PRODUCTION AND TESTING OF SOME PHYSICOCHEMICAL PROPERTIES OF POLYETHYLENE TEREPHTHALATE WASTE BOTTLES (FARO)/TEA LEAVES WASTE FIBRES COMPOSITE

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Abstract: Composites of polyethylene terephthalate (PET) and tea leaves waste fibres were produced. Modulus of rupture, flammability, water absorption and hardness tests were carried out. Modulus of rupture test showed that increase of fibre in composite decreased the modulus of rupture, while increase of PET in composite increased the modulus of rupture. This could be because of the poor interface of bonding between hydrophilic fibre and hydrophobic polymer matrix. The burning rate increased with increase in the amount of PET but decreased with increase in the amount of fibres. This was ascribed to the high heating value of polymer matrix against that of fibres. The water absorption test showed that increase of fibre in the composite increased the amount of water absorbed while increase in PET decreased water absorption. This was attributed to hydrophilic property of fibre which increases the attraction to water by the formation of hydrogen bonding. However, increase in PET decreased the water absorption due to hydrophobicity of the polymer matrix. The Meyer's hardness test showed that increase in amount of fibre decreased the hardness while high amount of PET increased hardness. This was credited to the ability of the polymer matrix to bind the fibre strongly in order to form a hard solid composite structure. Increasing fibre in composite led to soft material because it became less likely for the polymer matrix to bind strongly to the fibre.

Keywords: Waste, fibre, composite, polymer, plastics

Introduction

Plastics and plant fibres have been the main environmental concern due to a large amount of wastes generated from them with plastic being the biggest problem due to its non-biodegradability (John, 2011). The presence of a large amount of plastic and plant fibre waste has caused many studies to be carried out to find how there wastes can be used to create useful composites materials (Agarwal, 2012). Fibre plastic composite can be used in different applications ranging from construction to automotive industry. The decision to use fibre plastic composites instead of either plastic or wood only should be predicted on achieving greater performance and reduced price along with the less environmental impacts (Bavuga, 2009). United State decking market alone uses of about 18.5 million m^3 of wood per annum (Quiang, 2013). In 2005, about 400 million wooden pallets were sold to different companies which represent 86% of all the pallets sold worldwide (Esfahani, 2015). Tea, a drink which is prepared from the infusion of the leaves and buds of C*amellia sinensis* plant, is a popular beverage with annual worldwide consumption of about 4.5 million tons (Mulhall, 2015). The extraction of tea from *Camellia sinensis* plant resulted in the production of a large volume of waste tea leaves fibres which has contributed to solid waste with the resultant disposable problem in countries. On the other hand, plastic waste has the highest contribution and constitute largest share of the global industrial and municipal solid waste (West, 2010). Yearly estimate of municipal solid wastes showed that plastic wastes constitute more than 60% (Kikuchi, 2011). The study done by American Chemistry Council showed that average consumers use 166 plastic water bottles each year and that about 2.5 million plastic bottles are thrown away every day which create unnecessary waste in landfills (Nwehner, 2017).

Fig. 1: PET wastes bottles in Yola metropolis of Adamawa State, Nigeria

This research aimed at the production and testing of some physico-chemical properties of polyethylene terephthalate waste bottles (Faro) / tea leaves waste fibre composites with the view to reducing polyethylene terephthalate and tea leaves fibre wastes dispose in our environment. Also, to measure some composite physico-chemical properties which if suitable would be recommended for used in the construction, furniture and allied industries.

Materials and Methods

Collection and preparation of raw material

Polyethylene terephthalate (Faro Water bottles) was collected at various locations of Yola metropolis of Adamawa state-Nigeria. The bottles were crushed into small pieces to facilitate dissolution in solvent. Tea leaves waste fibres were collected from Highland Tea Processing Company, Mambila, Taraba State, Nigeria. Fibres were washed, dried and grinded using an electronic blender 2.80 beta. Groundwaste fibres were dried again at 25^oC for 30 min to further remove any moisture. The solvent for the dissolution of polyethylene terephthalate was prepared by melting phenol in oil bath at 45 ^oC and 1, 1, 2, 2- tetrachloroethane added in 60/40 w/w ratio (Udina, 2012). Both chemicals were supplied by Northern Scientific located in Jimeta of Adamawa State-Nigeria.

(a) (b)

Fig. 2: PET waste bottles (a) and Tea leave waste fibres (b)

Preparation of liquid polyethylene terephthalate

The shredded polyethylene terephthalate was added to phenol/1,1,2,2-tetrachloroethane solution in a beaker (Fig. 3) and heated at 100^{o}C. The mixture stirred until PET dissolved completely forming a viscous solution (Mahmud, 2016).

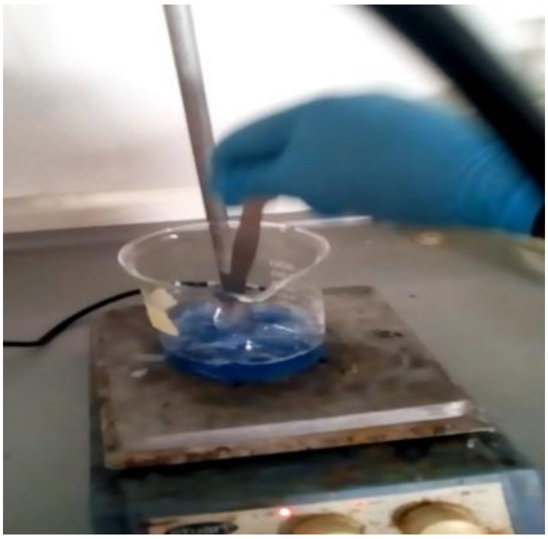


Fig. 3: Polyethylene terephthalate solution

Preparation of polyethylene terephthalate/tea leaves fibres composites

Composite had to be produced by adding a certain amount of fibre in a beaker containing melted PET. The mixture of tea leaves fibre waste and polyethylene terephthalate water waste bottle was mixed manually using a stirring rod. The mixture poured and casted in mold which was initially produced by Dubeli Aluminum Recycling Center, Yola Adamawa state. The mold was allowed to cool and the composites removed.

Fig. 4: Polyethylene terephthalate /tea leaves waste fibre composites

Characterization of fibre plastic composites

Water Absorption Test (ASTM D 1037)

The composite with thickness of 1 and 2 mm of width and 4 mm of length was used (Nourbakhsh, 2008). The specimens were immersed in water for 10 min. The amount of water absorbed was measured by weighing the specimen before and after immersion in water. The percentage of water absorbed was calculated using the following formula:

Wg = ((Wa-Wo)/Wo) × 100 % where, Wa is the weight of the fibre plastic composite after soaking and Wo is the weight before soaking.

Burning rate (ASTM D 635)

The composite of 2 cm long, 1 cm of thickness and width of 1.5 cm were used for burning test. The specimen was held horizontally, ignited using a Bunsen burner, and the time it took to burn completely was recorded (Cahill, 2006). The burning rate was calculated in mm/s using the following formula:

BR =Dp/Pt

Where: Dp= Propagation distance measured in millimeter

Pt = Flame propagation time measured in seconds

Meyer's hardness test

The hardness which is the resistance of a material to indentation was obtained using Meyer tester (Holzner, 2008). The following relationship was used to find out the hardness of the composites:

$$HD = \frac{F}{\pi / 2 \; x \; D(D - \sqrt{D^2 - Di^2})}$$

Where: F is the force used in N

D is the diameter of the indenter in millimeter

While Di is the diameter of the indentation in millimeter

Modulus of rupture test

Modulus of rupture test was carried out by supporting composite between two rollers at both ends, and loading done with some weights applied at the center (Bast, 2017).

Then the modulus of rupture was calculated using the following formula:

MOR = 3FL/2bd^2

Where;

MOR: Modulus of Rupture, Mpa / Pa

F: Force, N

L: The specimen length millimeter

b: Width of the sample millimeter

d: Thickness of the sample millimeter

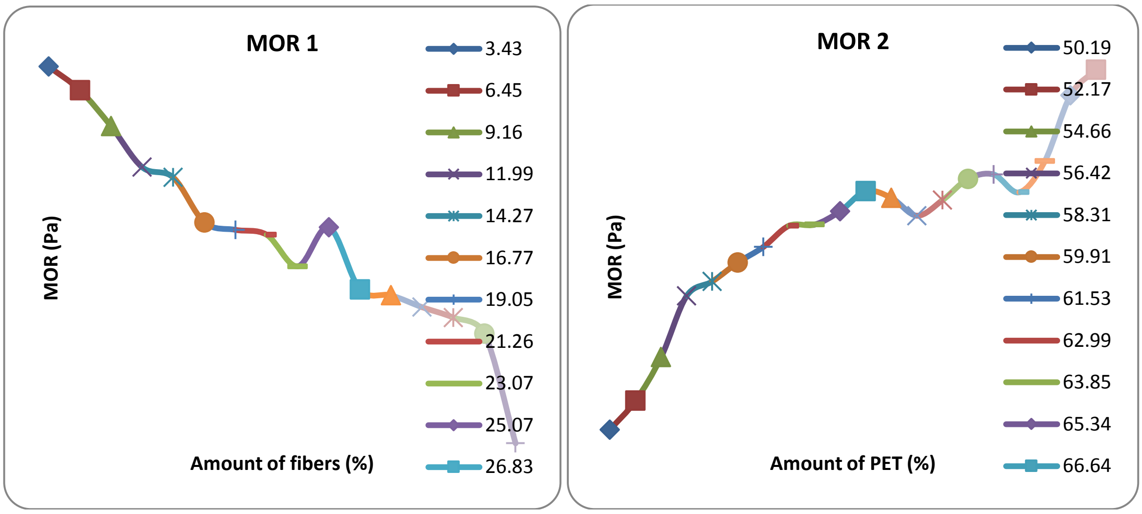
Results and Discussion

Modulus of rupture (MOR)test

Figure 5a and b show that MOR decreases as fibre increased and MOR increases as the amount of PET increases. This may be due to the poor interface bonding between hydrophilic fibre and hydrophobic polymer these two leading to poor modulus of rupture. Also, fibre agglomeration increases which make it less likely for polymer matrix to bind strongly. This leads to the formation of voids thus a poor modulus of rupture (Noor *et al*., 2018).

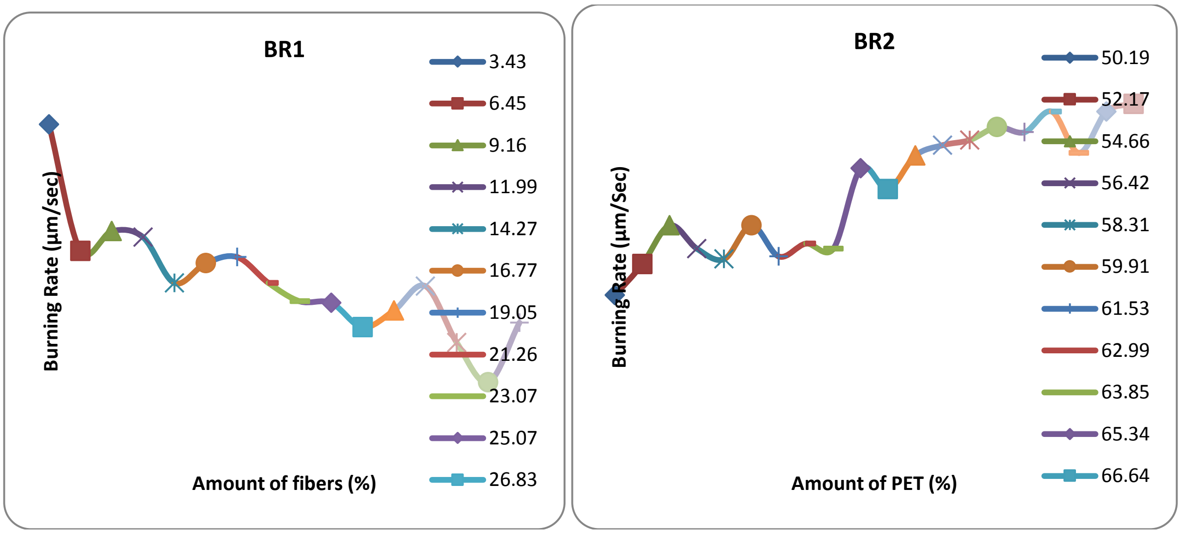
Burning rate test

Figure 6a and b show increase in fibre (%) increases the time of burning, thus a decreased burning rate. This is because the polymer that formed the matrix has high heating value (22.93 MJ/Kg) of PET compared to that of fibres heating value of 18.5M J/Kg. Also the presence of some moisture in fibres would cause the composite with high fibre (%) to burn slowly because thereby increasing burning rate (Henrik & Ulrike, 2011).



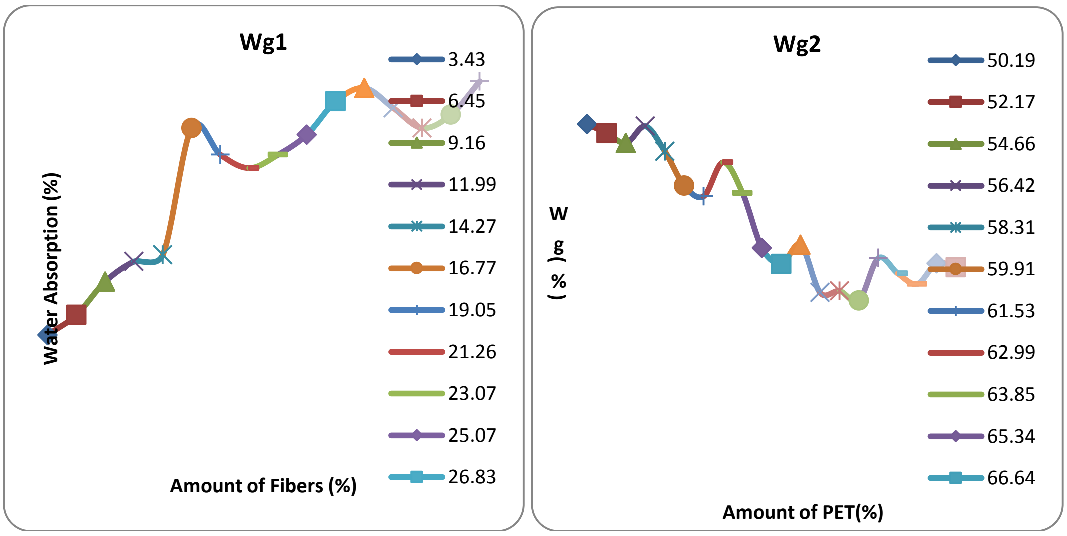
(a) (b)

Fig. 5: Effect of increase in fibre (%) on MOR of composite (a) and Effect of increase in PET (%) on MOR of composite (b)



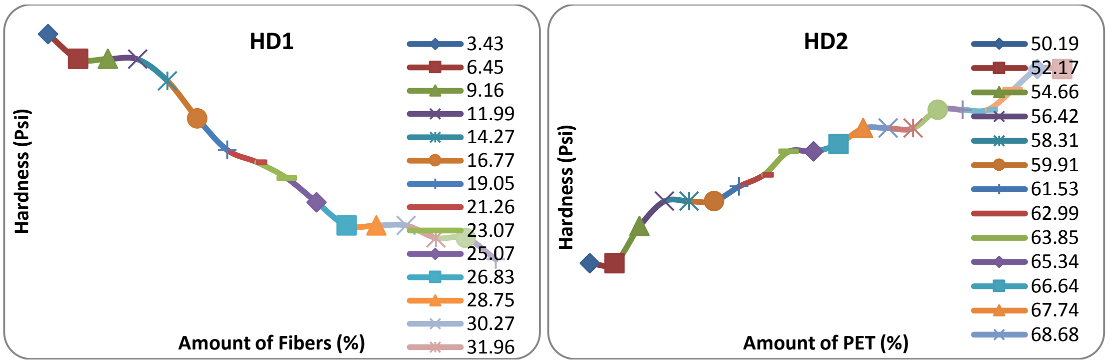
(a) (b)

Fig. 6: Effect of increase in fibre (%) on burning rate of composite (a) and Effect of increase in PET (%) on burning rate of composite (b)



(a) (b)

Fig. 7: Effect of increase in fibre (%) on water absorption of composites (a), Effect of increase in PET (%) on water absorption of composites (b)



(a) (b)

Fig. 8: Effect of increases in fibre (%) on hardness of composites (a), Effect of increases in PET (%) on hardness of composites (b)

Water absorption test

Figure 7a and b show that the higher the amount of fibre (%) the higher the water absorption while the higher the amount of PET (%) the lower the amount of water absorbed. This is because untreated fibre comprised of cellulose, hemicellulose, pectin and lignin. They all have varying degree of hydroxyl groups and other oxygen-containing groups which makes them hydrophilic. Thus attract water easily through by the formation of hydrogen bonds. PET is water repellent i.e. hydrophobic so that increase in PET decreases the amount of water absorbed (Behzad, 2011).

Hardness test

Figure 8a and b show that the higher the amount of fibre (%), the lower is the hardness of the composite and the higher the amount of PET the higher the hardness. This is because as the fibre increases the less likely it is for the polymer matrix to bind strongly, and thus the indenter used during the test can easily penetrate and provide an indentation with large diameter which gives a small hardness value.

Conclusion

A plastic fibre composite made from tea leave waste fibre and PET water waste bottles (Faro) was fabricated and some physico-chemical properties measured. The result showed that an increase of fibres in composite increase the water absorption while the increase of PET reduces the water absorption. Also, an increase in the amount of fibre reduces the burning rate while an increase of PET increases the burning rate of composite. The hardness is increased by the decrease of fibre amount. The modulus of rupture was found to be increased by the addition of PET and decreased by an increase of fibre. It was found and concluded that the physic-chemical properties of tea leave fibre waste/PET bottle waste composite strongly depend on the percentage of fibre and PET in the composite.

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Conflict of Interest

Authors wish to affirm that no competing exists.

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