Production and Characterization of Composite Board from *Swietenia macrophylla* Wood Dust and Polyethylene Plastic

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Accepted: June 22, 2024. Published Online: June 28, 2024

ABSTRACT

There is a growing demand for alternative materials that are environmentally friendly, economically viable, and socially responsible. The production of composite boards from *Swietenia macrophylla* wood dust and waste polyethylene was studied. Water absorption, hardness, flammability and morphology were evaluated using standard methods. High water absorption was observed in a composite made from waste high-density polyethylene film which varied from 32 to 112.7% after 2 h and 51.5 to 145.4% after 24 h water immersion. Composite made from virgin high-density polyethylene film varied from 29.5 to 86.8% and at 55.5 to 137.7% after 2 h and 24 h water immersion respectively. Ignition time increases as the wood dust particles increase which makes the flame propagation rate of the composite decrease from 0.65 to 0.22 mm/s for the virgin high-density polyethylene composite and 0.68 to 0.27 mm/s for waste high-density polyethylene composite. The result of the scanning electron microscope showed a considerable amount of filler and matrix breakage with finite intact material on the surface. At constant polyethylene content, the hardness decreased as the filler increased from 78.6 to 22 MPa for virgin high-density polyethylene film base composite while 60.7 to 17.7 MPa for waste high-density polyethylene film base composite. A composite board was produced from the waste and virgin polyethylene and *Swietenia macrophylla* wood dust.

Keywords: Composite, plastics, polyethylene, production, *Swietenia macrophylla*, waste

INTRODUCTION

Swietenia macrophylla is one of the most commercially used timber tree species in neo-tropical forests which belong to the family Meliaceae [1]. The *Swietenia macrophylla* tree can grow up to a height of 40 m, it also has an open compact and rounded crown composed of thick, ascending, and twisted branches, exfoliated bark in small plates, and persistent leaves monoecious. It is also a self-incompatible, and insect-pollinated tree [2].

Recycling is introduced as a way to curb the problems that arise [3]. When natural resources are recycled, they can be preserved for future use, similarly, recycling protect the environment such as the forest and green plant which provide oxygen for human to live [4]. Using plastic waste for the production of composite can also reduce the accumulation of waste produced and can help to prevent garbage accumulation problems. Waste management also reduces costs since manufacturing products from raw materials to finished products is getting more expensive due to economic policies affecting the production industries [5].

Wood plastic composite heave-in-sight as an issue of significance in recent decades [6]. Despite the efforts devoted to developing composites, it should be seen that the effective large-scale implementation of plastic recycling typifies a goal that is still far from being fully achieved by the recycling researchers. [7]. The major barrier arises from the low compatibility of different components in plastic recycling are still not satisfied, [8] hence, much devotion is still required in order to explore the versatility in the composite developments.

As a part to waste conversion to wealth, Dass *et al.,* [9] studied high density polyethylene films / wood dust particles composite. The physical properties were studied, such as water absorption, flammability, hardness, and the morphology of the produced composites. The composites made from high-density polyethylene material waste showed lesser values from those made of virgin high-density polyethylene films. However, the values reported from the study was close to the standards for notice board material. A gradual reduction in the flammability of the composite was reported as the wood dust particles and high polyethylene material as matrix increased.

Despite the vast researches carried out on plastic waste and agricultural materials, the market is still in need of more industrial materials [4, 9]. To overcome this problem, this research was aimed to develop a composite from recycled material such as *Swietenia macrophylla* wood flour (saw dust) and polyethylene film (package water bag). It is known as the Wood Plastic Composite (WPC). In this research, a study on the properties of wood plastic composite was done to develop and improve the usage of this composite in the future. The research work centered on investigating the workings and mechanical characteristics of the wood plastic composite materials fabricated with hardwood particle dust/polyethylene matrix.

The aim of this work is to provide evidence that the waste and virgin polyethylene (HDPE) and hard wood dust particle can be successfully used to produce stable WPCs suitable for exterior applications in terms of water absorption, flammability, hardness and morphology of the composite.

Plate I shows the *Swietenia macrophylla* wood log while Plate 2 shows *Swietenia macrophylla* wood particle**.**

Plate 1: *Swietenia macrophylla* wood

Plate 2: *Swietenia macrophylla* wood particle

MATERIALS AND METHODS

Sample collections

The *Swietenia macrophylla* wood was obtained from Wukari Local Government Area of Taraba State, Nigeria. This wood underwent the process of grinding into powder. This procedure was carried out at the Department of Chemistry laboratory, Federal University Wukari, Taraba State, Nigeria. Polypropylene plastic, sourced from around the neighborhood and some was bought from Wukari market in Taraba State, Nigeria, were utilized for the study.

Wood plastic composite preparation

The wood dust was dried in an oven maintained at 100 °C for 24 h. This was done to remove moisture. After this, it was ground to finely powdered particles and sieved for easy dispersion in the formulation. Fixed amount of toluene was measured and poured into a 250 ml conical flask before mixing with 12 grams of the filler resin at 135 °C in an oil bath till the resin dissolved totally in the toluene solvent. Saw dust which was the filler was measured and added appropriately to the solvent-resin mixture and stirred continuously for at least five (5) min at constant temperature. Then the mixture was cast into an aluminum mold with 3 mm thickness, 7 mm width, and 10 mm length. The composite was conditioned at a temperature of 23±2 °C for at least 40 h according to Dass *et al.* [9].

Characterization of wood plastic composite

Water absorption

Water absorption test was carried out following the ASTM D 570-98 method. In this method, water absorption of the composites was determined using 2 h and 24 h immersion. When the composites are immersed in distilled water maintaining a room temperature. Five specimens of each formulation were placed in an oven to further remove the moisture for 24 h. The dried specimens were all weighed using a weigh meter. After the 24 h immersion period, the specimens were all removed from the water, then the surface water was removed using water wiper material. The wet weight value for each immersed composite was determined using the water absorption percentage formula as illustrated in equation 1 [2]

$$M(\%) = \frac{(mt - m^{\circ})}{m^{\circ}} \times 100 \qquad (1)$$

Where m^{o} and mt are the oven-dry weight and after time weight respectively.

Flammability test

Flammability test was carried out following the ASTM D635 method. A mark was measured and marked out on each of the specimens. The specimen was then clamped horizontally in a retort stand with the marked 60 mm distance protruding out of the clamp. The free end of the sample was ignited and the time taken for the sample to ignite was recorded as the ignition (I_t). The sample was allowed to burn to 60 mm mark (D_p). The relative rates of burning for the different samples were determined using the expression in equation 2 [10].

$$Flame\ p.r.\left(\frac{mm}{s}\right) = \frac{Dp\ (mm)}{Pt(sec) - It(\text{sec})} \qquad (2)$$

D_p = Propagation distance measured (mm), P_t = Flame propagation time measured (sec)

I_t = Ignition time measured (sec).

Determination of hardness

Hardness is the resistance of a material to indentation. When the resistance is higher the harder the material can be and the lower the resistance the lower the hardness of the material. Hardness determination was carried out following ASTM D-2240 method. To determine the hardness, a modified Meyer hardness tester we employed. The hardness for the samples were determined using the expression stated in equation 3. [2, 9]

$$BHN = \frac{F}{\pi (d - \sqrt{d^2 - d_i})^2} \quad (3)$$

Where F = Imposed load, d = Diameter of the indenter, d_i = Diameter of the indentation

Scanning Electron Microscopy (SEM)

A morphology study was carried out using scanning electron microscopy (SEM) to evaluate the fractured surface of samples following ASTM E9862-97. The changes in morphology are important to predict fiber interaction with the matrix in composites [2, 8].

RESULTS AND DISCUSSION

Water absorption

Figure 1 shows the water absorption of virgin and waste high-density polyethylene/*Swietenia macrophylla* wood dust particle composite at a constant matrix. High water absorption was observed in a composite made from waste high-density polyethylene film which varied from 32 to 112.7% after 2 h and 51.5 to 145.4% after 24 h water immersion. Composite made from virgin high-density polyethylene film varied from 29.5 to 86.8% and 55.5 to 137.7% after 2 h and 24 h water immersion respectively. Figure 2 shows the water absorption of virgin and waste high-density polyethylene/*Swietenia macrophylla* wood dust particle composite at constant filler. The water absorption for virgin high-density polyethylene/*Swietenia macrophylla* wood dust particle composite decreased from 31.3% to 3.2% after 2 hours and 63.1% to 7.3% waste high-density polyethylene/*Swietenia macrophylla* wood dust particle composite after 24 hours.

As observed, the water absorption increased with increasing wood content and decreased with an increase in matrix content. This is because of the hydrophilic property of lignocellulosic fibers whereas water absorption decreased with increasing polyethylene film content in the composite because of the hydrophobic properties of the polymer resin [11]. With the increase in wood content, there are more water-residence sites thus more water was absorbed. On the other hand, the composites made with higher plastic content had fewer water-residence sites and thus lower water absorption [12]. High density polyethylene/*Swietenia macrophylla* wood dust particle composite boards are shown in Plate 3.

Plate 3: High density polyethylene/*Swietenia macrophylla* wood dust particle composite

The impact of wood to plastic ratio on water absorption can be explained by the differences in water absorption between wood and plastic [13]. Water absorption in composites is mainly due to the presence of lumens, fine pores, and hydrogen bonding sites in the wood flour, the gaps and flaws at the interfaces, and the micro-cracks in the matrix formed during the compounding process [14]. On the other hand, plastic is water-repellent and has much lower water sorption capability than wood [15].

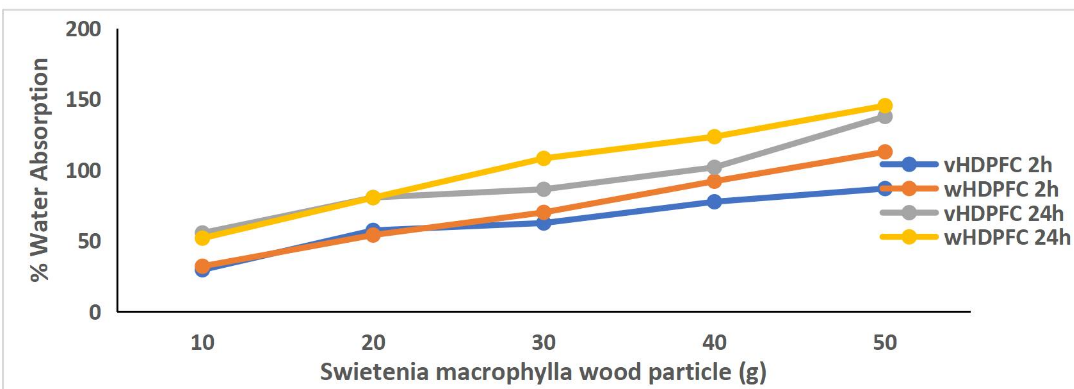


Figure 1: Water absorption of the *Swietenia macrophylla* wood particle with high density polyethylene film composites at constant matrix

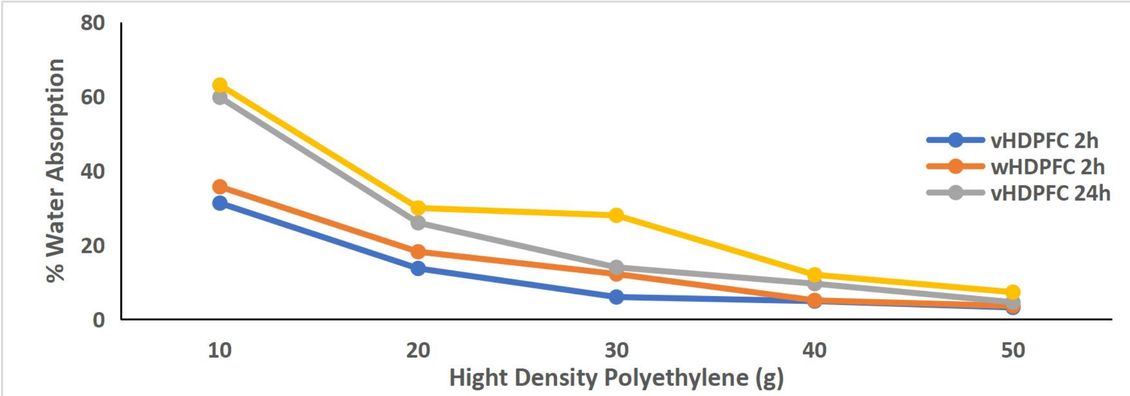


Figure 2: Water absorption of the *Swietenia macrophylla* wood particle with high density polyethylene film composites at constant filler

Flammability

Figure 3 shows the flammability of virgin and waste high-density polyethylene/*Swietenia macrophylla* wood dust particle composite. Ignition time increases as the wood dust particles increase which makes the flame propagation rate of the composite decrease from 0.65 to 0.22 mm/s for the virgin high-density polyethylene composite and 0.68 to 0.27 mm/s for waste high-density polyethylene composite. Figure 4, shows the flammability of virgin and waste high-density polyethylene/ *Swietenia macrophylla* wood dust particle composite at constant filler. Ignition time increased as the filler resin content increased which made the flame propagation rate of the composite decrease from 0.65 to 0.09 mm/s for the virgin high-density polyethylene composite and 0.73 to 0.2 mm/s for waste high-density polyethylene composite.

The results showed that ignition time and flame propagation time increased with increasing filler content whereas ignition time and flame propagation time increased as the matrix resin increased. This is because composite materials usually contain pores, which are created when steam mixes during production processes. Materials that with higher content of cellulose filler generally have a greater density and resistance to oxidation. Therefore, if the porosity of the composite is reduced, the oxidation is restricted [16]. As the ratio of wood flour to polymer matrix increases the oxygen index increases which was reported in literature [17]

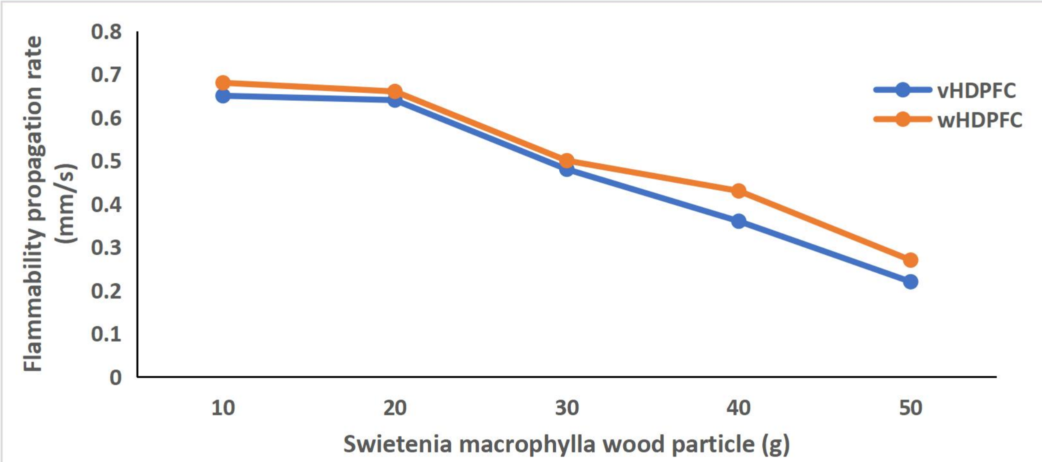


Figure 3: Flammability propagation rate (mm/s) of the Swietenia macrophylla wood particle with high density polyethylene film composites at constant matrix

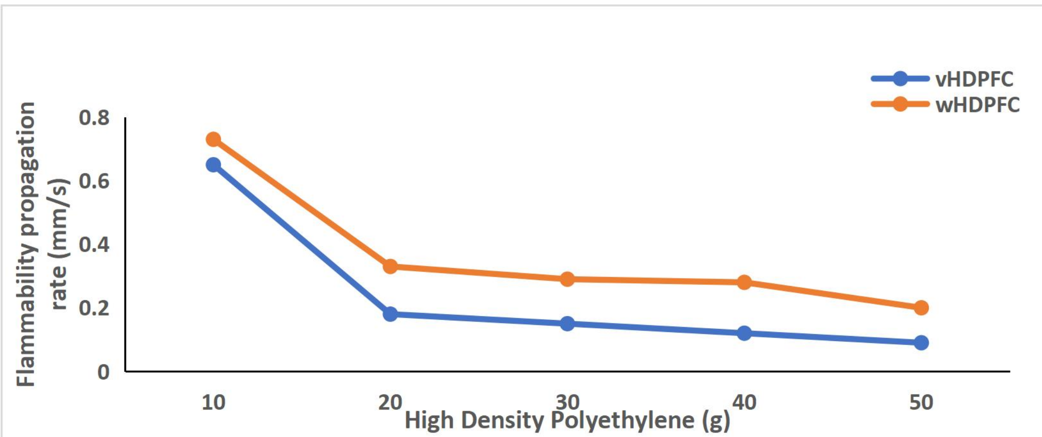


Figure 4: Flammability propagation rate (mm/s) of the *Swietenia macrophylla* wood particle with high-density polyethylene film composites at constant filler

Hardness

Figures 5 and 6 show the hardness of virgin and waste high-density polyethylene/ *Swietenia macrophylla* wood particle dust at both constant polyethylene film and constant filler content respectively. At constant polyethylene, the hardness decreased as the filler increased from 78.6 to 22 MPa for virgin high-density polyethylene film base composite while 60.7 to 17.7 MPa for waste high-density polyethylene film base composite. The virgin composite is harder than the waste composite. On the other hand, at constant filler content, hardness increases with an increase in matrix content from 81.4 to 442.8 MPa for the virgin composite while 68.8 to 378.6 MPa was recorded for the waste composite.

Indentation values increased with increasing filler content whereas they decreased with increasing polymer resin content. The increasing indentation value (i.e., depth) with increasing filler loading could be a result of the filler/matrix adhesion [18] Hardness values which showed the behaviour of the material under immediate impact and not gradual loading decreased with increasing filler content [19]. A decrease in shore hardness value with increasing filler content has also been reported by Khairaih & Khairhul [20, 21]. They also reported a decrease in shore hardness value with increasing filler loading when high-density polyethylene was reinforced with wood filler.

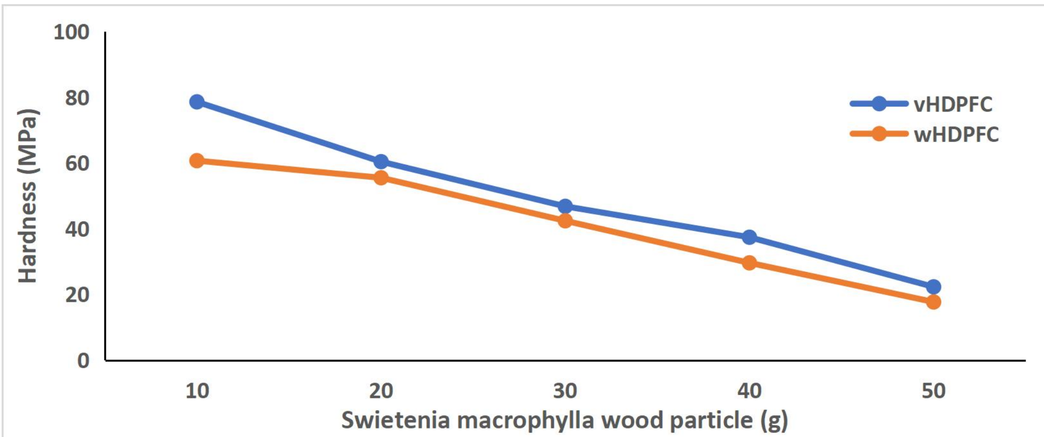


Figure 5: Hardness of the *Swietenia macrophylla* wood particle with high density polyethylene film (HDPE) composites at constant matrix

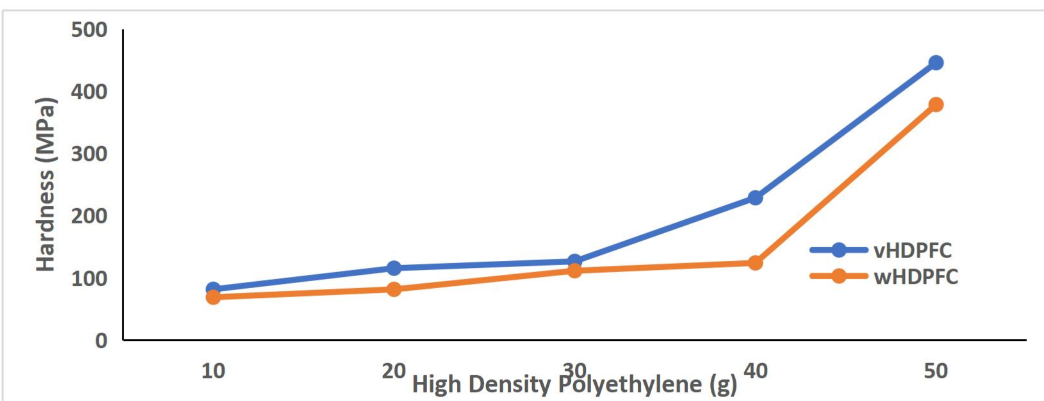
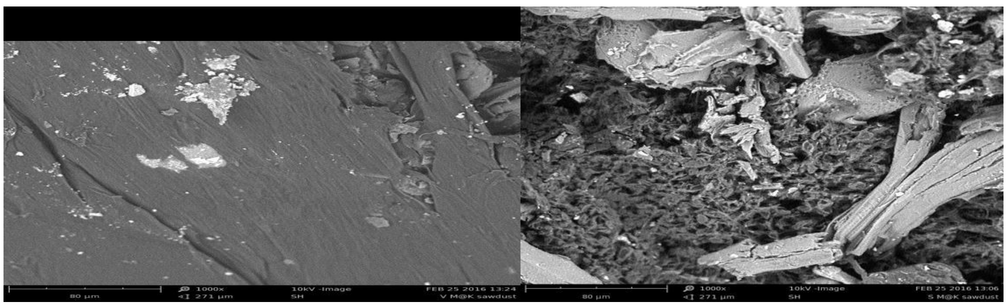


Figure 6: Hardness of the *Swietenia macrophylla* wood particle with high density polyethylene film (HDPE) composites at constant filler

Scanning Electron Microscope

The waste high-density polyethylene sample showed a considerable amount of filler and matrix breakage with limited intact material on the surface. Although there are some voids in the matrix, possibly due to the pull-out of the leather fiber agglomerates, good interfacial adhesion can be observed by the continuity of the leather fiber agglomerates with the HDPE matrix [22]. Good adhesion is usually difficult to achieve between nonpolar thermoplastic matrices and natural fibers due to the polarity differences between the hydrophilic fibers (composed of collagen macromolecules) and the hydrophobic thermoplastic matrices [23].

Figures 7 (a) and (b) show pronounced deformation of the polymer matrix and significant reduction in fiber pull-out, indicating the compatibilizer likely affects the interface, reducing interfacial tension and improving adhesion.



(a) (b)

Figure 7: SEM images (×1000) of (a) vHDPE/Swietenia macrophylla composite (b) wHDPE/Swietenia macrophylla composite.

CONCLUSION

With the increase in wood content, there are more water-residence sites hence, more water was absorbed. On the other hand, the composites made with higher plastic content had fewer water-residence sites and hence, lower water absorption. Ratio 1:5 of the wood/virgin and waste high-density polyethylene at constant saw dust showed the least water absorption in all the composite formulations. Flame Propagation Rate test, revealed the relative resistance of the composite to decompose and consume these because of the increase in the polyethylene matrix. The more readily the material consumes the higher the flame propagation rate value. Hardness values showed the behavior of the material under immediate impact. The result of the scanning electron microscope showed the matrix breakage with limited intact material on the surface. From the results, composite board produced can be used as a noticed board.

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