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Water Absorption, Flammability, Hardness and Morphology Tests on Composite Prepared from High Density Polyethylene Films/Doka Wood Dust Particles

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Authors' contributions

This work was carried out in collaboration between all authors. Author PMD designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Authors BM, AA and MAA managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

High density polyethylene films / Doka wood dust particles composites were prepared by dissolving high density polyethylene (waste and virgin) films in toluene at 135°C with Doka wood particles. Some physical properties of the composites such as water absorption, flammability, hardness and morphology of the composites were studied. It was found that the water absorption increases as Doka wood particles increased but decreases as the high density polyethylene films increased. The composites made from high density polyethylene films waste showed different results as those made of the virgin high density polyethylene films. Gradual reduction in flammability of the composite was observed as the Doka wood particles and high polyethylene films increases. This was attributed to the incombustility of high amount of ligninous materials Significant decrease in

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hardness of composite was observed as the Doka wood particles was increased but increase in hardness was obtained when the high density polyethylene films increases. This could be due to inability of the matrix to encapsulate the fibre strands but the increase in hardness was due to the strong binding effect of the polymer resin. Scanning electron microscopy images of the surfaces confirmed an interfacial bonding between the Doka wood particles and the high density polyethylene films at high polymer resin but decrease in interface bonding between the Doka wood particles and the high density polyethylene films at high Doka wood particles.

Keywords: composite; Doka; flammability; hardness; high density polyethylene; morphology.

1. INTRODUCTION

Composites which are heterogeneous systems with two distinct phases having different properties [1]. The two phases are the matrix and reinforcement, a combination that allows wide variations. The matrix can be introduced into the mold cavity or onto the mold surface before reinforcement. This may lead to chemical reaction or just physical reaction resulting to solidification from the molten state. Different types of resins which provide flexibility in composites have been used as matrix. They include: Polyester, vinyl ester, epoxy, phenol, polyimide, polyamide, and polypropylene resins [2]. Strong and low densities reinforced materials usually fibres have been commonly used although, metals and ceramics e.g. glass have also provided alternatives [3]. Principal among the fibres commercially used are those from vegetable plants such as Kenaf, Sorrel, Banana, Rice husks, etc. [4-6]. Fibre orientation has been manipulated by scientists to give composites with different chemical and physical properties [7]. Composites have classified based on the type of reinforcement used as either fibrous or particulate [8]. Polyethylene resin has been used as matrix in composite recently [9]. It has a density of 0.941 g/cm^3 with low degree of branching and thus demonstrates strong intermolecular strength [10]. It exhibits greater rigidity and physical strength and has a higher melting point (130 to 135^{o}C) with lower resistance to stress cracking. Other advantages of the use of high density polyethylene in composite were its flame retarding properties among which are the relative delay of the polymer to either ignite and combust without continuous flame or the rate of the spread of fire has been reported [11,12]. However, some mechanical properties of some of the composites formed have been identified to be poor [13] due to fibre-matrix incompatibility [14]. Furthermore, hydrophilicity of the fibres which attracts moisture from the atmosphere during composite formation was lost when heated. This off-gassing created voids in the composite microstructure resembling a highly dense foam [15] with subsequent loss of mechanical properties of the composite. Destructive or nondestructive 2 and 3 dimensional imaging tools are being applied to understand the interfacial characteristics of wood polymer composites. Scanning electron microscopy (SEM) is one of the most commonly used image techniques [16-20]. This study focused on the effect of filler and resin on the flammability, water absorption, hardness and morphology of composite prepared from Doka wood particles / high density polyethylene films.

2. MATERIALS AND METHODS

2.1 Sample Collection

A high density polyethylene films (FARO package water bags) was supplied by Adamawa beverages limited Yola-Adamawa State, Nigeria with some exposed to the sunlight for four weeks to initiate photo-degradation. Doka wood particle was collected from Actors furniture Numan-Adamawa State, Nigeria. Fibres were ground to powder and sieved with mesh size of 45 µm in Modibbo Adama University of Technology Chemistry laboratory.

2.2 Preparation of Composite (ASTM D618-99)

Doka wood particles was dried in an oven at 100℃ for 5 hours to removed moisture and cooled. The wood particles dispersed according to the formulation given in Tables 1 and 2. Toluene was measured into a conical flask and mixed with a given weight of the resin and the mixture heated at a temperature of 135℃ in an oil bath to allow the high density polyethylene films dissolved totally in the solvent. A given amount of the wood particles was measured and added to the solvent-resin mixture, stirred continuously for five minutes and was then cast in an aluminum mold with diameter 3m thickness by 7 m width by 10 m length. Composite was made to set at temperature of 23±2℃ and relative humidity of 50±5% for 40 hours.

Table 1. Formulation of composite from high density polyethylene and Doka wood dust particles at constant polyethylene

Ratio	Saw dust (g)	Polyethylene (g)	Solvent (ml)	Melt temperature (°C)
1:1	12	12	180	135
1:2	24	12	180	135
1:3	36	12	200	135
1:4	48	12	200	135
1:5	60	12	250	135

Table 2. Formulation of composite from high density polyethylene and Doka wood dust particles at constant polyethylene films concentration

Ratio	Saw dust (g)	Polyethylene (g)	Solvent (ml)	Melt temperature (°C)
1:1	12	12	180	135
1:2	12	24	200	135
1:3	12	36	200	135
1:4	12	48	300	135
1:5	12	60	350	135

Plate 1. Brown coloured Doka wood dust particles

2.3 Water Absorption (ASTM D 570)

Water absorption test was performed according to ASTM D 570 method. The water absorption of the composites was separately determined at 2 hours and 24 hours by immersion in distilled water at temperature of 24℃. Five specimens of each formulation were dried in an oven for 24 hour and weighed.Specimens were immersed in distilled water and at the end of the immersion periods, the specimens were removed from the distilled water. The surface water was wiped off using dry cloth andthe wet weight measured. The percentage water absorption was calculated using the following formula given below:

$$M\ (\%) = (m_t - m_o)/m_o \times 100,$$

Where m_o and m_t denote the oven-dry weight and weight after time t of composite respectively [21].

2.4 Flammability Test (ASTM D635)

A 60 mm mark was measured and marked out on each of the specimen. The specimen was then clamped horizontally in a retort stand with the marked 60mm distance projecting out of the clamp. The free end of the sample was ignited and the time taken for the sample to ignite will be recorded as the ignition (I_t). The sample was allowed to burn to the 60 mm mark (D_p). The relative rates of burning for the different samples were determined using the formua 2 [22] stated below:

$$\text{Flame propagation rate (mm/s)} = D_p(\text{mm})/P_t(\text{sec}) - I_t(\text{sec})$$

Where

D_p = Propagation distance measured in mm,
P_t = Flame propagation time measured in seconds
I_t = Ignition time measured in seconds.

2.5 Hardness Test (ASTM D-2240)

Hardness is referred to as the resistance of a material to indentation, the higher this resistance the harder the material and vice-versa. The hardness test was carried out using Modified Meyer hardness tester. The hardness for the samples was determined using the formula 3 stated bellow [23].

$$BHN = \frac{F}{\pi/2\ (D - \sqrt{D^2 - D_i})}$$

Where,

F = Imposed load
D =Diameter of the indenter
D_i = Diameter of the indentation

2.6 Scanning Electron Microscopy (SEM) (ASTM E9862-97)

A morphology study was carried out using scanning electron microscopy (SEM) to evaluate the fractured surface of samples. The changes in morphology are important to predict fiber interaction with the matrix in composites [24].

3. RESULTS AND DICUSSION

3.1 Water Absorption of the High Density Polyethylene / Doka Wood Particles Composite

Figs. 1 and 2 show that the water absorption increases with increase in doka wood dust particles and decreases with increase in high density polyethylene films of the composite. This trend is consistent for both 2 and 24 hours water immersion tests. The increase in the amount of water absorption as Doka wood increases could be due to the hydrophilic property of lignocellulosic fibers but the decreased in water absorption with increase in high density polyethylene films may be due to the hydrophobic properties of the polymer resin. With increase in doka wood dust particles there are more functional groups that could easily form hydrogen bond with water molecules thus the increase in water absorption. On the other hand, the composites with high density polyethylene films had less available sites to form hydrogen bonding with water molecules and thus lower water absorption [13]. It was also found that the water absorption for 2 and 24 hours immersion is higher in waste high density polyethylene films/ Doka wood dust particles composites compared to the virgin high density polyethylene films/ Dokawood dust particles composite. This could be due to the availability of free radical sites formed by photo-initiated degradation which could have enhanced dispersion and interfacial bonding between the resin and water molecules.

3.2 Flammability of the Composite

Figs. 3 and 4 give the rate of flame propagation against Doka wood dust particles and high density polyethylene films. The flame propagation rate decreases with increase in

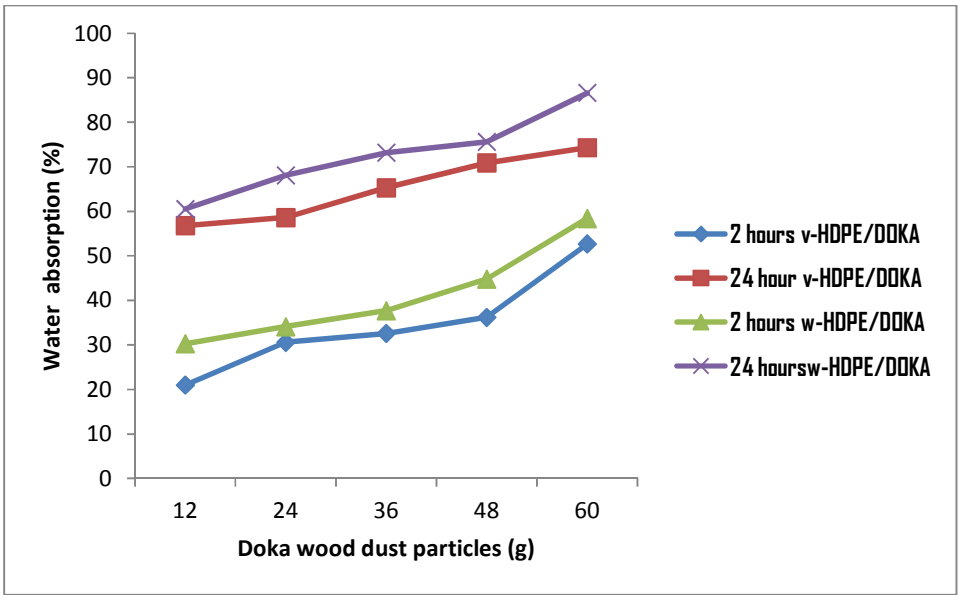


Fig. 1. Effect of Doka wood dust particles on water absorption at constant high density polyethylene films after 2 and 24 hours immersion

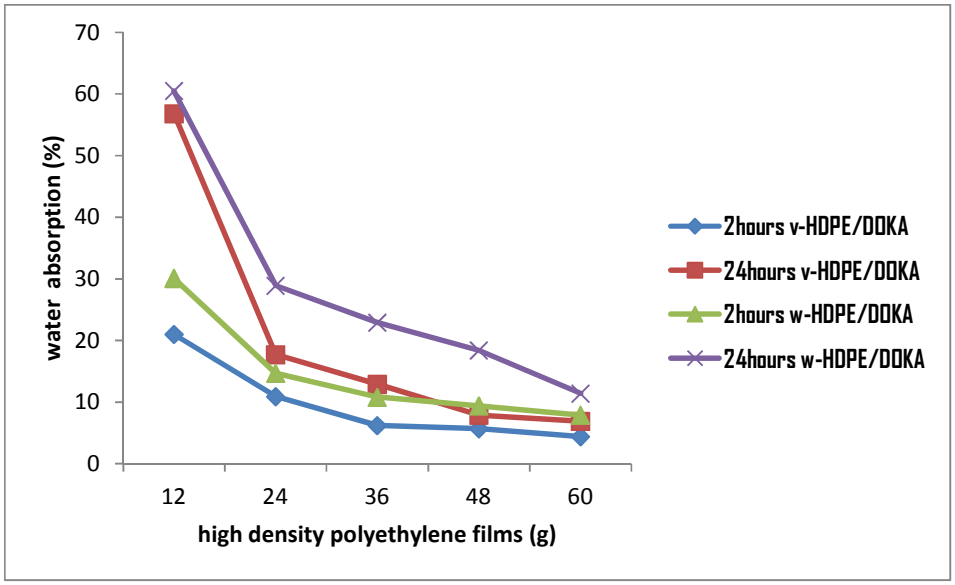


Fig. 2. Effect of high density polyethylene films on water absorption at constant Doka wood dust particles after 2 and 24 hours immersion

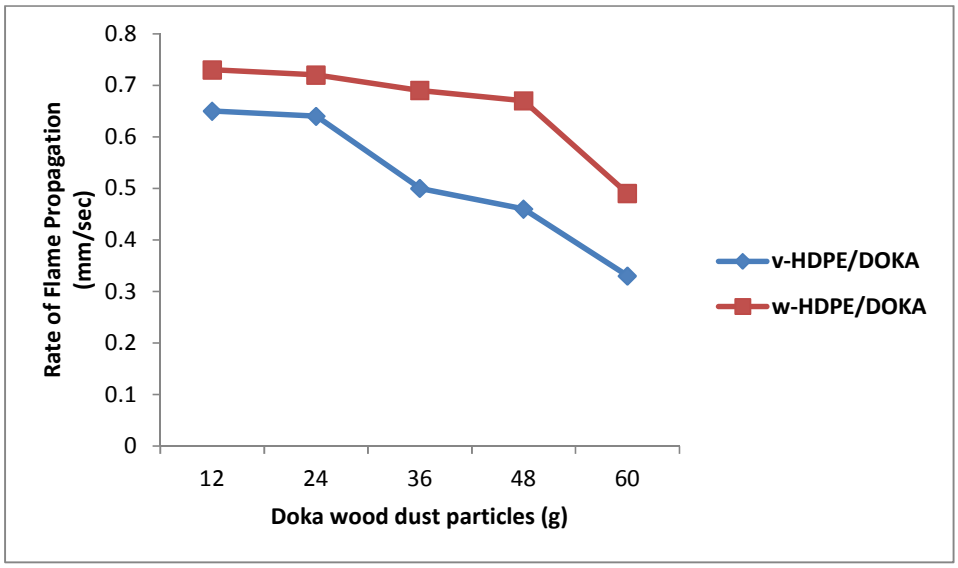


Fig. 3. Effect of Doka wood dust particles on rate of flame propagation at constant high density polyethylene films

Doka wood dust particles and high density polyethylene films. This could be attributed to the incombustility of high amount of ligninous materials. The rate of flame propagation of the waste high density polyethylene films / Doka wood dust particles composite decreases more than the virgin high density polyethylene films/Doka wood dust particles composite. Flame propagation rate showed an otherwise interesting result of the relative resistance of the composite to decomposition. The more readily the material burns the higher the flame propagation rate value. The decreasing value of flame propagation rate with increasing Doka wood dust particles and high density polyethylene films suggests that the presence of Doka wood dust particles in composite improve the relative structural integrity of the composite in the presence of heat.

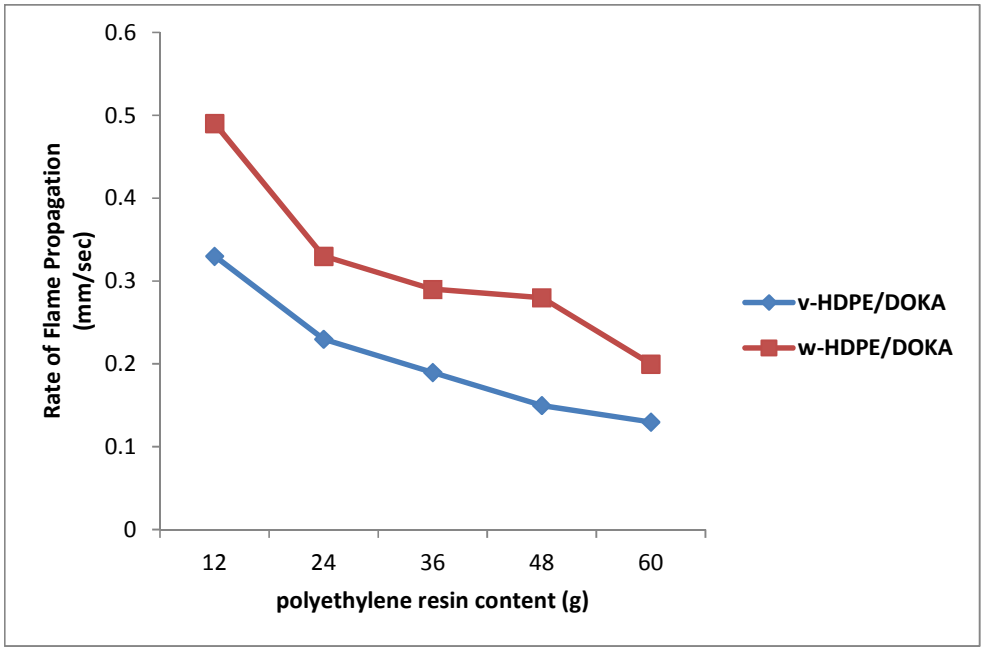


Fig. 4. Effect of high density polyethylene on rate of flame propagation at constant Doka wood dust particles

3.3 Hardness Test

Indentation test results show a linear increase in indentation values with increase in Doka wood dust particles in composite and gradual decrease in indentation values with increase in high density polyethylene films in composite. Figs. 5 and 6 show decrease in hardness of composite as Doka wood dust particles increase but increase in hardness with increase in high density polyethylene films. This decrease has been reported by other researchers when dealing with natural fibre based composites. Anap [25] reported that with increasing flax fibre content, hardness value of high density polyethylene/flax fibre composites and polypropylene/flax fibre composites decreased. Khairaih and Khairhul [26] also reported decreasing hardness values with increasing fibre content in their work on polyurethane and empty fruit bunch blend composites. They alluded that the decrease was due to the inability of the matrix to encapsulate the fibre strands but that the increase in hardness was due to the strong binding effect of the polymer resin. In this work composite made from virgin high density polyethylene films/Doka wood dust particles was harder than that made from waste high density polyethylene films /Doka wood dust particles composite. This may be due to rubbery like nature of the virgin films but in waste films the films may be degraded because of photo-degradation effect which created voids.

3.4 Scanning Electron Microscope

Scanning electron microscope images of the high density polyethylene films / Doka wood dust particles composites at filler loading of 24 g of virgin HDPE and 12 g of waste HDPE matrices are shown in Figs. 7(a) and (b) with 1000× magnification. From these images, it is clearly observed that there were distinct cluster and gaps between polymer matrix and wood. The patterns from wood fibres that were so weakly bonded to the matrix had been released from the matrix. The failure surface was undulated with clear wood flour surfaces with visible trachaids and lumen. This shows weaker part through the wood-wood interface and weakest polymer matrix. This suggests that the interface between the wood and HDPE matrix was weaker due to the poor dispersion and wettability between the two phases. The dispersion of the wood dust particles in the virgin HDPE (Fig. 8c) and waste HDPE (Fig. 8d) matrix is uniform. This may be due to the different grade of high ratio of plastic. In some cases, the part of the wood lumen was filled with plastic that could increase the strength of the composites because of mechanical interlocking. When wood content was increased, the polymer matrix was no longer continuously

distributed and many wood fibres were in direct contact with one another, resulting in poor bonding and adhesion at the interface. But as the amount of plastic films increases there is a good bonding and adhesion at interface because of the evenly distribution in the composite matrix.

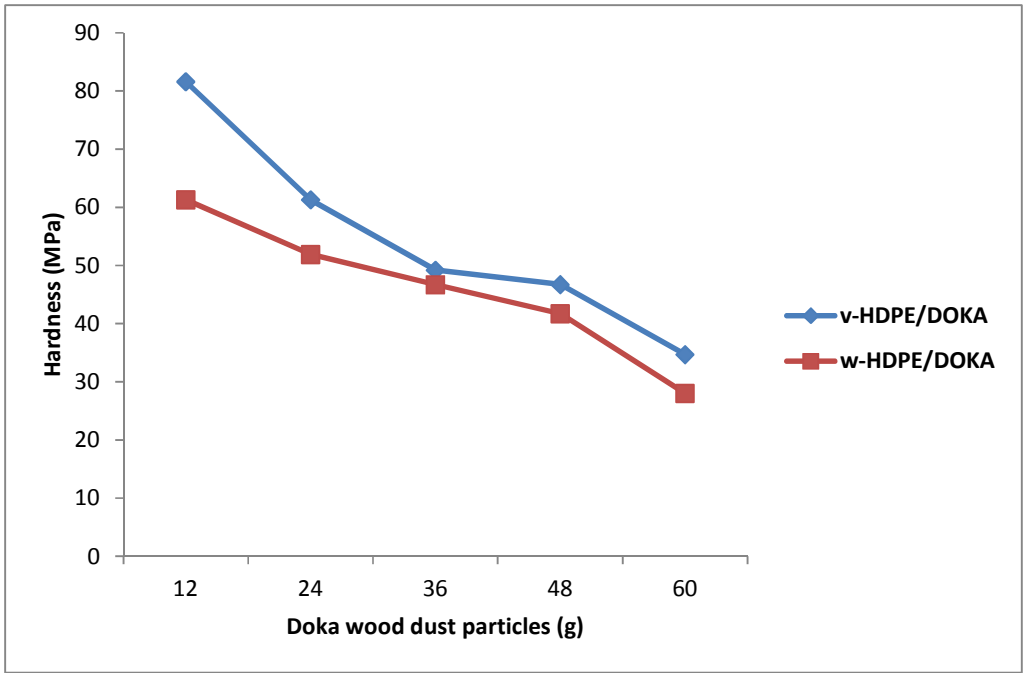


Fig. 5. Effect of Doka wood dust particles on hardnessat constant high density polyethylene

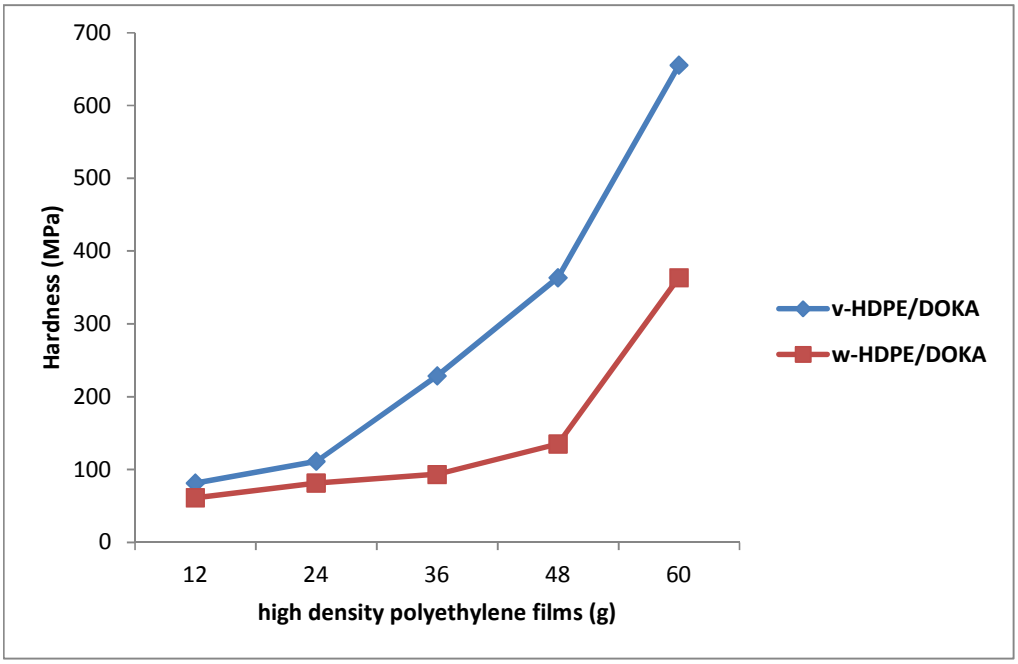
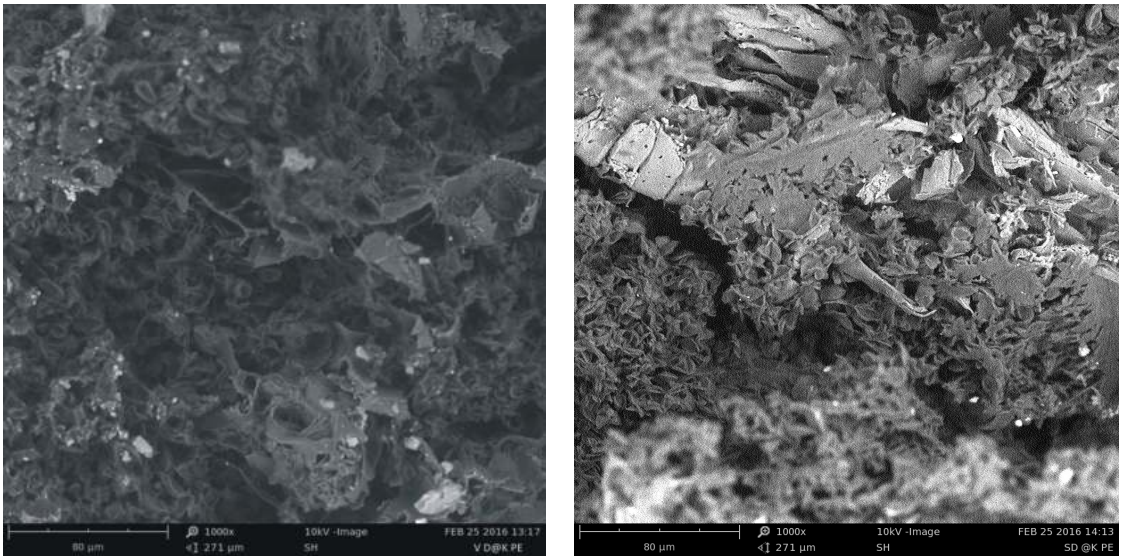
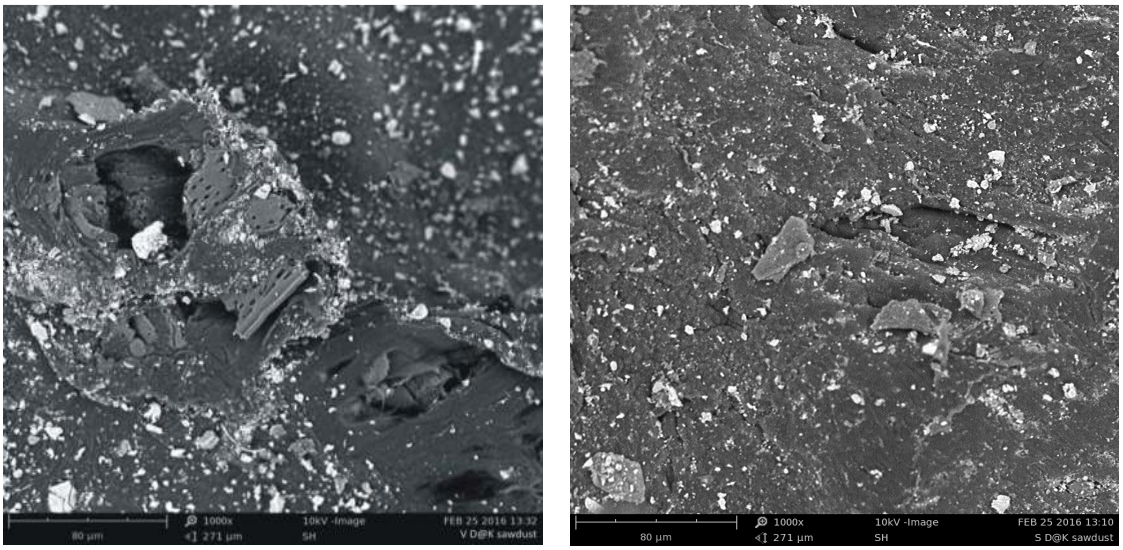


Fig. 6. Effect of high density polyethylene on hardness at constant Doka wood dust particles



(a) **(b)**

Fig. 7. SEM images ×1000: (a) virgin HDPE / Doka wood particles, (b) waste HDPE / Doka wood particles



(c) **(d)**

Fig. 8. SEM images ×1000: (c) virgin HDPE / Doka wood particles, (d) waste HDPE/Doka wood particles

4. CONCLUSION

Water absorption of high density polyethylene films / Doka wood dust particles composite increased with increase in Doka wood dust particles and decreased with increase in high density polyethylene films. Composite prepared with virgin high density polyethylene films showed significant decrease in the amount of water absorbed, whereas composite prepared with waste high density polyethylene films absorbed less amount of water less water than virgin high density polyethylene. The results of indentation showed similar trend in which the value increased with increase in Doka wood dust particle while hardness decreased with increase

in both Doka wood dust particle and high density polyethylene films. The flame propagation rate decreased with increase in high density polyethylene films and Doka wood dust particles for both virgin and waste films. The scanning electron microscope showed that increase in Doka wood dust particles which may have resulted to the increase in fiber-fiber interaction, which could have led to the reduction in wettability of the fiber- polymer matrix interphase. This resulted in the poor bonding at the interface however, good bonding at interface was observed with decrease in wood dust particles due to the even distribution of the fibres in the matrix.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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