PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 26 (5) 789-792 May 2022

Effect of Hybrid Fillers of Bamboo Fiber and Commercial Glass Fiber on High Density Polyethylene Matrix

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ABSTRACT: The focus of this research work is to study the effect of hybrid fillers of bamboo fiber and commercial glass fiber on high density polyethylene (HDPE) matrix without interfacial coupling agent. The hybrid composite was formed through melt blending method using two-roll mixing mill at temperature of 160 ºC and was shaped using compression molding machine. The highest value of Tensile Modulus at break and Hardness were obtained at hybrid ratio of 70 % of HDPE/ 15 % bamboo/ 15 % glass particles ($H/B_{15}/G_{15}$). However, the inclusion of the hybrid fillers did not show any significant difference in Impact strength from the molded blank HDPE samples ($H/B_0/G_0$) while the percentage water absorbed by the samples predominantly decreased as the content of the commercial glass filler was increase in the HDPE matrix.

DOI: **https://dx.doi.org/10.4314/jasem.v26i5.2**

Impact factor: **http://sjifactor.com/passport.php?id=21082**

Google Analytics: https://www.ajol.info/stats/bdf07303d34706088ffffbc8a92c9c1491b12470

Dates: Received: 28 March 2022; Revised: 13 April 2022; Accepted: 15 May 2022

Keywords: Melt blending; hybrid composites; bamboo fibre; glass fibre; HDPE; tensile strength

Hybrid composite materials have in recent times received great attention from researchers due to their excellent potential when compared to the non-hybrid or single fiber-reinforced composites. Hybrid composites comprising two or more types of particulate fillers/fibers embedded in a single material matrix (Patrycja *et al*., 2020; Oboh *et al*., 2018; Girisha *et al*., 2012). Polymer hybrid composites are formed by embedding more than one types of particulate fillers/fibers of different properties into a base polymer be it an elastomer or plastic. The performance of a hybrid composite is usually a collective effect of the individual constituents such that there is a better balance between the inherent advantage and disadvantages of their constituents (Widiasstuti *et al.,* 2022). however, the extent of balance in the overall properties of the hybrid composite is strongly dependent on processing method, types, surface conditions and dispersion of the filler elements (Patrycja *et al*., 2020; Oboh *et al*., 2018; Girisha *et al*., 2012; Widiasstuti *et al.,* 2022). Glass fibers is a synthetic fibre consist of numerous fine fibers of glass characterized with high tenacity, zero percentage moisture regain, low friction, little or no environmental and insect attack, high resistance to sunlight attack, incombustibility and highly susceptible to brittle failure (Sushanta *et al.,* 2008). Bamboo fiber on the other hand is a natural fiber usually extracted from fresh bamboo tree. Bamboo fiber is characterized by micro-gaps which makes it softer than glass fiber and absorb moisture (Rohmat *et al.,* 2021; Xian *et al.,* 2018; Imadi *et al.,* 2014; Biswas and Xess, 2012). They are elastic, biodegradable environmentally friendly and UV light resistant (Nguyen *et al.,* 2012; Smita and Sanjay, 2010; Cho *et al.,* 2009; Chen *et al.,* 1998). Rohmat *et al.,* 2021, reported increase in the Tensile strength and Modulus of HDPE reinforced with bamboo fibre**.** Xian *et al,* 2018 also reported increase in flexural strength, tensile and impact properties of bamboo plastic composites with a high-density polyethylene matrix with the aid of maleic anhydride grafted polyethylene (MAPE)

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interfacial compatibilizer. Similarly, Sushanta *et al.*, 2008 also reported improvement in tensile, flexural and impact strength of the bamboo/ glass fibre polypropylene hybrid composites coupled interfacially with maleic anhydride grafted polypropylene (MAPP). The focus of this research work is to study the effect of hybrid fillers of bamboo fiber and commercial glass fiber on high density polyethylene (HDPE) matrix without interfacial coupling agent.

MATERIALS AND METHODS

Materials: The major materials and equipment used in this experiment were high density polyethylene (HDPE), bamboo fiber, commercial grade glass fiber, lab size two roll mill, compression moulding machine, Izod impact tester, Shore A hardness tester and tensiometer.

Formulation and Formation of Hybrid Composites: The bamboo fiber used in this experiment was obtained by a method described by Oboh *et al* 2017, while the commercial grade glass fiber was purchased in an open market in Zaria, Nigeria. Both fibers were separately particulated to an average particle size of 250 micrometers, they were subsequently used in the formulation of HDPE matrix-based hybrid composites. The formulation used for the hybrid composite is based on 70% of HDPE and 30% of hybrid fillers such that the 30% was distributed between the two fillers in the 30/0, 25/5%, 20/10%, 15/15%, 10/20%, 5/25%, 0/30% of bamboo fiber/glass fiber respectively. This is shown in Table 1. The particulate fillers obtained from the respective fibers were pre-blended into the various ratios stipulated in Formulation Table 1 with the aid of a high-speed mixer to increase homogeneity. The hybrid composites were formed using melt blending method. The melt blending of HDPE and bamboo fiber/glass fiber was carried out on a two-roll mixing mill at a temperature of 165 ºC and compressed into various test samples at ambient temperature.

Table 1: Formulation of hybrid composites of HDPE/Bamboo Fiber/Glass Fiber

Ingredient	Composite Samples							
	H/ B_0/G_0	H/ B_{30}/G_0	H/ B_{25}/G_5	H/ B_{20}/G_{10}	H/ B_{15}/G_{15}	H/ B_{10}/G_{20}	H/ B_5/G_{25}	H/ $B/_0/G_{30}$
HDPE	100	70	70	70	70	70	70	70
Bamboo Fiber (B)	_	30	25	20	15	10	5	0
Glass Fiber (G)	_	0	5	10	15	20	25	30

Note that subscripts represent the percentage ratios of bamboo fiber and glass fiber

Properties Evaluation of Hybrid Composites: The hardness index was obtained using a Shore A hardness tester while tensile strength/modulus at break and impact strength were respectively obtained in accordance with ASTM D412-87 and BS-EN 29653. The percentage of water absorbed by hybrid composite samples after 24 hours of water immersion at ambient temperature were also evaluated.

RESULTS AND DISCUSSION

The results obtained from the hardness, tensile strength, modulus at fracture, impact energy of fracture and water resistance of the HDPE/Bamboo Fiber/Glass Fiber hybrid composites are presented in Figures 1,2,3,4 and 5 respectively. From the hardness results as presented in Fig 1, the best synergistic effect of hybrid filler from bamboo and glass fibers on the matrix of HDPE studied in this experiment was obtained at ratio 20/10 ($H/B_{20}/G_{10}$) and 15/50 ($H/B_{15}/G_{15}$) with Shore A hardness values of 99 and 99.7 respectively, resulting in slight increase in hardness over that of pure matrix ($H/B_0/G_0$) which has a value of 90, it was however observed that hybrid ratio reduced the hardness of HDPE.

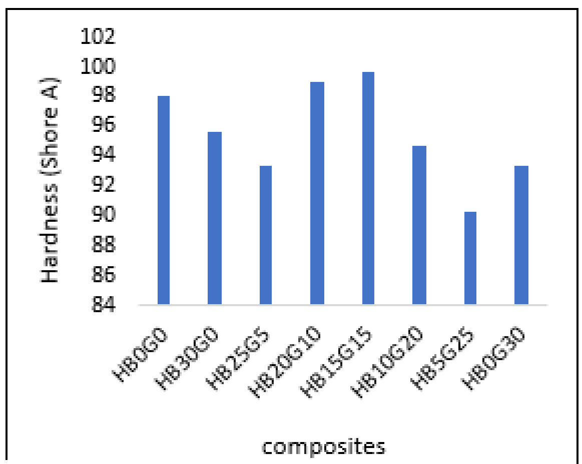

Fig 1: Effect of Bamboo Fiber/Glass Fiber Hybrid Ratio on Hardness of Composite

Hardness measures the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. In the case of Tensile strength result shown in Figure 2, the best synergy of the hybrid fillers on HDPE matrix was obtained at B25/G5 with a value of 28.13 MPa resulting in a marginal increase over 100% HPDE with value of 28.5 MPa, while other loading ratio resulted in decrease in tensile strength. On the other hand, composites with heavier ratio of glass resulted in superior water resistance.

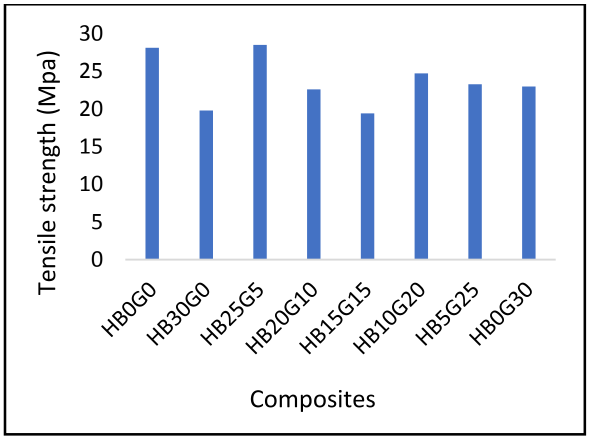

Fig 2: Effect of Bamboo Fiber/Glass Fiber Hybrid Ratio on Tensile Strength of Composites

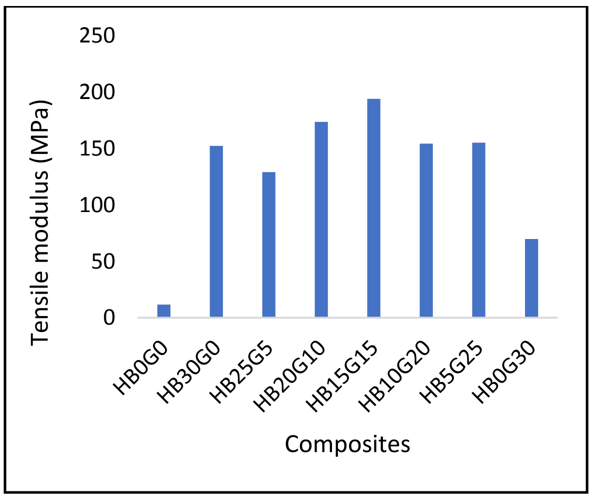

Fig 3 Effect of Bamboo Fiber/Glass Fiber Hybrid Ratio on Modulus of Composites

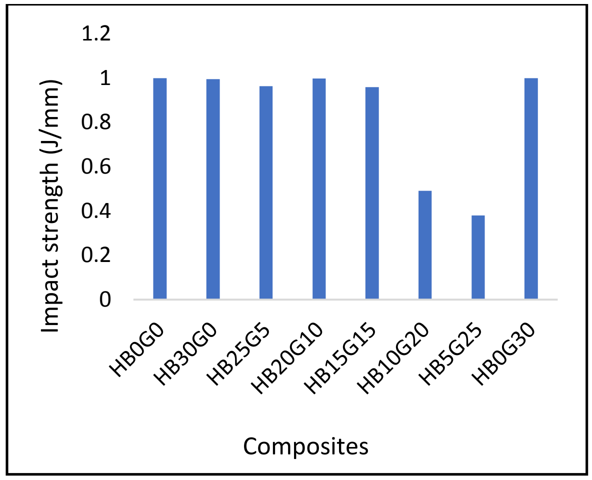

Fig 4: Effect of Bamboo Fiber/Glass Fiber Hybrid Ratio on Impact Property of Composites

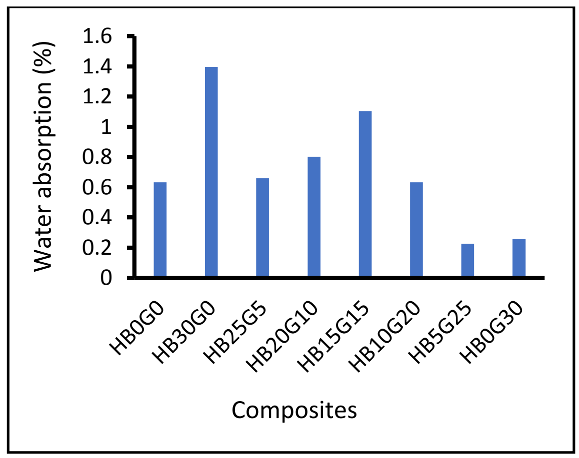

Fig 5: Effect of Bamboo Fiber/Glass Fiber Hybrid on Water Absorption of Composites

The results of modulus at fracture as shown in Figure 3 showed similar trend to that hardness such that the best synergistic effect of hybrid filler from bamboo and glass fibers on the matrix of HDPE studied in this experiment was obtained at ratio 20/10 ($H/B_{20}/G_{10}$) and 15/50 ($H/B_{15}/G_{15}$) with moduli values of 174.8 and 194 MPa respectively, resulting in increase in modulus value over that of pure matrix ($H/B_{0}/G_{0}$) which has a value of 152.3 MPa. In the case of impact strength, there was no significant influence of the hybrid fillers in HDPE matrix; rather, there was drastic drop in impact property was observed at ratio of glass fiber to bamboo fillers. This is expected owing to the fact that the glass materials have a brittle microstructure. The result of water absorption as shown in figure 5 clearly shows that the hybrid composites with heavier bamboo filler ratio showed reduced water resistance due to the hydrophilic nature of cellulosic bamboo. On the other

Conclusion: The preparation and properties evaluation of HDPE/particulate bamboo fiber/glass fiber hybrid composites (H/B/G) without interfacial coupling agent has been studied. The preparation of the hybrid composites was achieved through 70 % by weight of HDPE melt blending with 30% by weight of premixed hybrid bamboo/glass fillers. From the findings, the best properties synergy for hardness and modulus were achieved at hybrid ratio of 15% bamboo fiber/15% glass filler ($H_{70}B_{15}/G_{15}$) corresponding to 99.7 Shore A and 194 Mpa respectively, whereas tensile and impact strengths were achieved at hybrid ratios of 25% bamboo fiber/5% glass fiber ($H_{70}/B_{25}/G_{5}$) and 20 % bamboo fiber/10% glass fiber ($H_{70}/B_{20}/G_{10}$) with values of 28.5 Mpa and 0.998 J/mm respectively. However, for water absorption resistance, the best synergy was obtained at hybrid ratio of 5 % bamboo fiber/25 % glass fiber ($H_{70}/B_{5}/G_{25}$) with 0.2 % water regain. This shows a strong potential application of both bamboo fiber and glass fiber as low-cost filler in HDPE composites.

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