Fabrication and Characterisation of PP/TS Biocomposites

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Abstract. Biocomposites are eco-friendly composite materials formed by the combination of any polymer matrix and the reinforcement of any natural fiber. This particular composite is gaining more attention in research field in order to reduce the utilization of inorganic fillers in the reinforcement of thermoplastics and biodegradable plastics. In this study, we used various amounts of turmeric spent (TS) viz, 5%, 7%, 10%, 15%, 20% and 25% (w/w) for the fabrication of Polypropylene/TS composites. These various composition mixtures are blended and melt on a Haake mixer, then it is placed over a compression mould of 2mm thickness and forms composite films of different composition. The developed composites were characterized using different techniques such as scanning electron microscopy, contact angle measurement and water absorption. SEM images clearly shows the presence of TS content in biocomposites. From contact angle measurement, it is clear that the 7% PP/TS composite shows better hydrophobic nature. From absorption measurement technique, the higher composition samples show better absorption capacity due to the presence of OH- group within the turmeric spent.

1. Introduction
The shortage of petroleum based resources and various environmental issues have prompted many researchers to think about biodegradable resources in substitution of petroleum based products. The recycling of composites manufactured from petroleum based non renewable resources is complicated due to the tiring effort required for the separation of their components. Due to its non biodegradable properties, several environmental issues may cause due to landfills or burning. The biocomposites exhibit superior mechanical and thermal make it to utilize in different domains such as aerospace, military, automobile, construction, naval and packaging [1]. “Toyota Raum” is a Toyota launched model where the interior parts are made up of hemp fibers and a potato derived PLA with the reinforcement of
sugarcane bagasse was used in its manufacturing of springboard [1]. The biocomposites can be processed by utilizing many methods such as extrusion, thermoforming and injection moulding [2]. Many other automobile industries are investing huge amount in research and development for implementing green technology in their products. For the past several decades, scientific researches are conducting across the world on wide variety of natural fillers such as hemp, flax, kenaf, abaca, bagasse, banana etc. to reinforce this to various polymer matrices [3].

Here the polymer matrix intends to use is polypropylene (PP) and the natural filler is turmeric spent. PP have remarkable properties such as low density, high stiffness, heat resistance, good impact and stretchability [3,5]. The agro industrial waste Turmeric spent (TS) which is a byproduct of nutraceutical industry consists of soluble and insoluble dietary fibers [4]. It is more abundant, cheap, renewable and easily recycled.

The reinforced fiber PP composites shows better tensile and flexural properties compared to unreinforced PP [6,7]. PP/Banana yarn composites showed an increment of 294% in tensile strength and 72% increment in flexural strength when compared to unreinforced PP [5]. The Modulus/Cost and specific modulus of Kenaf (30% by weight) –PP composites are higher than different natural fibers such as flax, hemp, sisal, E-glass and coir [6].

The incorporation of various sizes of fillers in composite shows considerable change in mechanical properties The 3% addition of nano oil palm empty fruit fiber (OPEFB) filler into kenaf/epoxy composites reduces the presence of voids, fiber pull outs, fiber tearing and protruding on the fractured surface due to the interfacial bonding and good adhesion between fiber and matrix [8]. The addition of talc which is a hydrophobic mineral possessed stiff character to Low Density Polyethylene (LDPE) / Kenaf Core Fiber (KCF) biocomposites whereas the addition of calcium carbonate which is a hydrophilic mineral caused a tough behavior to the same biocomposites [7]. The hybrid polypropylene biocomposites with rice husk/ground nut husk wastes as fillers showed water absorption 85% lower than gypsum tiles which gives an advantage to use it as a ceiling tiles compared to gypsum tiles [9].

Recently, turmeric spent has attracted a great attention due to the increase in cellulose content after some chemical treatments. It has very little commercial value hence it can be utilized as reinforcing filler in engineering thermoplastics. The interest of using agro industrial waste has grown in recent years to promote sustainable agriculture and recycling. The specific gravity of this filler is very low and its incorporation in polymer matrix reduces the overall weight of composite and enhances their bulk property. The antimicrobial property of turmeric spent makes it possible to explore in new applications in automobile as well as in medical field.

The main objective of this work is the fabrication of a cheap thermoplastic biocomposite ie, PP/TS biocomposite and evaluation of morphological, chemical and hydrophobic properties for various applications in automobile as well as in medical field.

2. Experimental

2.1. Materials

In the present study Turmeric spent (TS) was procured from M/s. Sami Labs, India and the polymer matrix, polypropylene, REPOL H200MA obtained from M/s. Reliance Polymers, India. The density of PP was 0.92g/cc and its melt flow rate (230 °C/2.16 kg) was 35 g/10 min.

2.2. Methodology

Overnight dried TS in oven at 80°C was thoroughly mixed in different ratios of PP/TS (wt/wt, %) such as 95/5, 93/7, 90/10, 85/15, 80/20 and 75/25. Torque Rheometer (Thermo Haake Rheocord 600) was used to prepare all composites. And the mixture is placed in the Haake mixer in order to blend and melt the mixture. The Haake mixer is preheated for 10 minutes in order to attain the melting temperature of polypropylene that is about 180°C. Then fed the different composition in the machine and melt it and mix it for 10 minutes with a screw speed of 60rpm. The blended composite is placed in a 2mm mould in a compression moulding machine. Before placing the composite, the compression moulding machine
is preheated for 10 minutes along the mould inside the machine to achieve the melting temperature of polypropylene that is around 180°C. Then placed the composite over the mould and run the machine for 10 minutes and then cooled by water around the mould to the room temperature of 50°C to remove the prepared composite sheet from the mould. The three stages of moulding cycle were 2 min preheating, compression under a pressure of 120kg/cm² for 10 min, and cooling of mould by using water until it reached 50°C.

2.3. Measurements

2.3.1. Scanning Electron Microscopy. The structure of PP/TS composites obtained after compression moulding process was investigated using Scanning electron microscope (Vega3Tescan, Germany). Aluminium stubs were used to place the samples by using double sided carbon tape. 10kV was used as the accelerating voltage to examine the samples.

2.3.2. Contact angle analysis. The method adopted for contact angle analysis was sessile drop method and the instrument used was Phoenix-i model from Surface Electro Optics – SEO (Florida, EUA). The micrometric dozer was used to drop distilled water on the surface of specimen and by using an interval of 200s the images captured was analysed using a software. The measurement of contact angle was done programmatically by considering the angle between the tangent of the droplet edge and the base line where the drop lies.

2.3.3. Water absorption analysis. For water absorption analysis, the specimens were prepared according to ASTM D 570-99. Two samples of each composition in the disc shape of 50mm diameter and 2mm thickness was prepared for the analysis. These all samples were immersed in distilled water at room temperature and its change in weight was recorded at the end of 48h.

3. Results and Discussion

3.1 Scanning Electron Microscopy
SEM image of Neat PP (Fig. 1(a)) shows smooth and it is free from any contaminants. On the other hand, Fig. 1(b) to Fig. 1(g) shows the presence of turmeric spent filler as white dots and white lines. Between Fig. 1(b) and Fig. 1(c), it is visible that better dispersion in Fig. 1(c). When the content of TS was enough higher, the particles were uniformly distributed in the PP matrix. TS exhibited many single disperse particles and aggregates integrated with the particles. From, Fig.1 (d) to Fig. 1(g), it is clear that the PP matrix is not enough to encapsulate the solid micro particles of TS. However, large aggregates were found, and the aggregate size increased substantially in these micrographs with higher TS loading due to the hydrogen bonding between TS particles [10].

3.2 Contact angle analysis
In order to find the effect of TS in biocomposites, the contact angle of the calibrated water droplets deposited on the PP/TS biocomposites measured were evaluated. There was a change in polarity on the composite surfaces were observed by analysing the contact angle results. The higher contact angle specimens show the higher hydrophobic nature.

From Fig. 2(a) to Fig. 2(g), it is clear that there is a slight increase in contact angle of 7%TS/PP composite which is 84.780, it is due to the presence of TS content in composite. However, the composites having higher content of TS displaying lower contact angle is due to the agglomeration of TS on the surface of the composite.

3.3 Water absorption analysis
By using equation (1) the predicted water absorption (PWA) can be calculated.
PWA = \frac{(W_f - W_o)}{W_o} \times 100 \tag{1}

Where \( W_f \) = weight of specimen after immersing in distilled water in g,
\( W_o \) = weight of specimen before immersing in distilled water in g.

**Figure 1.** SEM images of (a) Neat PP, (b) 5\%TS/PP, (c) 7\%TS/PP, (d) 10\%TS/PP, (e) 15\%TS/PP, (f) 20\%TS/PP & (g) 25\%TS/PP
Fig. 3 shows the behaviour of composites in water absorption after 48h immersion in distilled water. From the results, it is clear that as the addition of TS to biocomposites increases, its water absorptivity increases. The overall hygroscopic nature and higher fiber content of TS makes it less enclosed structure leads to the increase in absorptivity. There is an enhancement of water pathways created by the TS from surface to core due to the increase in porosity leads to the easiness of water entrance to the core.

\[ \text{Figures. 2} \] Contact angle measurements of (a) Neat PP, (b) 5%TS/PP, (c) 7%TS/PP, (d) 10%TS/PP, (e) 15%TS/PP, (f) 20%TS/PP & (g) 25%TS/PP
Also there is some polarity interactions of TS fibers with the water due to the presence of hydroxyl groups in TS fiber. The water molecules are more chemically attractive to OH molecules from TS surface.

![Water absorption vs TS loading](image)

**Figure.3** Graph showing variation of water absorption % corresponding to wt% of TS

### 4. Conclusions

Biocomposites based on turmeric spent and polypropylene were melt blended in this work. It is clear from the contact angle measurement that higher the TS content in bicomposite leads to lower the contact angle due to the agglomeration of TS particles on the surface. The water absorptivity of higher composition increased due to the presence of more hydroxyl groups on the TS surface leads to provide more opened structure which favours the water entrance. The polarity effects also provided more easiness of water entrance from surface to core and which improve the interactions between matrix and fiber respectively.

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