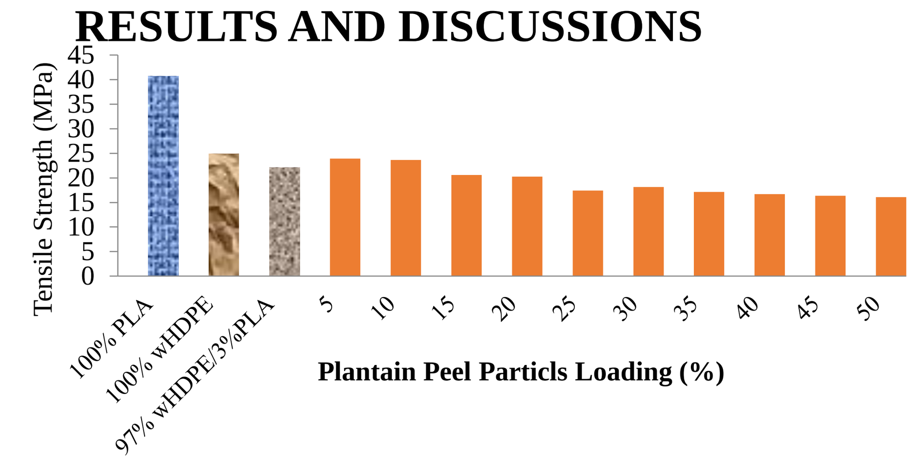

Figure 1: Tensile Strength as a function of plantain peel particles (%) for PLA / wHDPE blend / plantain peel particulate composites
The tensile strength of the matrices was 22.073 MPa, while the composites at 5 wt.% and 10 wt.% were 23.906 MPa and 23.651 MPa, respectively. The higher tensile strength is attributed to better interfacial adhesion from removing lignin, pectin, and hemicellulose in plantain peel particles. However, tensile strength decreases from 5 wt.% to 50 wt.% due to weak interfacial adhesion at saturation of matrices.

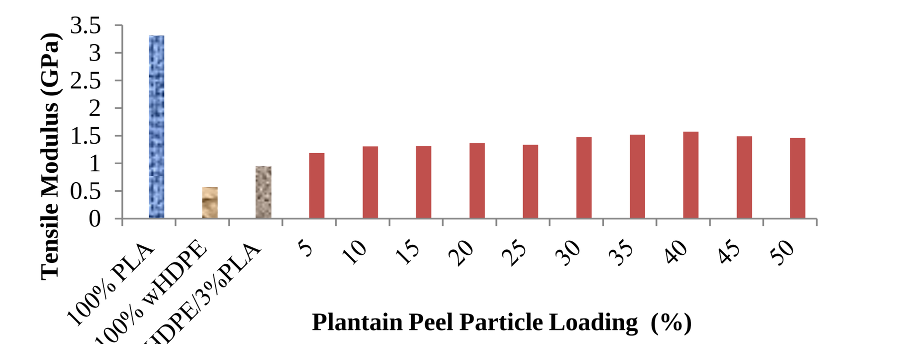

Figure 2: Tensile Modulus as a function of plantain peel particles (%) for PLA / wHDPE blend/plantain peel particulate composites
The tensile modulus of the matrices was 0.944 GPa. It increased progressively from 5 wt. % to 40 wt. % plantain peel particles loading due to reduced ductility but decreased at 45 wt. % and 50 wt. % loading due to saturation. The highest tensile modulus was 3.307 GPa at 100% PLA, and the lowest was 0.562 GPa at 100% wHDPE.

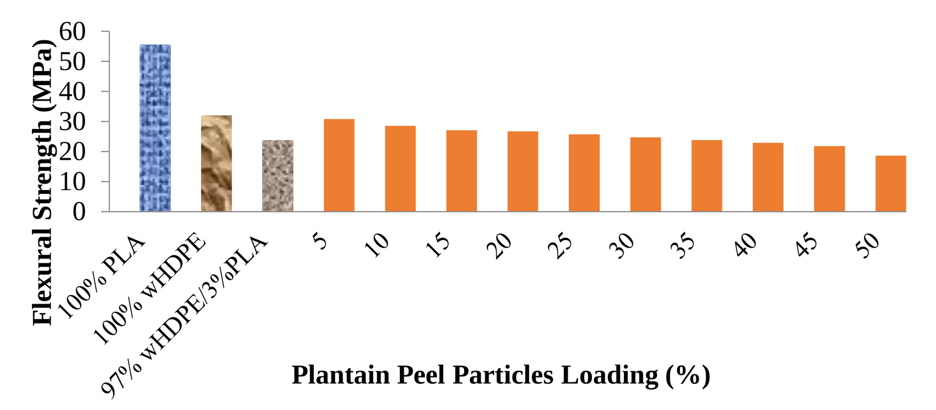

Figure 3: Flexural Strength as a function of plantain peel particles (%) for PLA / wHDPE / plantain peel particulate composites
The flexural strength of the matrices (wHDPE/PLA) was 23.75 MPa. The composites' flexural strength increased from 5wt. % to 35 wt. % plantain peel particles, ranging from 30.865 MPa to 23.8015 MPa. However, it decreased from 5 wt.% to 50 wt. % plantain peel particles, ranging from 30.865 MPa to 18.645 MPa, due to matrices saturation. The highest flexural strength was 55.599 MPa at 100% PLA, while 100% wHDPE with 31.986 MPa.

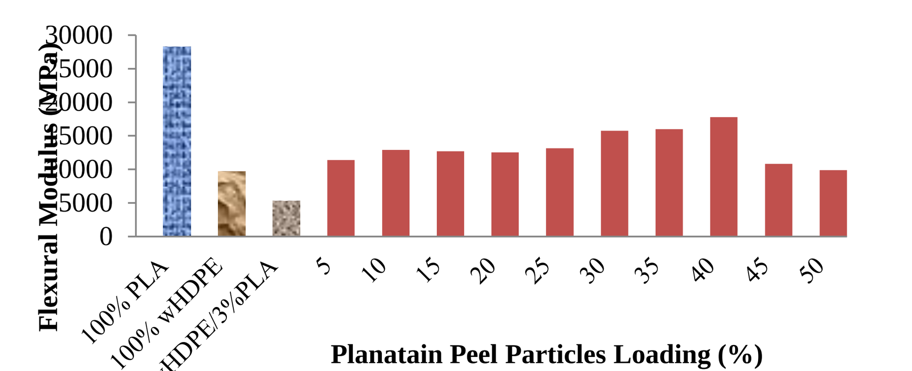

Figure 4: Flexural Modulus as a function of plantain peel particles (%) for PLA / wHDPE blend / plantain peel particulate composites
The flexural modulus of the matrices was 5227.486 MPa. It improved progressively with plantain peel particles from 5 wt. % to 40 wt. %, but decreased at 45 wt. % and 50 wt. % due to matrix saturation. The increase is attributed to added stiffness from rigid plantain peel particles. The highest flexural modulus was 28271.76 MPa at 100 % PLA and 9704.11 MPa at 100 % wHDPE.

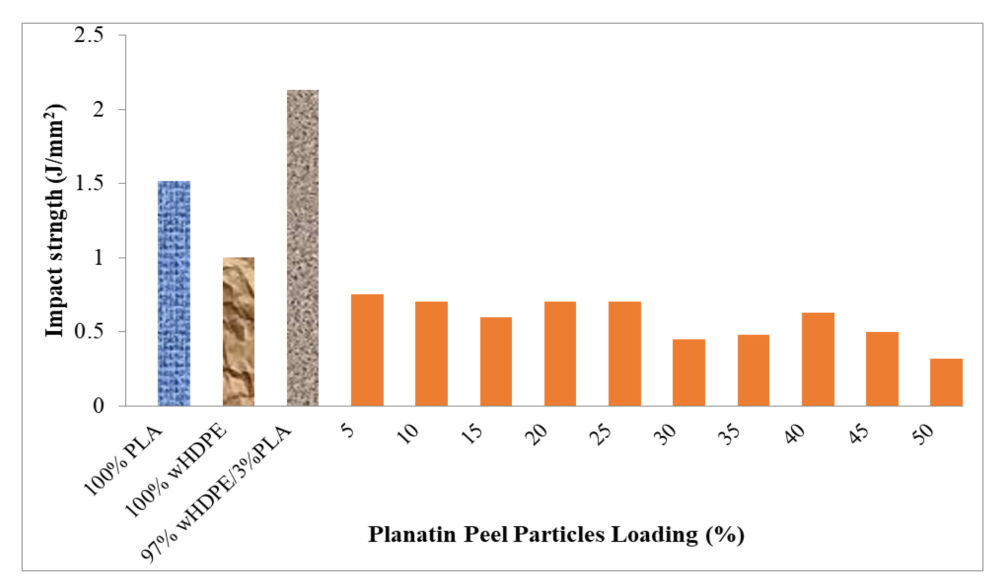

Figure 5: Impact Strength as a function of plantain peel particles (%) for PLA / wHDPE / plantain peel particulate composites.
The impact strength of the composites decreases as the concentration of plantain peel particles increases, which reduces the Composites ability to absorb energy and resist impact. This reduction in toughness is because the particles stiffen the composite, resulting in higher stress transfer. The highest impact strength was 2.31 J/m² for wHDPE/PLA, 1.5 J/m² for 100 % PLA, and the lowest was 0.32 J/m² at 50 % plantain peel particles.

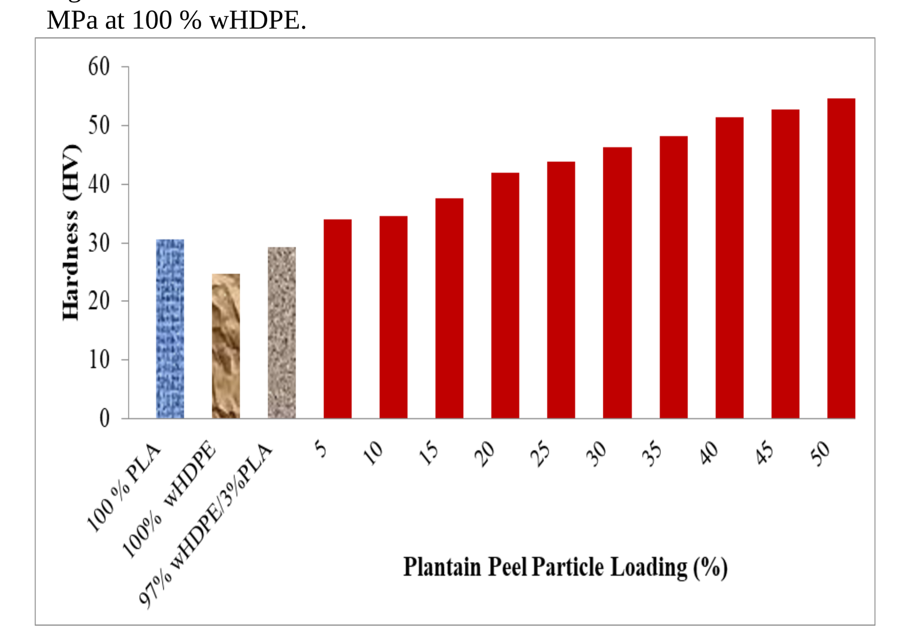

Figure 6: Hardness as a function of plantain peel particles (%) for PLA / wHDPE / plantain peel particulate composites
The hardness value of the PLA/wHDPE matrices was 29.30 HV. As plantain peel particles content increased, the composite became stiffer and harder, raising its hardness. The lowest hardness value was 24.8 HV for 100 % wHDPE, and the highest was 54.61 HV for 50 wt. % plantain peel particles due to increased stiffness of the polymer matrices.

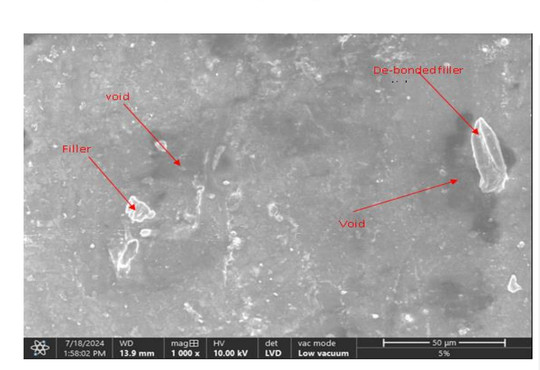

Plate 3: SEM micrograph of fracture surface for PLA / wHDPE / plantain peel particulate composites (50 % plantain peel particles at 1000 magnification

The SEM micrographs in Plate 3 and 4 show the fractured surfaces of PLA/wHDPE composites with 5 wt.% and 50 wt.% plantain peel particles. The 5 wt.% composite has better dispersion and interfacial adhesion due to alkali treatment, resulting in a homogeneous surface. In contrast, the 50 wt.% composite shows agglomerations and clusters of particles, leading to poor interaction and dispersion within the matrices due to high particle concentration and saturation.

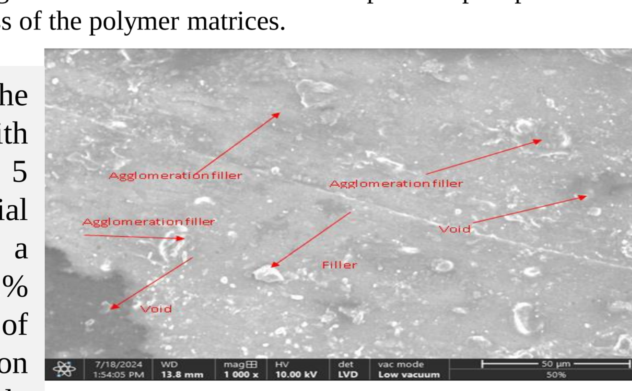

Plate 4: SEM micrograph of fracture surface for PLA /wHDPE / plantain peel particulate composites (5 % plantain peel particles at 1000 magnification)

CONCLUSION

The study shows that useful composites could be successfully produced using plantain peel particulate (PPP) as filler into the thermoplastic blend (PLA/ wHDPE) matrices and mechanical properties measured such as the tensile strength, impact strength, flexural strength decreases with increase in plantain peel particles due to clumping, voids, and agglomeration formation which result in weak bonding. This demonstrated that the plantain peel particles used in this work acted as a filler rather than reinforcement. However, the tensile, flexural modulus and hardness value of the composites increase with an increase in plantain peel particles, the highest tensile modulus was recorded for 100 % PLA with 3.307 GPa, flexural modulus with 28271.76 MPa and highest hardness value at 50 % with 54.61 HV. The plantain peel particles incorporated into PLA/ wHDPE matrices give an amazing hard composite with an excellent and unique surface appearance that may be interesting in packaging and interior applications.

SEM analysis of micrograph for 5 % plantain peel particle composites shows better dispersion of the plantain peel particles within the matrices leading to better interfacial adhesion between the plantain peel particles and polymer matrices whereas 50 % micrograph shows agglomerations and clustering of the plantain peel particle within the matrices at saturation which cause the formation of voids and cracks during processing.

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