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Original Research Article

The Influence of Alkaline Treated *Anthracothorax viridis* Mango Wood Fiber on the Characteristics of Mango Wood Fiber Low Density Polyethylene Composite

***[1]Government, R.M., [1]Amani, D.H., [2]Ayuba, S., [3]Ani, A.K. and [4]Aha, J.**

[1]Department of Chemical Engineering, Federal University Wukari, Taraba State, Nigeria.
[2]Department of Agricultural Engineering, Federal University Wukari, Taraba State, Nigeria.
[3]Department of Chemical Engineering, Nnamdi Azikiwe UniversityAwka, Anambra State, Nigeria.
[4]Department of Chemical science, Federal University Wukari, Taraba State, Nigeria.
*govt_4real@yahoo.com

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ABSTRACT

This present study examines the effects of sodium hydroxide (NaOH) treatment on the mechanical properties of Anthracothorax viridis mango wood fiber-low density polyethylene (MWF-LDPE) composite. The mango wood fiber (MWF) after initial preparation was alkalized with NaOH (ATMWF) and untreated mongo wood was kept aside (UNMWF). The UNMWF and ATMWF were infused in the LDPE by 4-20 wt%., respectively. The individual mixtures were compounded by the application of injection molding machine. The alkaline treated mango wood fiber-low density polyethylene (ATMWF-LDPE) and untreated mango wood-low density polyethylene (UNMWF-LDPE} composites obtained as an output from machine were tested for tensile, flexural and impact characteristics of the resulting products. The surface morphologies of both (ATMWF-LDPE) and (UNMWF-LDPE) composites were examined using scanning electron microscopy (SEM), respectively. The result indicated that the alkali (NaOH) treatment was able to cause a significant adhesion between the mango wood fiber (MWF) and low density poly-ethylene (LDPE) matrix. The investigated mechanical properties showed the potentials of the MWF as a suitable alternative for composite production. Generally, the tensile strength of the alkali modified mango wood fiber (ATMWF) was enhanced in comparison with the untreated mango wood fiber (UNMWF) in LDPE matrix. Due to the alkalization process, the tensile modulus of MWF-LDPE composite for the injection of ATMWF in LDPE matrix was comparable to the original LDPE and UNMWF in LDPE. The alkaline treatment process was also able to enhance surface modification thereby inhibiting composite bending, stiffness, and contributing to an improvement in the flexural modulus and strength.

1. INTRODUCTION

In recent years, natural fibers are preferred over synthetic fibers because of their low cost, light weight, abundance and appreciable mechanical properties (Atuanya *et al.*, 2014; Government and Ngabea, 2023a;

2023b; Lakshumu and Kona, 2018). Natural fibers are favored over synthetic fibers with concept of their properties as previously elaborate by scholarly works (Government *et al.*, 2019a; 2019b). Ayu *et al.*, (2020) and Government *et al.*, (2019a) also attest to their numerous applications in many fields such as automotive, textile, fiber board, cushion, paper, mattress, door, wall panel, air cleaner, and car dashboard. Other than their mechanical properties, natural fiber reinforcement also enhances the application of green materials, which are harmless to the environment (Joseph *et al.*, 2002; Lee *et al.*, 2014). With its significant mechanical properties, natural fiber could serve as a good alternative to synthetic fibers. However, research into the development of the natural fiber is still emerging.

The suitability of natural filler in the production of polymer matrix composites has its merits and demerits. This include: good resistance to corrosion, enhance mechanical damping, improvement in toughness, good specific strength, good resistance to fire, outstanding fatigue strength, low cost etc (Yang *et al.*, 2004; Muthukumar and Lingadurai, 2014; Ayu *et al.*, 2018). The demerits are: low compatibility between the polymer matrix and massive water retention. The use of the appropriate binding agents or chemical treatments is generally regarded as a way mitigating the demerits of natural fiber (Pickering *et al.*, 2011).

Another natural fiber of interest in this present research is mango wood fiber (MWF). Mangos are common tropical fruit that is usually consumed in the Southeast Asia region. It originated in the rain forests of the Western Ghats in the southwestern part of India and widely distributed throughout the world (Nunez *et al.*, 2002). Ripe mangos are composed of yellow pulp rich in vitamins and minerals. The waste produced from its bark is about 65–80% of the total weight of the mango (Ayu *et al.*, 2020). The waste from mango bark can be potential biomass through the incorporation as a filler or reinforcement into natural polymer matrix (Aisyah *et al.*, 2018). Previously, Government and Okeke, (2023a; 2023b) reported that wood fiber reinforcement and/or fillers have been used in polymer for car and printer components, respectively. However, limited studies conducted on this fiber made it one of the most under-utilized biomasses.

Chemical treatment as illustrates like alkali (using NaOH, or KOH) and acetylation (soaking in acetic acid solution) exploited for modification of natural fiber to provide remedy on the composite compatibility (Yang *et al.*, 2004; Nachtigall *et al.*, 2007; Reddy *et al.*, 2013). The essence of modification was to scrutinize lignin and hemicelluloses from the organic fillers and perk up cellulose content which augments superior mechanical properties of the composite (Ayu *et al.*, 2018).

Later researchers have studied, tested and commercialized some biomass in polymeric composite for domestics, industrial and automated applications such date-palm Bendahou *et al.*, 2008; Government *et al.*, 2013; Atuanya *et al.*, 2014; Government and Okeke, 2023a; Government and Ngabea, 2023b), breadfruit peel(Government *et al.*, 2021), groundnut shell (Government *et al.*, 2022; Lakshumu and Kona., 2018; Muthukumar and Lingadurai;, 2014; Edith, 2014), avocado wood (Government *et al.*, 2018a; 2018b; Government *et al.*, 2021; Government and Okeke, 2023b; Government and Ngabea, 2023b; Government *et al.*, 2019a; 2019b; Government *et al.*, 2016a; Government and Onukwuli, 2016b) etc. Therefore, this present study aims to investigate the effects of alkalized MWF content on the mechanical properties of MWF-LDPE composite such as tensile strength, modulus, flexural strength, modulus, and impact strength. Furthermore, the surface morphologies of both composite for ATWMF and UNMWF were examined using SEM.

2. MATERIALS AND METHODS

2.1. Materials Collection

The sample (mango wood fiber) was collected from Federal University Wukari Local Government Area of Taraba State, Nigeria. The mango wood fiber was cut in to small pieces dry, crushed and sieved.

2.2. Methodology

Mango wood fiber (MWF) was obtained from mango tree. The preparation of MWF involved chopping, washing, drying, grinding, and sieving. The chemical applied for the delignification process is NaOH. This was done at 4 h soaking and 7.2wt% and dried for 6 h in 5 days before varying of fiber contents (4-20 wt%)

and particles size 60 mesh size (250 µm) to infused in the low density polyethylene (LDPE) of 96-80), respectively. The mixing was done in bowl and production in injection molding unit. The produced MWF-LDPE composite was tested for mechanical and SEM analysis.

2.3. Composite Preparation

The composite production took place at Olikaeze plastic factory Onitsha Anambra state. The ATMWF and UNMWF was inter-mixed using LDPE at 4-20 wt% each, respectively. The mixture was compounded using injecting molding machine to produce the composite sample. The composite products were size in accordance to ASTM standard (Atuanya *et al.*, 2014).

2.4. Composite Treatment

The MWF was immersed in solution of 7.2 wt% of sodium hydroxide for 4 h. The MWF was rinsed with distilled water, filtered and sun-dried for 6 h.

2.5. Mechanical Properties Testing

2.5.1. Tensile properties testing

This analysis was examined in University of Nigeria (UNN) Civil Engineering Lab, Nsukka by the application of tensiometer BSS1610 model no 8889 made by Hounsfield tensiometer limited with a specific accordance of the ASTM D638 (3.2mm x 19mm x 160mm) method The composite specimen was slotted in the grip chucks of the equipment. It was held strongly. The force from the equipment pulled MWF-LDPE composite sample in the machine. The tensile strength and modulus of MWF-LDPE composite were determined and evaluated using Equation (1) and (2), respectively (Atuanya *et al.*, 2014).

$$\sigma T = \frac{fm}{A1} \tag{1}$$

Where σT, fm (KN), $A1$ (m) were optimum tensile strength, the force during tensile mode at maximum and the cross-sectional area of MWF-LDPE composite specimen.

$$Ee = \frac{\Delta \text{stress}}{\Delta \text{strain}} \tag{2}$$

The *Ee* (GPa), stress (GPa), strain are defined as the young's modulus, stress and strain of the slope of stress-strain graph, respectively.

2.5.2. Flexural testing

This examination of flexural properties was carried using ASTM D790 (3.2 mm × 19 mm × 300 mm) standard (Reddy *et al.*, 2013). The testing composite was subjected in the equipment and passed through a bending system till MWF-LDPE composite breaked through the application of force (Reman et al., 2010). The flexural strength and the bending modulus were computed applying Equation (3), (4) and (5).

$$\sigma = \frac{3FL}{2bd^2} \tag{3}$$

$$E_b = \frac{L^3 m}{4Wb^3} \tag{4}$$

$$m = \frac{\Delta F}{\Delta e} \tag{5}$$

The following parameters σ, E_b, m, F, L, w, b, d, ΔF, Δe are bending streangth, flexural modulus, slope of a force-extension curve, flexural force applied, length, width, thickness of the composite specimen, change in the flexural force and extension respectively.

2.5.3. Impact strength testing

The Charpy impact testing machine Los Losenhausenwerk Dusselldorf, (Germany) model no.17562/1963 was initiated for impact energy per unit cross-sectional area. The Mechanical Engineering Workshop, University of Nigeria, Nsukka was chosen to examine impact energy failure per square meter. The sample was cut by ASTM D610-02M (Atuanya *et al.*, 2014) corresponding to the size of 3.2 mm × 19mm ×80 mm. A pendulum hammer after MWF-LDPE composite sample is hinged on the machine and allowed to strike the sample. The impact strength estimation was done using Equation (6).

$$IST = E_{IST}/A \quad (6).$$

The IST, E_{IST} and A were impact strength, energy at the period of the impact and cross-sectional area of the sample under impact mode, respectively.

2.5.4. SEM analysis

The model used for the SEM is PHENOM ProX with size of 15 KV as voltage. The MWF-LDPE composite of 1g was mixed with platinum. The components mixture was slotted the SEM equipment and photograph of internal arrangement of MWF-LDPE composite was observed as output.

3. RESULTS AND DISCUSSION

The influence of wood content on the tensile strength of MWF-LDPE composite at various MWFC is highlighted in Figure 1. It depicts that the tensile strength of MWF-LDPE reduced from 10.88 MPa to 9.63 MPa, and 9.72 MPa to 6.25 MPa, for UNMW and ATMWF, as the fiber weight increase from 4 to 20 %, respectively. This reduction of MWF-LDPE composite could be attributed to the addition of MWF in the LDPE matrix. This addition caused an increase in the interfacial area which leads poor mixing of MWF and LDPE matrix. The maximum strength was attained by ATMWF as a consequence of creation of hydrophilic hydroxyl groups from the filler with sodium hydroxide (Iklef *et al.*, 2012; Noorunisa and Almaadeedi, 2015).

The decrease in tensile strength when treated with NaOH solution is due to the removal of impurities like lignin, hemi-cellulose, fats and waxes, from MWF. However, the LDPE composite treated with NaOH solution shows an increase in tensile strength, which could be attributed to agglomeration as a result of coating of the MWF and the matrix (Nunez *et al.*, 2002). Similar results were recorded by previous authors (Bendahou *et al.*, 2008; Iklef *et al.*, 2012; Government et al.,, 2013; Nwanonenyi *et al.*, 2013; Atuanya *et al.*, 2014; Government *et al.*, 2021; Government and Okeke, 2023a; Government and Ngabea, 2023 b).

The effect of wood content on the tensile modulus of MWF-LDPE composite is shown in Figure 2. The inclusion of UNMWF and ATMWF in the LDPE matrix showed an increase the tensile modulus 0.678 GPa to 0.784 GPa, and from 0.472 GPa to 0.578 GPa, as weight of MWF increases from 4 to 20 %, respectively. The increase in tensile modulus indicates a slight separation of micro-spaces which are produced in the process that halts stress propagation in the LDPE/MWF interface. The ATMW a satisfactory result compared to LDPE and UNMW filler due to the alkalination process (Figure 2) and have been reported elsewhere (Iklef *et al.*, 2012; Government *et al.*, 2020; Government *et al.*, 2021; Government *et al.*, 2022).

The effect of wood content on the flexural strength of MWF-LDPE composite is shown in Figure 3. The UNMWF and ATMWF addition increased the flexural strength of MWF-LDPE from 30.58 to 33.37 MPa, and 22.84 to 25.51MPa, respectively. This is attributed to the accumulation of MWF particles which enhances the bond between MWF and LDPE matrix. This strengthened resistance of MWF-LDPE composite with enough strength to undergo bending/ The ATMWF displayed tremendous enhancement of flexural strength of MWE-LDPE composite than UNMWF. This is aligned with works studies of later (Yang *et al.*, 2004; Government, *et al.*, 2016a; Government and Onukwuli, 2016b; *Government, et al.,* 2018a; 2018b*; Government et al.*, 2021; Government and Ngabea, 2023b; Government and Okeke, 2023b).

Figure 4 shows that the flexural modulus of MWF-LDPE composite. The flexural modulus of the MWF-LDPE composite drastically improves from 0.42 GPa to 0.592 GPa and 0.227 to 0.438 GPa as UNMWF and ATMWF is injected in LDPE matrix at weight fraction of MWF from 5 to 20%, respectively. Additionally, the progress of the flexural modulus of MWF-LDPE composite is an attribution to the alkalization of MWF that aid to defy bending and developes material stiffness (Iklef et al., 2012; Noorunisa and Almaadeedi.,2015; Government et al., 2020; Government et al., 2021). Overall, the ATMWF indicated intensify flexural characteristics of MWF-LDPE composite than the UNMWF and LDPE (Figure 4). This results has been displayed by later scholars (Yang *et al.*, 2004; Government, *et al.*, 2016a; Government and Onukwuli, 2016b; Government *et al.*, 2018a; 2018b; Government *et al.*, 2019a; 2019b; Government *et al.*, 2021; Government and Okeke, 2023b; Government and Ngabea, 2023b).

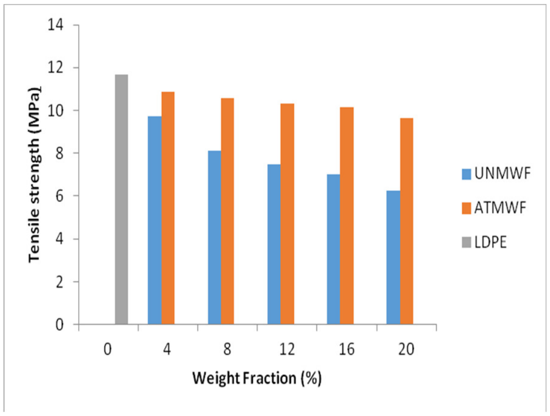

Figure 1: Effect of mango wood content on the tensile strength of MWF-LDPE composite

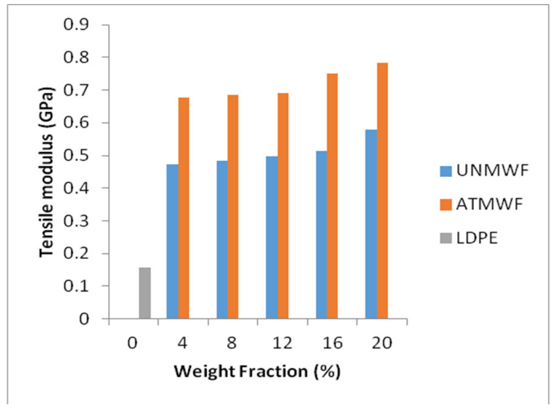

Figure 2: Effect of mango wood content on the tensile modulus of MWF-LDPE composite

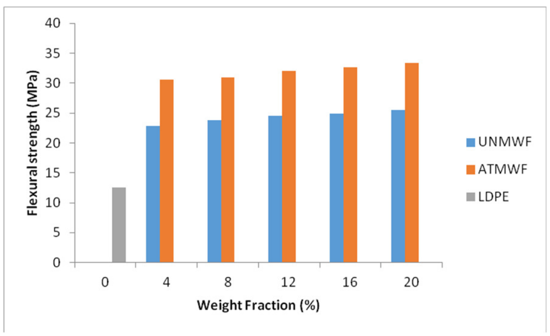

Figure 3: Effect of mango wood content on the flexural strength of MWF-LDPE composite

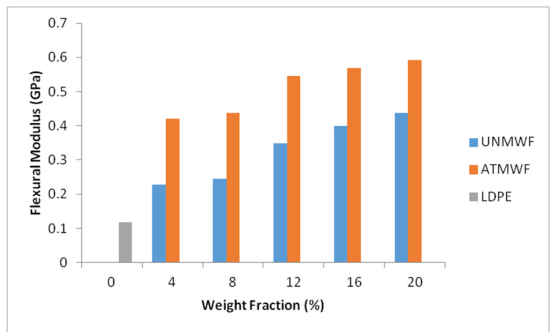

Figure 4: Effect of mango wood content on the flexural modulus of MWF-LDPE composite

As shown in Figure 5, the effect of wood content on the impact strength of MWF-LDPE composite was presented. The result showed that the MWF-LDPE reduces at the range of 57.51 KJ/m^2 to 54.55 KJ/m^2 and from 54.75 KJ/m^2 to 50.56 KJ/m^2 during the adding of ATMWF and UNMWF from 4-20 % wt, respectively. This phenomenon generates due to occurrence of stress which is produced by the injection of MWF into LDPE matrix. Also, ATMWF yields better impact energy per square meter with the help of alkalinity in MWF needs energy more to halt the advancement of cracking initiative than UNMWF in LDPE matrix. Moreover, the minimization of the impact strength of the MWF-LDPE composite was observably noticed. This is later reported (Nachtigall *et al.*, 2007; Iklef *et al.*, 2012: Government *et al.*, 2016a; Government and Onukwuli, 2016b; Government *et al.*, 2018a; 2018b; Government *et al.*, 2019a; 2019b; Government *et al.*, 2021; Government and Ngabea, 2023b; Government and Okeke, 2023b).

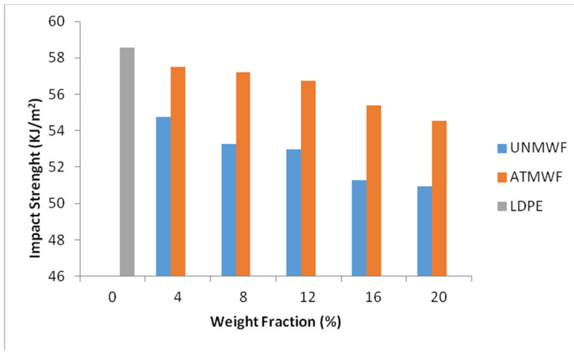

Figure 5: Effect of mango wood content on the impact strength of MWF-LDPE composite

Figure 6(a) and 6(b) show the SEM photograph for UNMWF and ATWMF of MWF-LDPE composite, respectively, Figure 6(a) indicates an observable reinforced MWF-LDPE composite with scanty particle of UNMWF in the LDPE surface of SEM photograph which is a trace of feeble contact adhesion of UNMWF and polymeric material due to the absence of NaOH alkalization process. Figure 6(b) indicates most of UNMWF and LDPE matrix had a stronger adhesiveness comparable to one as figured out in Figure 6(b). This may conclude as ATMWF inter-mixed with LDPE matrix, more of ATMWF adheres to the molten LDPE and distributes evenly on the MWF-LDPE composite inter-phase. This warrants improvement for characteristics of MWF-LDPE composite, this is later enumerated by scholarly work (Nachtigall *et al.*, 2007; Government *et al.*, 2016a; Government and Onukwuli, 2016b, Government *et al.*, 2018a; 2018b; Government *et al.*, 2019a; 2019b; Government *et al.*, 2021; Government and Ngabea, 2023b; Government and Okeke, 2023b).

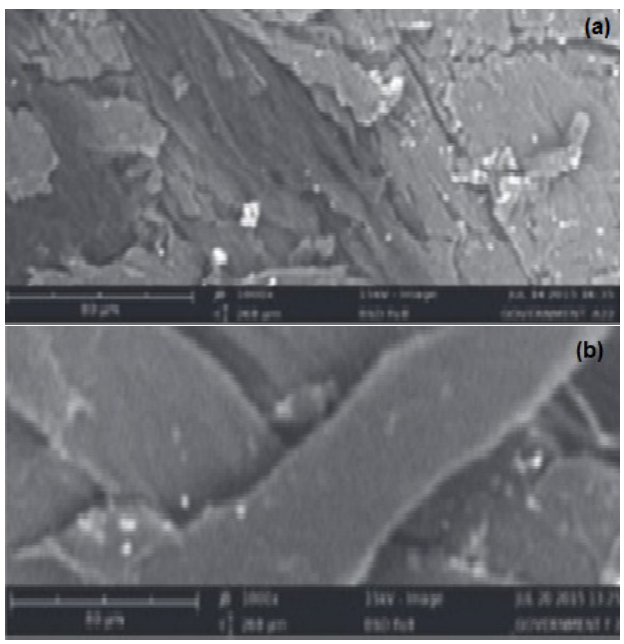

Figure 6: SEM of the MWF-LDPE composite (a) UNMWF (b) ATMWF

4. CONCLUSION

The utilization of mango wood fiber in low density polyethylene matrix for composite production has been studied. The content of MWF and the alkalized MWF were influential on the characteristics of MWF-LDPE composite. A novel-low cost fiber, MWF has shown the capacity to compete with other existing fibers for development of engineering material as alternative component for both domestic and industrial product. Results showed that the ATMWF enhanced the morphological and mechanical properties on the MWF-LDPE composite. However, it is recommended that more chemical treatment techniques should be investigated to provide new insights for industrial composite application. Furthermore, underutilized agro-based natural fiber should be investigated due to their cost-effectiveness in comparison to synthetic fiber. Finally, this study also shows that natural fiber when modified can be used as a suitable composite for industrial parts production

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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