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Synthesis and Characterization of PLA/Luffa Cylindrica Composite Films

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Abstract: In recent days, natural fibers have been replaced with synthetic fibers as an alternative material for the reinforcement in the polymer composites due to their renewability and sustainability. The aim of the present work is to study the performance of using natural fiber powder in the preparation of composite films. The fiber powder used in the present study is extracted from the Luffa cylindrica plant. Fourier Transform Infrared (FTIR) spectrum is utilized for the identification of functional groups in the fabricated composite film. Scanning Electron Microscopy (SEM) analysis is carried out to observe the bonding between matrix and reinforcement in the composite films. Thermal degradation behavior of the composite film is also studied by the Thermo-gravimetric Analysis (TGA). From the studies, it was observed that the natural fiber reinforced composite film were able to withstand higher temperatures. The fabricated composites films can be effectively used for different applications where there is a necessity of bio polymers.

Keywords: Luffa cylindrica, PLA, tensile properties, SEM, TGA, FTIR

1. Introduction

Worldwide progress of emerging environmental consciousness attracts the researchers working in the diversified field for the benefit of global needs. Accordingly, the thrust for developing new polymer systems and polymeric based materials with ecological advantage were found to be growing in the field of polymer science and technology. As a part of this, many works have been reported using polymer composites with the addition of natural fillers for the enhancement of matrix performance as well as environment friendliness. However, it is necessary to replace the synthetic polymers due to their characteristics like non-degradable nature and emission of harmful gases to ocean. By considering these aspects into account, many of the composite materials have been fabricated and studied using various bio-degradable matrix systems [1-4]. In this direction, researchers have worked on for the development of biodegradable polymer composite films for packaging and medical applications. Some of the developed biodegradable polymer composites include wheat protein isolate/Hildegardia populifolia natural fabric [5], soy protein isolate [6], polypropylene carbonate/short lingo celluloses fiber Hildegardia populifolia [7], Polylactic acid/Sterculia urens uniaxial natural fabric bio-composites etc [8,9].

Further, the research result from the waste management ideas were continuously motivated by the government approaches towards the decrease of green house impacts. In like manner, the section of biodegradable composite films using renewable resources is just toward the starting phase of research [10-13] and more data is required for proposing their utility towards the replacements for appropriate applications. In such Nawrath et al. [14] investigated the use of new yield plants with the synergistic impact of microbiology, polymer science and plant science on delivering

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significant non-sustenance items along these lines investigating the likelihood of finding financial development in agriculture, land filling and urban waste disposal. The disposal like sugar cane was utilized as reinforcement in poly vinyl alcohol (PVA) which displays great film development with moderate strength [15]. Among different naturally available matrices, PLA has extraordinary degradability and decreased green house impact and found to be contributing extensively in adhesive industries [16-17]. To work on these, a portion of the analysts have built up the composites utilizing PLA as matrix and generally available wastes like Egg shell Powder [18] and Spent Tea Leaf Powder [19] as particulate fillers and they have demonstrated the improvement in properties of PLA matrix. Gonen *et al.* [20] reported that SEM micrographs of fractured specimen of tensile test exhibited finer fracture and fiber pull-out which were the central parameters of the fracture mechanism during tensile testing of the developed composite. However, the experimentation methodology should be embraced with novel support for the upgrade of properties as for modern scale. Tikka beera (plant name: Luffa cylindrica) is generally utilized as an added substance in the sustenance plan. In addition, a lot of Luffa cylindrica fibre wastes are available with the farmer lands; these are collected and converted into powder form that can be used in the PLA. Further, the Luffa Cylindrica can lead to several applications in food and pharmaceutical industries which are evident in the published papers. There are few works based on these fibers, and suggested suitable applications based on the obtained mechanical properties of the composite materials [21-23].

However, the utilization of this agro waste, Luffa cylindrica filler in the field of particulate composite technology is not explored well. Hence, this article focuses on the possibilities of using the Luffa cylindrica as reinforcing filler in PLA matrix.

2. Materials and method

Accordingly, the PLA/Luffa Cylindrica composite films were fabricated with varying wt% of Luffa cylindrica filler content. Thereafter, the fabricated PLA/Luffa Cylindrica composites were subjected to various characterization studies such as Scanning Electron Microscopy (SEM), Fourier Transform Infrared (FTIR) spectroscopy, Thermo-gravimetric Analysis (TGA) and tensile tests to expand the positive characteristics of the Luffa Cyndrica for wider applications.

2.1 Matrix and Reinforcing Filler

PLA was supplied by Nature Tech INDIA in the form of granules. The luffa cylindrica fibres were collected from the Pesaravai village of Kurnool district in Andhra Pradesh state INDIA, these fibres were dried under sun light and then the fibres were crushed through a shear mixture until the fine powder is obtained. The fine powder was dried in oven at a temperature of 80^{o}C to remove the moisture content. Using the sieve, the particle size of Luffa cylindrica powder was measured as 20 μm, which was used in the present work.

2.2 Fabrication of Composite Films

Initially, the PLA granules were converted into PLA solution with the help of chloroform. The sieved Luffa cylindrica powder was mixed with PLA solution and rigorously mixed with stirrer. The PLA/Luffa cylindrica solution was spread over the petri dishes to acquire uniform thickness. After 24 hours, the dried films were separated from the dishes and used for further testing.

3. Results and Discussion

3.1 Tensile tests

The specimens for tensile test were prepared according to ASTM D882-02 and tested on Instron 3369 universal testing machine with a cross head speed of 10 mm/min. During tensile testing, the elongation of any material before break is another important characteristic revealing the information about the brittle/ductile behaviour of that material. A total of 4 specimens with varying compositions were tested and is shown in Fig.1. From Fig.1, it was observed that the tensile strength of the film increased with the reinforcement percent increment but it was also noted that the elongation of the film is decreased as the reinforcement content growth. From this, it was noted that the improvement of the reinforcement leads to brittleness and vice-versa.

3.2 Morphological analysis

After tensile testing, the interface of the films was observed using scanning electron microscopy (SEM). Morphology of PLA/Luffa cylindrica interface of the developed composite films was examined by SEM. As these are polymeric based specimens, to improve the conductivity of these specimens of polymer composites, gold sputtering was coated over it to record the bonding nature of the films. The SEM micrographs

exhibit the appearance of matrix breakage and voids at the fracture surface of composite films. Surface characteristics of natural fiber are the major governing factor in deciding the level of adhesion between natural fiber and polymer matrix [24-25]. The surface of natural fibers is clean, non-oily and hence relatively dry and rougher, for that better adhesion level with the polymer matrix is observed from Figure 2b. Improvement in tensile strength of this thermo-set polymer is due to this reason only, this has already been reported by several studies and the governing mechanism of failure has been reported through SEM images. Figure 2a and 3a reveals the poor bonding of the matrix and reinforcement such that reinforcement has poor wettability with matrix which leads to improper interfacial adhesion between fiber-matrix and reduces fiber pull-out, fiber fracture and debonding between fiber and matrix

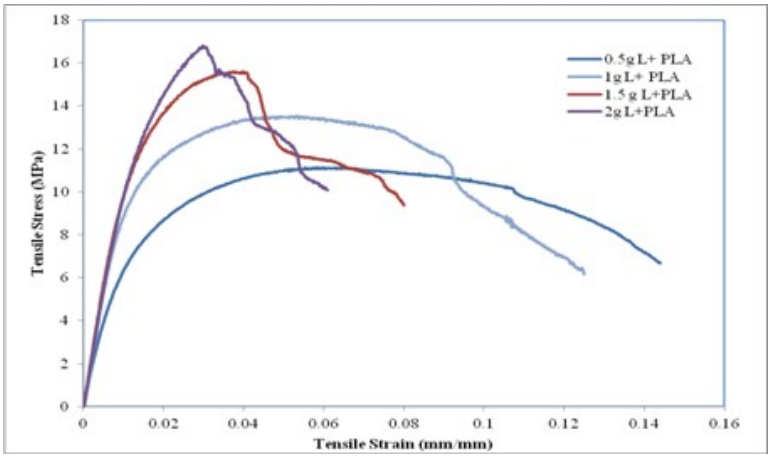

Figure 1 - Tensile strength of the composite films with varying natural fiber powder loading

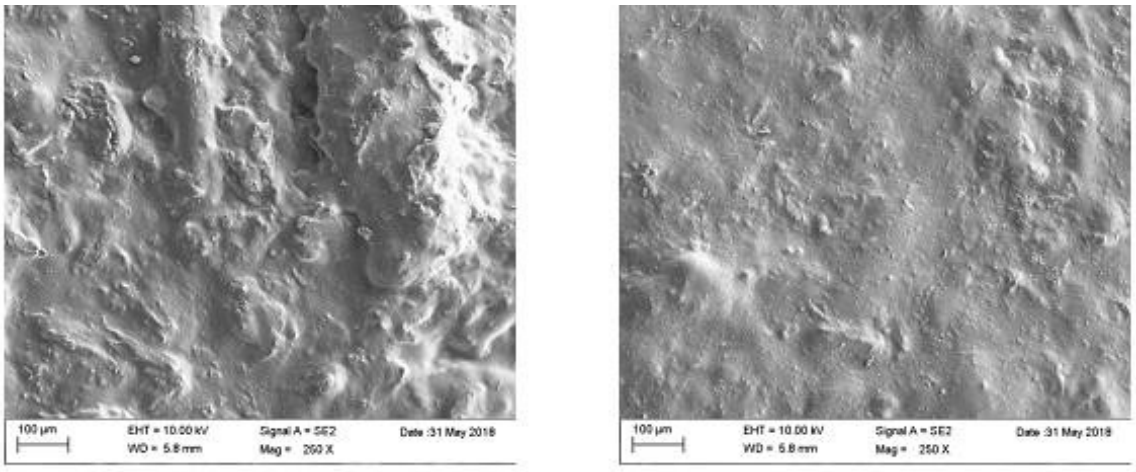

Figure 2 - a. SEM image of 0.5 gms luffa cylindrical reinforced composite b. SEM image of 2 gms luffa cylindrical reinforced composite.

3.3 FTIR analysis

The functional groups present in the fabricated PLA/Luffa cylindrica composite film were identified by Fourier Transform Infrared Spectroscopy as shown in Figure 4. The presence of –OH groups which is the characteristic feature of any natural fiber, can be observed from the peak regions between 3860 cm^{-1} to 3250 cm^{-1}. The broad peak observed at 3510 cm^{-1} which claims the hydrogen and hydroxyl groups of α-cellulose released from the composite film. Next, the presence of C-H region (self absorption peaks) in the composite film was observed from the sharp edged peak at 2424 cm^{-1} and 2352 cm^{-1} which claims the presence of cellulose, lignin, hemi cellulose and other minor extracts. Presence of CN stretching regions were observed with minute protrusions in the range of 1833 cm^{-1} which claims the presence of wax in the composite film. Blunt peak at 1520 cm^{-1} reveals the presence of C=O (carbonyls) in addition with cellulose and hemi cellulose, which is very common in any natural fiber composites. Moreover, a tiny protrusion was found at 1100 cm^{-1} that is because of C-O bond stretching, C=C, C-C-O vibrations of cellulose and

hemi-cellulose in the natural fiber composite film. Finally, glucose bond can be observed between 700 cm^{-1} and 500 cm^{-1} with small protrusions, which are non-symmetric confirming the presence of ß glycosidic linkages between the mono-saccharides.

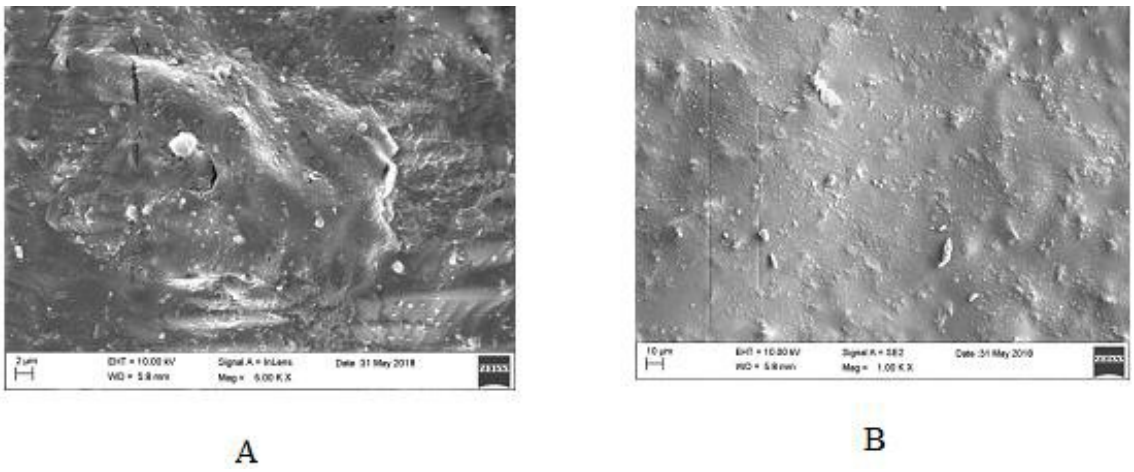

Figure 3 - a. SEM image of 0.5 gms luffa cylindrical reinforced composite at 2 µm b. SEM image of 2 gms luffa cylindrical reinforced composite at 10 µm

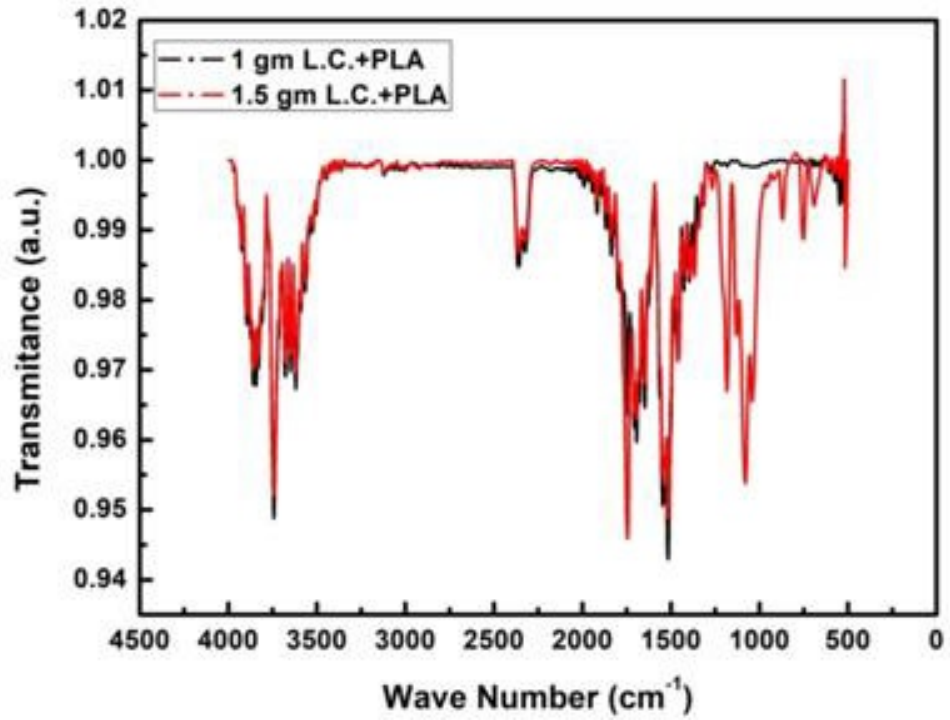

Figure 4 - FTIR graphs of both 1 gm and 1.5 gm luffa cylindrica reinforced composite films

3.4 TGA Analysis

Thermal degradation behaviour of the fabricated natural fiber composite film is studied by Thermo Gravimetric Analysis (TGA) for two different weight proportions as shown in Figure 5 & 6. The analysis was carried out to find the thermal stability against temperature ranges, which causes the sample to contract or expand such that the moisture absorption make the sample to swell and alter its mechanical performance. From the Figures 5 and 6, about 60% of the thermal decay took place in the temperature region around 210°C and 320°C. The thermal degradation took place in two stages as is observed from the figures 5 & 6. The initial weight loss due to the evaporation of water content and other volatile extracts in the fibers occurred at 118°C. The hydrophilic nature of the fibers was lost at this temperature. Later, the release of hemi cellulose and devolatization of cellulose was initiated at 220°C, such that the mass loss of

the sample takes place at around 250ºC. From the figures it can be clearly observed that the initiation of mass loss of fiber was started at 223ºC and the final loss took place at around 320ºC. The point where the final loss takes place is due to the breakage of bonds and cellulose chains [26-28]. The final breakage of lignin took place at a temperature of 339ºC and finally wt% of about 3.1 residues is left over after heating the sample to 800ºC.

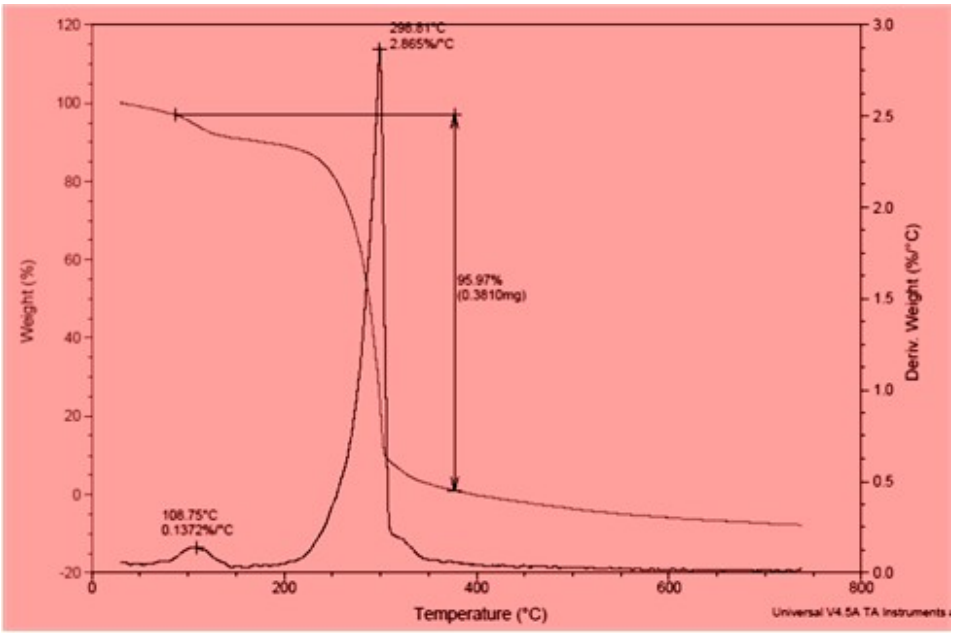

Figure 5 - TGA graph of 2 gram Luffa cylindrical reinforced composite film

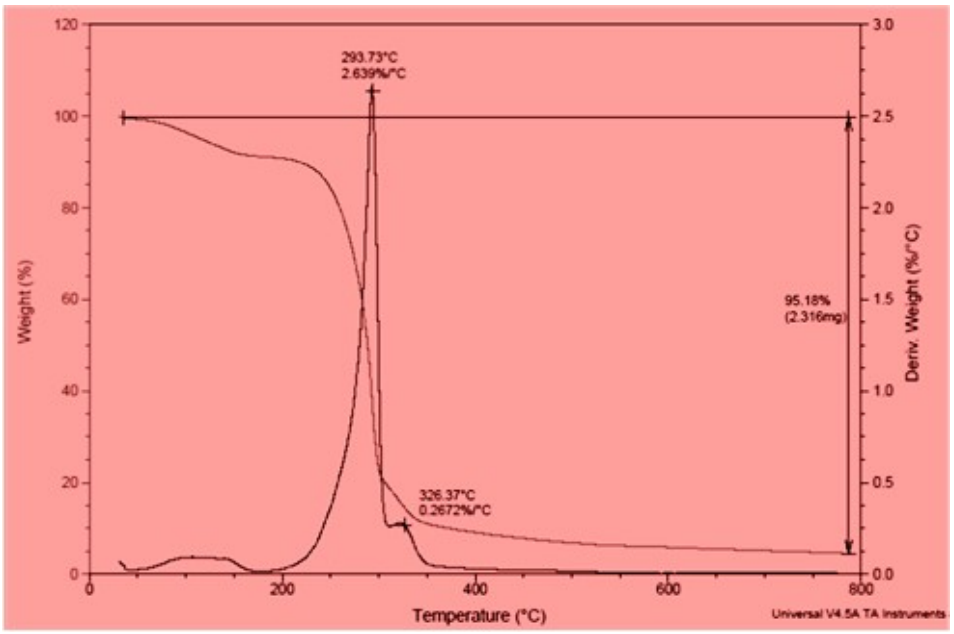

Figure 6 - TGA graph of 1 gram Luffa cylindrical reinforced composite film

4. Conclusions

Luffa cylindrica reinforced composites films were fabricated successfully without any defects. The composites films were studied for the mechanical, morphological and thermal characteristics of these fabricated composite films. The following conclusions were drawn from the present study:

1. Morphological studies revealed better bonding with the matrix and reinforcement such that higher tensile strength was obtained.

2. Tensile strength of the composite films increased with increase in reinforcement content but decrement in elongation was observed such that an optimal percent of reinforcement is suggested for the preparation of composite film was suggested.
3. FTIR studies of the composite film represented the presence of crucial biopolymer like cellulose, hemicelluloses and lignin content in the utilized natural fiber powder.

The thermal stability and degradation is as similar as of the other natural fiber reinforced composite film such that luffa cylindrica can be used as reinforcement in the composite film.

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