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## ***Grewia optiva* Fiber Reinforced Novel, Low Cost Polymer Composites**

A.S. SINGHA and VIJAY KUMAR THAKUR

Applied Chemistry Research Laboratory,  
National Institute of Technology,  
Hamirpur – 177005, Himachal Pradesh, India.  
[assingha@gmail.com](mailto:assingha@gmail.com)

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**Abstract:** In this research article, the assessment of properties of compression molded *Grewia optiva* fiber reinforced Urea-Formaldehyde (UF) matrix based polymer composites is reported. Reinforcing of the UF resin with *Grewia optiva* fiber was accomplished in the particle, short and long fiber reinforcement. Present work reveals that mechanical properties such as: tensile strength, compressive strength and wear resistance of urea - formaldehyde resin increases to a significant extent when reinforced with *Grewia optiva* fiber. Analysis of results shows that particle reinforcement is more effective as compared to short and long fiber reinforcement. Morphological and Thermal studies of the matrix and fibre reinforced biocomposites have also been carried out.

**Keywords:** Polymer composites, Reinforcements, Optimization and Mechanical properties.

### **Introduction**

Emerging community concerns and a growing environmental awareness throughout the world has forced the researchers to synthesize new green materials and processes that enhance the environmental quality of products<sup>1-2</sup>. In this perspective, biodegradability, eco-friendliness, easy availability and light weight *etc.* have become important considerations in the fabrications of new products<sup>3-4</sup>. Natural fiber reinforced polymer composites materials are almost replacing materials such as ceramics, metal, glass, *etc.*<sup>5-7</sup>. The use of natural fibers, derived from a number of renewable resources, as reinforcing fibers in both thermoplastic and thermoset matrix composites provides positive environmental benefits and offer numerous advantages over conventional materials including lightness, resistance to corrosion and ease of processing *etc.*<sup>8-9</sup>. Natural fibers like flax, hibiscus sabdariffa, pinus, jute, pineapple leaf fiber, oil palm fiber have all been proved to be good reinforcements in thermoset and thermoplastic matrices. The properties of natural fibers depend mainly on the

source, age and separating techniques of the fiber. These properties generally vary for all plants according to climatic conditions *etc.* *Grewia optiva* plant is abundantly found in the Himalayan region. Literature survey has revealed that no work has been done on utilization of this fiber as reinforcing material in the polymer composites<sup>1-5</sup>. Keeping in view the easy availability and many other ecofriendly advantages we have used this bast fiber as reinforcing material for the preparation of urea-formaldehyde (U-F) resin based biocomposites.

## **Experimental**

### *Material and methods*

Urea, formaldehyde solution and sodium hydroxide supplied by Qualigens Chemicals *Ltd.* were used as received. *Grewia optiva* fibers were collected from local resources.

### *Synthesis and mechanism of urea- formaldehyde resin*

UF resin was synthesized by the standard method developed in our laboratory, reported somewhere else<sup>2</sup>. The resin samples were then cured at 130 °C in compression molding machine. The cured samples were then subjected to various mechanical, thermal and morphological studies. Chemical reaction is supposed to take place in two steps<sup>3</sup>. Suitable conditions of temperature, acidity of the medium and pH are maintained while carrying out the reaction as reported earlier<sup>3</sup>. At the required level, reaction is arrested by neutralization (pH 7.5-8). The condensation is closely watched and controlled at the stages of production because if the reaction is allowed to continue, cross linking leads to the gelatization of the resin.

### *Fabrication and processing of biocomposites*

Biocomposite of *Grewia optiva* fiber reinforced UF polymers were prepared by taking *Grewia optiva* fiber in three different forms as discussed below:

#### *Particle reinforced composites (P-Rnf)*

*Grewia optiva* fiber was grinded to a powder and filtered through a sieve of pore size 200 microns. The specific amount of resin and fiber was taken and were mixed thoroughly by suitable loading (1.0:0.01). Curing of samples was done in compression molding machine at 130 °C and were further subjected to different studies.

#### *Short- fiber reinforced composites (SF-Rnf)*

*Grewia optiva* fibers were chopped into 3 mm size and mixed with the known weight of UF resin in a dish. After proper mixing the curing of samples was carried- out at 130 °C in compression molding machine.

#### *Long fiber reinforced composites (LF-Rnf)*

*Grewia optiva* fibers were chopped into 6 mm length and mixed with weighed amount of resin. Curing of samples was done as described above.

### *Analysis of mechanical properties of polymer resin and biocomposite samples*

Tensile, compressive, and wear tests were performed on specimens cut from the above prepared polymer composite materials. For tensile and compressive strength results the measurements were made on Computerized Universal Testing Machine (HOUNSFIELD H25KS). Wear test of polymer composites was done on Wear & Friction Monitor (DUCOM- TR- 20L). The specimens of dimension 100 mm × 10 mm × 5 mm were used

for analysis. The tensile and compression tests were conducted in accordance with ASTM D 3039 and ASTM D 3410 methods respectively. Wear resistance tests of composites were carried-out as per ASTM D 3702 method.

#### *Thermal and morphological analysis*

Thermal analysis of materials gives us good account of their thermal stability. Thermo gravimetric analysis (TGA) and differential thermal analysis (DTA) studies of samples were carried out in nitrogen atmosphere on a thermal analyzer at a heating rate of 10 °C /min. Morphological analysis of different samples was carried out by studying SEM micrographs. These SEM micrographs of the samples give us information about the morphology of the resin and its respective biocomposite. These micrographs clearly show the difference between loaded and unloaded matrix.

### **Results and Discussions**

Analysis of mechanical properties have been proved to be an effective method in studying the behaviour of the materials under various conditions of tension, compression *etc.* Mechanical properties of *Grewia optiva* fiber reinforced composites depend on the (i) nature of the matrix material and (ii) distribution and orientation of the reinforcing fibers (iii) the nature of the fiber–matrix interfaces and the interphase region.

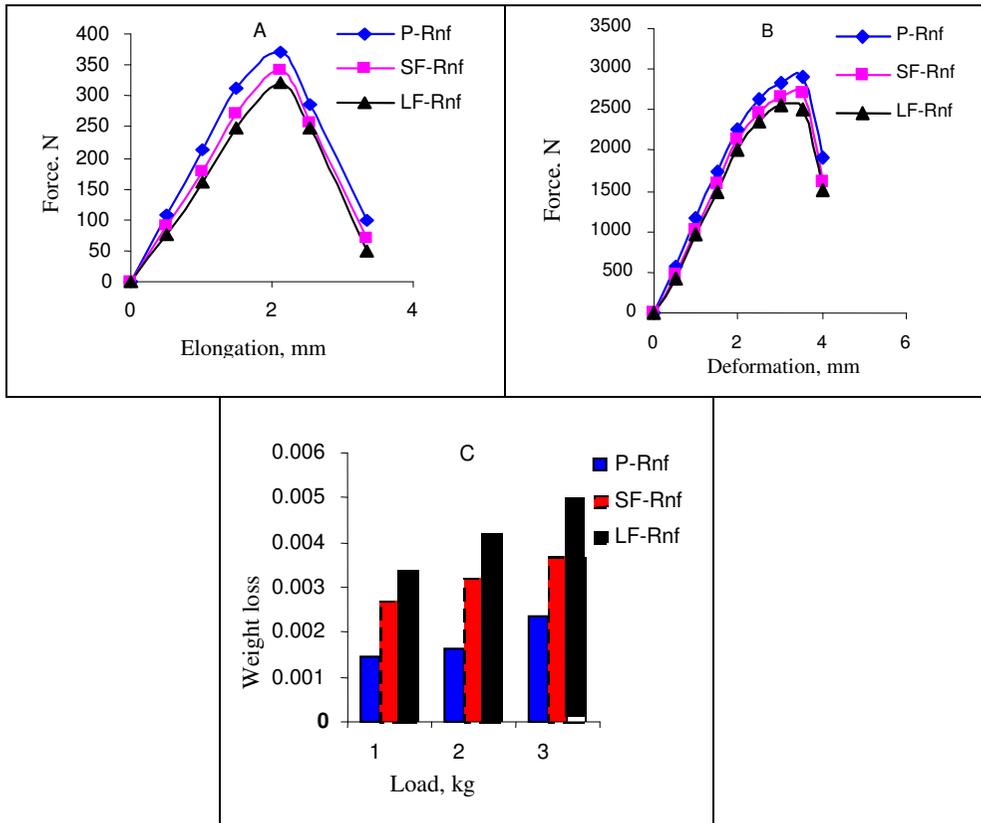
#### *Optimization of urea – formaldehyde resin*

Optimization of urea – formaldehyde resin has been done by evaluating optimal mechanical properties such as tensile strength, compressive strength and wear resistance *etc* as reported earlier<sup>3</sup>. It has been found that urea–formaldehyde resin in the ratio 1.0:2.5 exhibits optimum mechanical properties, so this ratio was taken for further preparation of polymer composites.

#### *Mechanical properties of Grewia optiva reinforced biocomposites*

Experimental results obtained through tensile test reveal that particle reinforced composites showed more tensile strength which was followed by short fiber and long fiber reinforced composites (Figure 1 A). It is clear from figure that the particle, short and long fiber reinforced polymer composite bears a load of 371.47, 341.0 and 321.1 N at an extension of 2.11, 2.18, 2.2 3 mm respectively. Compression test results also reveal that particle reinforced composites showed more compressive strength followed by short and long fiber reinforced composites (Figure 1B). It is clear from Figure 1B that the particle, short and long fiber reinforced polymer composite bears a load of 2893.5, 2753.0 and 2663.0 N at compression of 3.51 mm, 3.54 mm, 3.56 mm respectively. Further it is evident from Figure 1C that wear rate of UF matrix decreases appreciably after reinforcement with *Grewia optiva* fiber. It has been observed that particle reinforcement decreases the wear rate to a much more extent than short and long fiber reinforcements.

From these results it is clear that particle reinforcement is more effective than short and long fiber reinforcements. This may be due to larger surface area and more fiber/matrix interaction in case of particle reinforced composite as compared to short and long fiber reinforced composites. The chemical bonding accounts for the adhesion between amino resin (urea formaldehyde) and the natural fibrous material. The higher bond strength obtained for amino resin matrix is due to the possible reaction between the methylol groups of the resin with the hydroxyl group of cellulose.



**Figure 1.** Tensile/compressive and wear resistance curves (A-C) of *Grewia optiva* fiber reinforced polymer composites.

#### *Thermal and morphological analysis of UF resin and its biocomposites*

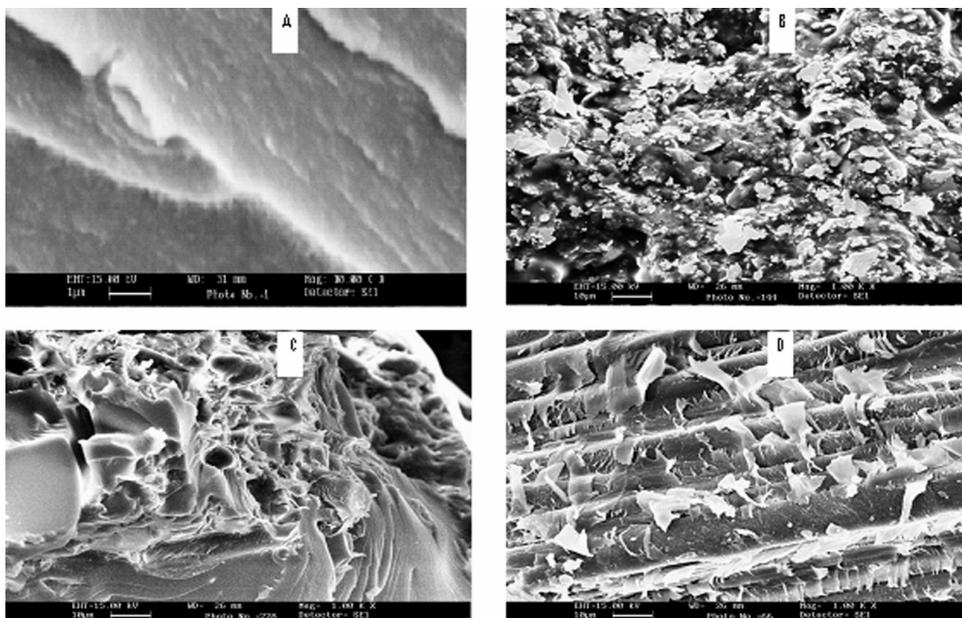
Thermogravimetric analysis (TGA) of materials such as raw *Grewia optiva* fiber, polymeric UF resin and biocomposites was investigated as a function of % weight loss with the increase in temperature. The initial decomposition (IDT) temperature and final decomposition temperature (FDT) of fiber, resin and biocomposite are presented in the Table 1. These studies are further supported by differential thermal analysis (DTA) (Table 2). These results are consistent with results reported earlier<sup>2</sup>. Morphological results obtained from SEM micrographs (Figure 2 A-D) clearly show that there is proper intimate mixing of fiber with the resin in the biocomposites synthesized. In case of particle reinforcement there is more intimate mixing as compared to short and long fiber reinforcement.

**Table 1.** Thermogravimetric analysis of UF, GO and P-Rnf-UF composites

S No.	Sample code	Exothermic/Endothermic peaks <sup>0</sup> C( $\mu$ V)
1.	GO	61 [-2.0]; 361 [-3.3]
2.	U-F Resin	179 [6.8]; 253 [5.7]; 271 [27.9]; 545 [9.4]; 725[-23.0]
3.	P-Rnf-UF	82 [-1.4]; 263[17]

**Table 2.** Differential thermal analysis of HS, UF and *P-Rnf-UF* composites

S. No.	Sample code	IDT, °C	% wt. loss	FDT, °C	% wt. loss	Final residue, %
1.	GO	200	7.25	501	87.44	12.66
2.	U-F Resin	238	22.48	993	87.51	12.49
3.	P-rmf-UF	234	20.51	815	83.33	16.37



**Figure 2.** SEM images of UF resin (A) and *Grewia optiva* fiber reinforced polymer composites (B-D).

### Conclusions

Mechanical properties of randomly oriented intimately mixed *Grewia optiva* fiber reinforced UF composites were investigated with special reference to the size of the fiber. In case of mechanical behaviour particle reinforcement of the UF resin has been found to be more effective as compared to short and long fiber reinforcement. The mechanical behaviour has been strongly supported by the SEM analysis. Finally, it can be concluded that by utilizing *Grewia optiva* fiber, we can prepare user friendly and cost effective composite materials possessing appropriate mechanical properties.

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