JSR Vol. 2(1), 2023: 88-98, ISSN: 2814-3329

JOURNAL OF SCIENTIFIC RESEARCH

Department of Pure and Applied Chemistry
Faculty of Science
University of Maiduguri
https://jsrunimaid.com/

Research Article *https://doi.org/10.5281/zenodo.8414066*

EFFECTS OF *GREWIA MOLIS* FIBERS ON PHYSICAL/MECHANICAL PROPERTIES OF RECYCLED POLYETHYLENE TEREPHTHALATE COMPOSITES

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ABSTRACT

This study aimed to propose potential structural applications of the GMF/RPET composite materials. Grewia molis fibers (GMF) were prepared and incorporated into recycled polyethylene terephthalate (RPET) matrix to obtain the GMF/RPET composite materials in this study. Furthermore, the effects of different amounts of GMF (10 – 50%) on some of the composite material's mechanical and physical properties were evaluated. The results showed that the tensile strength (0.22 – 0.095 Pa) and elongation at break (20.2–2.7 %) of the GMF/RPET composite materials decreased as the amount of GMF in the composite was increased. This showed that the increase in GMF decreased. flexibility and deformation of the composite materials under load. Conversely, flexural strength, compression strength, and hardness increased as the amount of GMF in the composites increased. This consistently indicated that rigidity and hardness increased in the GMF/RPET composite materials as the GMF in them increased. Density and water absorption of the GMF/RPET composites also increased with GMF due to the size and hydrophobicity of the fibers. GMF/RPET composite materials exhibit their potential in structural applications where rigidity is desired.

Keyword: Composite Materials; *Grewa molis* Fiber (GMF); Mechanical Properties; Physical Properties; Recycled Polyethylene Terephthalate (RPET)

INTRODUCTION

Composite materials are produced from two component materials. It is expected to exhibit unique properties that overcome the limitations of its component materials in specific applications. In composite formulation, the process of incorporation of materials may range from physical blending to reactive copolymerisation of materials. In physical blending, fibers and particles are incorporated into the polymer matrix of resins. The incorporation may also be enhanced by inter and intra molecular, van der waals and other partial electrostatic forces among the fiber/particles and macromolecules of the polymer matrix [1].

A fiber is a polymer with a unique dimension in its length to diameter ratio 100:1 [1]. Fibers form a class of materials that are relatively resistant to deformation, exhibit high modulus and low flexibility [2]. Fibers have been widely used in the development and modification of structural materials for application in which flexibility may be a limiting property [3]. Natural fibers are green and economic alternatives to synthetic fibers. Natural fibers are largely renewable resources, they are easy of fabricate; the cost of fabrication is low and they are compatible with the environment due to their biodegradability [4, 5]. Natural fibers are chemically constituted majorly by cellulose, while other minor macromolecular components may include lignin and pectin [6,7,8]. The bonded and unbounded OH groups on the macromolecules in natural fibers play meritorious roles in the desired physicochemical interactions with the matrix molecules to create a structurally stable composite. Natural fibers extracted from different plants have been well studied and used in many applications, including pulp and paper making, cordage, filtration products, fireboard, reinforcing materials in tires, rubber, ceiling boards concrete and nano bio-composite [9,8]

Grewia molis is a shrub or tree widely distributed in northern Nigeria and other African countries [10]. It can also be regarded as the multipurpose tree of the Himalayan region in India, where it has been reported to be used for many purposes [11]. In Nigeria, it is known to be a strong fire-resistant plant, and its parts are used in food and traditional medicines [12,10]. GMF typically contains cellulose, hemicelluloses and lignin in the ranges of 58–62 %, 20– 25 % and 15-20 % respectively [13,9], studied the effect of water and different chemical treatments on the mechanical properties of GMF. The study concluded that GMF with optimum treatments shows potentials in structural applications such as reinforcement of carpets and mats [9,11] used GMF as reinforcement in polymer blends and the adhesion characteristics of GMF in the composite were shown to improve with the levels of the fiber treatment.

Polyethylene Terephthalate (PET) is an important engineering polymer with a wide variety of applications in the biomedical, material, and food industries [14]. PET constitutes a major solid waste due to the large volume of PET materials that have been disposed of after use. Solid waste is a global challenge that has continued to increase with industrialization and urbanization, and recycling is agreeably the most economical and environmentally friendly process for solid waste management [15]. PET materials, especially PET bottles have been recycled using different methods, and the products have been used in many applications [16,17,18].

In the present work, we prepared GMF and recycled PET by dissolving it in a medium constituted by phenol and tetrachloroethane. A composite of the GMF and the RPET was prepared, and the effects of the different amounts of GMF on some mechanical and physical properties of the GMF/RPET composite materials were studied. The aim of the study is to propose potential structural applications of the GMF/RPET composite materials.

MATERIALS AND METHODS Materials

Analytical-grade sodium hydroxide, phenol crystal, and tetra chloroethane were utilised. *Grewia molis* stem bark was obtained for the tree in the vicinity of Yola Main Market in Yola. The bark was washed, split into smaller pieces (about 10 cm by 5 cm), and carried to the lab in a clean polyethene bag. Waste PET bottles were collected from Modibbo Adama University's waste bin in Yola.

Retting

Water and chemical retting of *Growia molis* bark were performed using procedures described in [9] with minor modifications. Water retting was accomplished in the stepwise method by immersing approximately 100 g of the sample in 10 litres of water for thirty days. This was followed by scouring to eliminate impurities such as ligneous, woody, and mucilaginous materials, and then the fibres were rinsed under tap water to remove them. This was followed by chemical retting, in which 15 g of the fibre was immersed in 600 ml of 5% NaOH and heated in a water bath at 100° C for 30 minutes. The resulting fibre was washed three times in distilled water and dried in an oven at 40° C for eight hours.

Formulation of Recycled PET Matrix

PET bottles were cut into small pieces. Phenol crystal (15 g) and 1,1,2,2, tetra chloroethane (7.6 ml) were mixed in a beaker at 100^{o} C, and PET (3 g) was added to the mixture while stirring for 10 mins at 40^{o} C to dissolve the PET.

Formulation of *Grewia molis* Fiber/PET Composite Materials

The formation of 5 to 50 % w/w of the fiber/PET composites were carried out by vigorously mixing different amounts of the fiber with 50 g of the recycled PET matrix using a stirring rod. The mixtures were poured into the mould (6cm/3cm/0.3cm), and were allowed to cool and cast, before the materials were removed for analysis.

Determination of Mechanical Properties

The tensile and flexural strength test were performed using a Monsanto Tensometer (serial number 9875) according to the method described by [19]. A compression test was carried out using the Universal Materials Testing Machine (Cat.Nr.261). An Inston Tensile testing machine (Model 1026) based on ASTM D638 method, was used in the determination of elongation at break as described by [20]. The hardness test was performed using a Hardness Tester (Shore A, model 5019), based on standard method ASTM D 2240. Results were recorded from an average of triplicate determinations.

Determination of physical properties

The materials were kept in distilled water for 48 h, and the water absorption was determined gravimetrically according to the method described by [15]. The volume of the materials was determined from the volume of water displayed in the measuring cylinder when a known mass of the material was carefully dropped into the measuring cylinder. The volume obtained was used in the calculation of density as described by Dimitrov *et al*. [15].

RESULTS AND DISCUSSION

Effects of GMF on tensile strength and elongation at break of GMF/RPET composite materials

Tensile strength and the elongation at break are very important and relative mechanical properties that must be established for any structural material. The effects of different amounts of GMF on the tensile strength and elongation at break of the GMF/RPET composite materials are presented in Figures 1 and 2, respectively. The trend wholesomely showed that tensile strength and the elongation at break of the composite materials decreased with an increase in amount of GMF. The decrease in these properties was more extensive with the lower amounts of GMF, up to about 20 %. This showed that the GMF can impact the mechanical properties of the RPET matrix remarkably even at low proportion of GMF to the RPET. Incorporation and the initial increase in GMF significantly disrupt crystallinity, propagation of elasticity, long range molecular interactions, and the intrinsic interfacial interactions in the RPET matrix and the composited produced respectively [21,22,23]. This basically impact stiffness and rigidity, and reduced the both the tensile strength and the percentage of elongation of the materials. The amount of GMF in the composite materials may reach an optimum level, and the excess amount of GMF may not increase both tensile strength and the elongation at break any further as similarly reported by [24,25]. The effects of GMF on the tensile strength and the elongation at break of the GMF/RPET composite materials in this study are consistent with various reports in the literature [21,22,26,25]

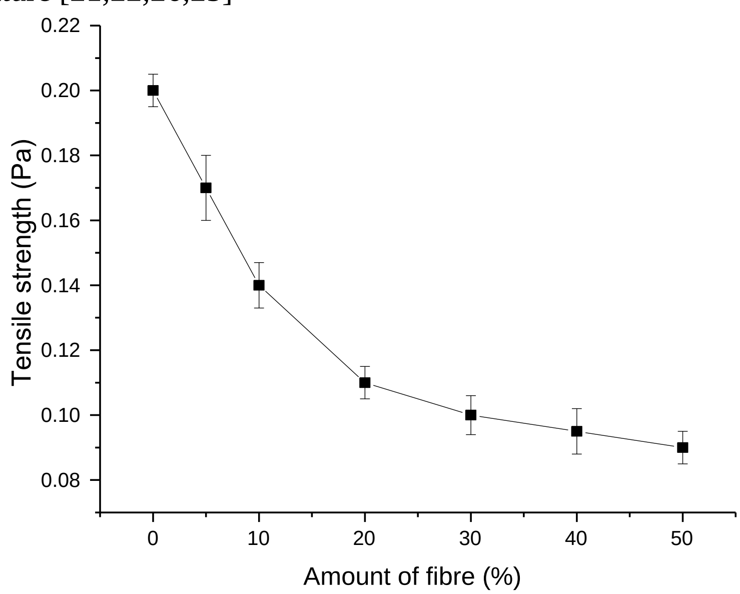

Figure 1: Effects of GMF on tensile strength of GMF/RPET composite materials

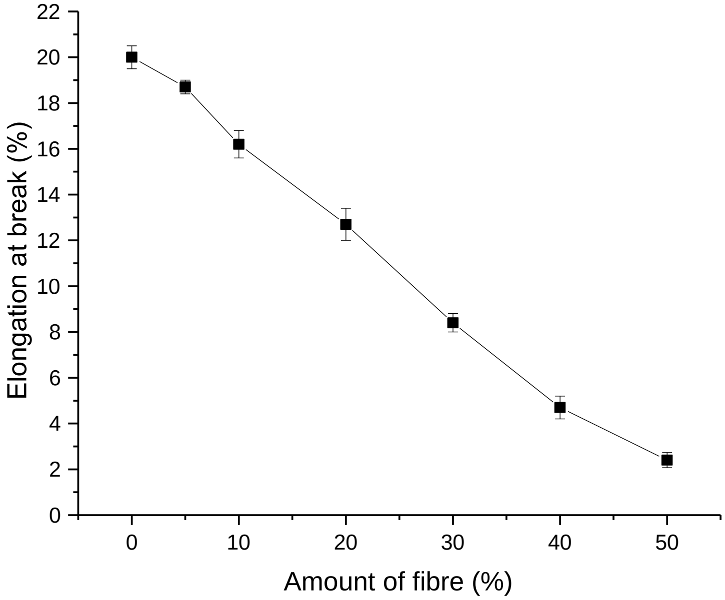

Figure 2: Effects of GMF on elongation at break of GMF/RPET composite materials **Effects of GMF on Flexural Strength of GMF/RPET Composite Materials**

The effects of different amounts of GMF on the flexural strength of GMF/RPET composite materials are presented in Figure 3. In less common fashion, the flexural strength increased towards equilibrium as the amount of GMF in it increased. Rahman *et al*. [28] reported a similar effect while increasing the hybrid fiber load of coir and jute fiber in polyethylene composites. The effect was attributed to the entanglement of the matrix polymer chain with the fiber, which laterally increased the strength of the composite materials with an increase the in GMF [29,30,28,31]. Increase in flexural properties of composite materials with increase in fiber loading recorded in this study has also been well reported in the literature [32,33,28,31]

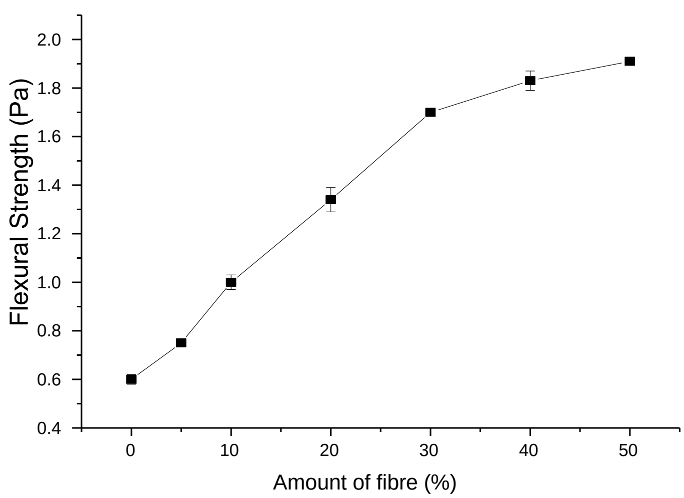

Figure 3: Effects of GMF on flexural strength of GMF/RPET composite materials

Effects of GMF on Compression Strength of GMF/RPET Composite Materials

Figure 4 presents the effects of variation in GMF on the compression properties of the GMF/RPET composite materials. The results showed that the compression strength of the GMF/RPET composite materials increased with an increase in the amount of GMF. The increase in compression strength can be attributed to increases in mass per unit area of composite as the GMF increased in the composite. An increase in mass per unit area is expected to increase the resistance to compression, thereby, increasing the compression strength. Similar effects have been reported for bamboo and siwak fibers in polymethyl methacrylate (PMMA) composites [34]. They also reported an increase in the compression strength of concrete reinforced with human air.

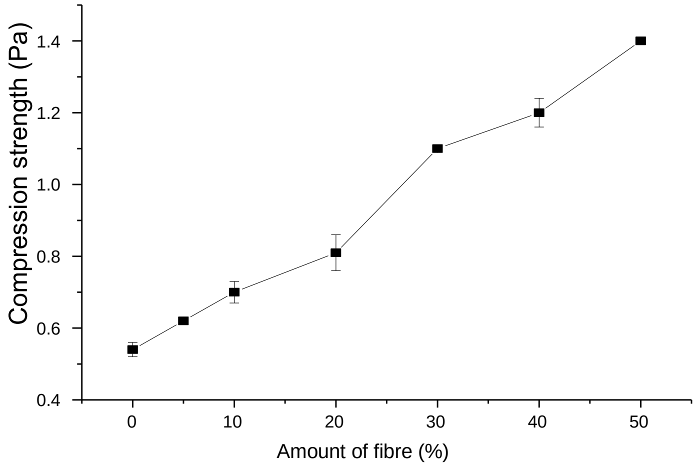

Figure 4: Effects of GMF on compression strength of GMF/RPET composite materials

Effects of GMF on Hardness of GMF/RPET Composite Materials

Hardness is a mechanical property that reflects material compactness and is often correlated with the material's compression strength [35]. As demonstrated in Figure 5, an increase in GMF increased the hardness of the GMF/RPET composite materials in this investigation. According to [3,] the rise in hardness strength is caused by an increase in fiber interphase and close packing within composite materials. Increases in fiber and filler load have also been found to increase the hardness of composite materials [36, 2].

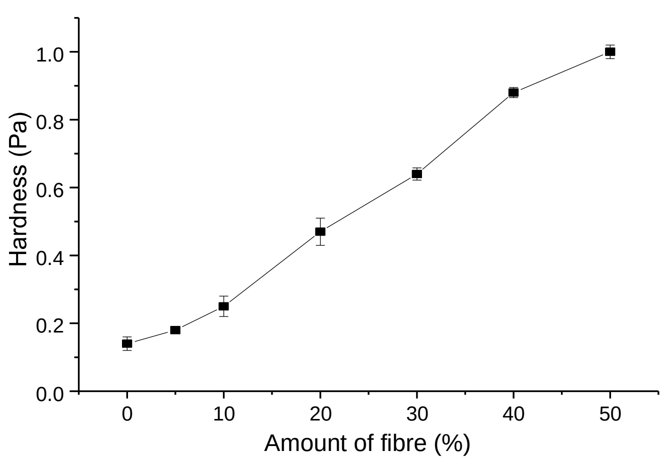

Figure 5: Effects of GMF on hardness of GMF/RPET composite materials

Effects of GMF on Water Absorption of GMF/RPET Composite Materials

Water absorption increased in GMF/RPET composites with an increase in the amount of GMF. Water absorption can be attributed to the hydrophilic nature of the natural GMF, as well as the void spaces created due to the incorporation of GMF. An increase in GMF in the composites is expected to increase water affinity sites, such as OH groups in the composites [29,37]. Furthermore, incorporation of the fiber disrupts the intrinsic crystallinity of the materials, which creates voids and porous structures in the material. These effects will consequently increase the aggregate amount of water retention in the materials as the amount of fiber increases. The result of this study is in agreement with many results reported in the literature [38,39].

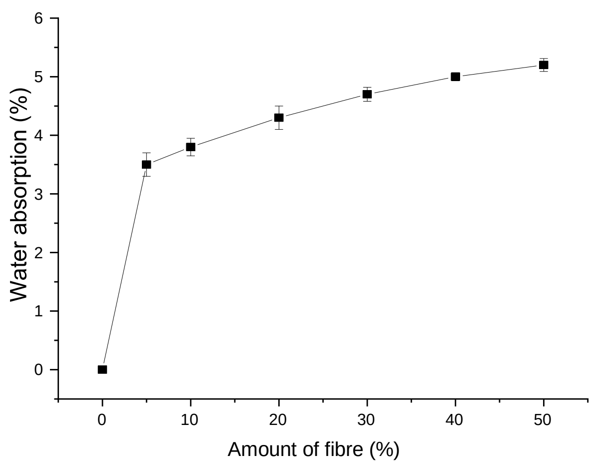

Figure 6: Effects of GMF on water absorption of GMF/RPET composite materials

Effects of GMF on Density of GMF/RPET Composite Materials

Figure 7 also showed that the density of the composite materials increased with the amount of GMF incorporated into them. Natural fibers are typically dense materials with a large mass per unit volume [37]. The results showed that GMF increased the mass per unit volume of the composite. This result correlates with the increase in compression strength, which cumulatively indicates that GMF improved structural compactness in the composite materials. The result of this study is consistent with the reports [40, 41].

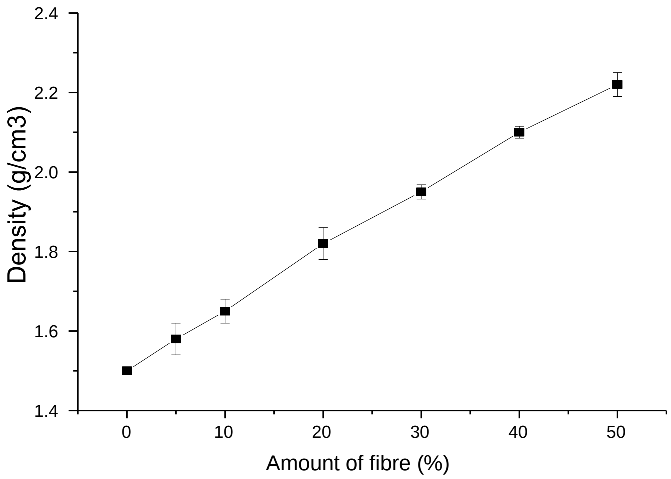

Figure 7: Effects of GMF on density of GMF/RPET composite materials

CONCLUSION

Grewia molis fiber was extracted and treated optimally, while waste PET bottles were recycled (RPET) to produce a composite material of the two materials (GMF/RPET). The basic mechanical and physical properties of the composite produced were studied to establish its potential structural applications. Tensile strength and the elongation ability of the composite materials reduced with an increase in GMF, while flexural strength, compression strength, hardness and density increased. This consistently indicated that the incorporation of GMF improved rigidity, compactness and the mass per unit volume of the composite. This suggested that the GMF/RPET composite material may exhibit desired stability in structural applications that does not involve lateral loading. GMF, however, increased water absorption in the composites and this may pose a potential challenge to the longevity of the material. Further studies on the effects of GMF sizes and even instrumental analyses to investigate the morphology of the composite are recommended.

ACKNOWLEDGMENT

Authors acknowledge the mentorship of Professor Buba A. Aliyu as well as the professional and technical contributions by Dr. Ayodele Akinterinwa, both of the Department of Chemistry, Modibbo Adama University, Yola, Nigeria.

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