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Date palm wood flour/glass fibre reinforced hybrid composites of recycled polypropylene: Mechanical and thermal properties

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ABSTRACT

Recycled polypropylene (RPP) based hybrid composites of date palm wood flour/glass fibre were prepared by different weight ratios of the two reinforcements. Mixing process was carried out in an extruder and samples were prepared by injection molding machine. Recycled PP properties were improved by reinforcing it by wood flour. The tensile strength and Young's modulus of wood flour reinforced RPP increased further by adding glass fibre. Glass fibre reinforced composites showed higher hardness than other composites. Morphological studies indicated that glass fiber has good adhesion with recycled PP supporting the improvement of the mechanical properties of hybrid composites with glass fiber addition. Addition of as little 5 wt% glass fibre to wood flour reinforced RPP increases the tensile strength by about 18% relative to the wood flour reinforcement alone. An increase in wood particle content in the PP resulted in a decrease in the degree of crystallinity of the polymer. The tensile strength of the composites increased with an increase in the percentage of crystallinity when adding the glass fibre. The improvement in the mechanical properties with the increase in crystallinity percentage (and with the decrease of the lamellar thicknesses) can be attributed to the constrained region between the lamellae because the agglomeration is absent in this case.

1. Introduction

Wood can be used as filler to increase the strength, stiffness and decrease the raw material cost in thermo plastics and thermosets. Wood polymer composites (WPCs) that exhibit good material properties and consists primarily of wood and thermoplastic polymers made by various techniques of processing such as extrusion, compression or injection molding. The polyolefins are the most used thermoplastics for making the wood composites because of their low cost and because processing temperature is below degradation of wood. Virgin thermoplastics such as High Density Polyethylene (HDPE) and polypropylene (PP) are widely used for wood polymer composites and many literature available based on these thermoplastic wood composites [1–3]. The improvement in properties of wood/recycled polymer composites may also be enhanced with different chemicals [4–7]. WPC are currently used in building applications, automobiles, marine applications, highway structures, etc.

Researchers around the world have gained interest on recycled materials because of the increase environmental pollution. Waste plastics are abundantly available as solid waste in all countries around the world. Polymers made from petroleum wastes were easy to recycle with only addition of energy and the properties of waste plastics are approximately similar to those made from virgin materials. Recycled polymers based on thermoplastics and wood fibre make a unique opportunity for industrial useful products. Several researchers have focused on their research on recycled thermoplastics based wood composites [8,9]. Effect of different wood filler size and also different fibre loading on the properties of the wood saw dust/recycled polymer composites were also available in the literature [10,11] studied by researchers using recycled polymer as matrix we Some researchers using the chemicals and coupling agents for improved the properties of the wood flour reinforced recycled polymer composites [12–15].

In the present work we used recycled PP as a matrix for making the composites. Recycled PP is available as a waste material and it causes many environmental problems. To reduce the environmental problem PP can be recycled to produce new value added product with low production cost. Polypropylene is used as a thermoplastic polymer for many structural applications due to its good properties like stiffness and toughness. It is an inexpensive material, which can be processed many times without losses of properties and it is easily modified to required application.

Wood derivatives like fibre, flour and flakes are also agro wastes and have been widely used as reinforcement material in recycle thermoplastic composites. Hence the usage of recycled plastics

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with waste wood for WPC results in less waste disposal problems and lowers the production costs. With this view, in the present work we prepared the recycled PP/wood flour composites. The addition of wood flour to waste plastics renders the good mechanical properties and it is also an inexpensive additive. Limited literature is available on wood flour and recycled PP [16–18]. In the present work, we used the date palm wood flour as filler for preparation of composites.

Some researchers published their work on utilization of date palm fibre as reinforcement in both thermoset and thermoplastic composites [19,20]. Recently, considerably interest has been shows on the surface treatment of date palm fibre with Sodium Hydroxide (NaOH) [21,22] for improve the properties of the date palm fibre. It can also be seen from the literature that short fibres improved the mechanical properties of the date palm fibre reinforced epoxy composites [23].

The date (*Phoenix dactylifera* L.) has been an important crop in the Middle East countries. The date palm tree (Fig. 1) is a member of the palm tree family (*Phoenix dactylifera*). This tree is played an important part in the economic and social life of the people and their products are extensively used in daily life. The date palm wood flour, which is used in the present work, is agriculture waste product. However wood flour reinforced recycled PP composites have poor mechanical properties due to the poor hydrophilicity of wood fibre. This hydrophilic nature of wood makes poor interfacial adhesion with PP. Several methods are reported in literature to improve the adhesion and reduce the moisture absorption of the surface of the wood flour [24]. Very few papers incorporated on wood flour and glass fibre in thermoplastics, i.e. making of hybrid composites. By hybridization, it is possible to achieve a balance between performance and cost of the composites, which would not be obtained with a single kind of reinforcement. Reports of hybridization of wood and glass fibre reinforced composites are cited in the literature [25–28]. These reports shows that, the properties of the wood flour was improved by adding glass fibre to the wood fibre reinforced polymer composite.

In this study we used the glass fibre as reinforcement for making the hybrid composites to improve the properties of date palm wood flour/recycled PP composites. No study has been done on this kind of wood.

Use of glass fibre as reinforcement with wood floor in recycled PP is less costly than glass fibre reinforced PP composites. Glass fibre reinforced composites have been widely used in the automotive and aerospace industries due to their high strength and low weight properties. In spite of many published work based on date palm fibre composites, no research has been reported on the recycled PP based date palm wood flour/glass fibre hybrid composites. With this view, in the present work we prepared the recycled polypropylene based date palm wood flour/glass fibre hybrid composites at different compositions. So, the objective of the present study is to use the recycled products in composites and develop hybrid composites of recycled PP by adding glass fibre and local wood products. These prepared recycled hybrid composites will be more economical than pure glass fibre composites.

Fig. 1. Photograph of a date palm tree.

2. Materials and methods

2.1. Materials

Recycled PP was supplied by Qatar Polymers Company in the form of pellets, with a density of 0.9 g/cm^3 and melt flow index of 12 g/10 min (230 °C/2.16 kg). The wood flour reinforcement used in the composite was from date palm species obtained from Qatar landfill. Wood pieces was dried in an oven at 65 °C for 24 h, after that they were grinded and stored in sealed plastic covers. In this work we are using the date palm wood without any treatment. Most totally dried samples have been achieved. Commercially available E-Glass fibre with 4.55 ± 1 mm average length and 2.9 g/cm^3 average density was used as reinforcement for making the hybrid composites.

2.2. Composite preparation

The compounding of recycled PP and wood flour/glass fibre was carried out in a Brabender twin screw extruder. The processing temperature was used in the range of 190–230 °C. Polymer composites samples with different percentage of wood flour and glass fibre were prepared. The weight percentages of wood flour and glass fibre as used in the composites prepared in the present work are showed in Table 1. The mixtures were extruded, cooled and granulated. The compounded samples were prepared by 5 injection molding machine.

2.3. Mechanical testing

2.3.1. Tensile properties

The tensile tests were carried out according to the ASTM D638-02 [29] standard, by using a Universal Testing Machine at a crosshead speed of 10 mm/min. The standard dimension is 20 mm length, 12.5 mm width and 3 mm thickness. The Young's modulus is calculated automatically by Nexygen Plus software, Lloyd Instruments, UK, by selecting tangent method. The tensile test direction is uniaxial and five samples were taken for the tensile test from the total of 140 samples of each series of composites. In each case five samples were tested and average value was reported.

2.3.2. Hardness properties

Micro-hardness test was conducted to all samples by HRF Rockwell Hardness F Scale 0.0016 m Ball Penetrator. A 60 kg load was applied and a total of 10 indentation measurements were performed on each sample surface. For this test, ASTM D785-08 and ASTM E 18-11 method was applied for measuring the hardness [30,31].

Table 1
Codes and composition of the wood and glass fibre composites.

Code	Wood (w%)	Glass fiber (w%)	RPP (w%)
W-RPP	30	0	70
G-RPP	0	30	70
WGFRPP1	25	5	70
WGFRPP2	20	10	70
WGFRPP3	15	15	70
WGFRPP5	5	25	70