Investigation of Tensile strength and Water absorption properties of natural composites with Poly lactic acid

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Abstract- Polylactic Acid (PLA) is a completely biodegradable potential replacement of plastics used in the structural applications due to its enhanced load-bearing capabilities. Mostly, the mechanical properties of the natural fiber reinforced hybrid composites are better than the single fiber reinforced composites and almost equal to the synthetic fiber composites. This paper presents the extraction and preparation methodology of the polylactic acid (PLA) composites using the naturally available fibers like snake grass and elephant grass fibers. Natural fiber composite materials are one such capable material which replaces the conventional and synthetic materials for the practical applications where we require less weight and energy conservation. Snake grass fiber and elephant grass fiber composites have the maximum tensile and water absorption properties when compared with other fiber composites. The result shows that the snake grass fiber and elephant grass composites have the maximum tensile and water absorption properties of natural composites with polylactic acid.

Keywords- Natural composites, Polylactic acid, Snake grass fiber, Elephant grass fiber

I. INTRODUCTION

The use of natural fibers as reinforcement in composites has considerably increased during recent decades. Even though there is a very large verity of fibers, matrices and manufacturing techniques used to produce natural fiber composites. TP Sathishkumar, [1] they were said about the natural fibers such as sisal, coir, banana, vakka, date, bamboo, elephant grass, flax, hemp, jute, abaca, pineapple, sanasevieria trifasciata and husk fiber are the widely used fibers for preparing the composites. These natural fibers composites are now a days widely used instead of synthetic fibers due to their advantages like bio degradability, low light, low cost and high specific mechanical procondentperties. Synthetic fiber composites have far better mechanical properties then natural fiber composites but since they are highly expansive, they are justified only for aircraft and military applications. H.Anuar [2] Studies about the Polylactic Acid (or) PLA is a linear aliphatic thermoplastic polyester produced through ring opening polymerization (or) poly condensation of lactic acid monomer which can be obtained from fermentation of renewable resources such as corn, sugar, beet, wheat, sugarcane or any starch-rich source material. PLA is fully renewable, compassable and bio degradable material. The bio plastics are capable to undergoing decomposition at the end of biodegradation process, carbon dioxide, methane, water, inorganic compounds or biomass products. In a nutshell, PLA is a cradle-to-grade material. PLA offers several advantages associated to mechanical, thermal and bio degradable properties and as such, it is suitable for wide range of applications. J. P. Mofokeng, [3] this was explained as being due to the incompatibility between the fibers and the matrix, which promoted micro crack formation at the interface as well as no uniform stress transfer due to fiber agglomeration in the matrix. Reports also indicated an increase in the thermal stability of the PLA in the presence of Fibers. Rafael A. Auras [4] gives the properties of PLA such as glass transition temperature (Tg) of PLA ranges from 50 to 80C while the melting temperature (Tm) ranges from 130 to 180C. K. Murali Mohan Rao, [5] it is explained the extraction process of Elephant grass fiber and properties of elephant grass fiber. The tensile strength and the modulus of chemically extracted elephant grass fiber composites have increased by approximately 1.45 times to those of elephant grass fiber composite extracted by retting process. Kovier. K [6] researchers have reported the tensile properties of elephant grass fibers in literature. K. Ramanaiah [7] Information is available on thermo physical properties of natural fiber reinforced composites over and above room temperature. TP. Sathish Kumar [8] explains the extraction of snake grass fibers by simple manual water treatment process. The experimental tensile and flexural strength results were compared with the Hirsch theoretical method. B. Vijaya Ramnath [9] gives the details about the preparation of composites and matrix mixture ratio. C. Thiruvasagam [10] deals with the fabrication and investigation of hybrid natural fiber composites and compares it with other normal natural fiber composites like fiber and jute as reinforcements used separately. Mechanical characterization of the natural composite is obtained by testing the composite lamina for tensile, flexural, shear, and impact strength. Herrera-Franco and Valadez-Gonzalez [11] concluded that the stress distribution between the fibers and matrix for a short discontinuous fiber were better than the continuous fibers. The importance of the short fiber composites was also discussed. Rigoberto et al. [12] investigated the significance of the natural fiber composites by making it as a housing panel. Random orientation technique was adopted to archive the isotropic behavior of the nature fiber reinforced composites. Sergio et al. [13] suggested that the different interior and exterior components of the automobiles can be replaced with the help of natural fiber reinforced composites. M. Boobalan [14] study is to investigate and compare the mechanical and thermal properties of natural fiber composites and preparation composites at various ratios then incorporate with the molding techniques to form composites. VS Sreenevasan [15] [16] work described the tensile, flexural and impact properties of randomly oriented short Snake grass fiber composites. Composites were fabricated using raw Snake grass fibers (SG) with varying fiber lengths and weight percent's of fiber and also analyzed the microstructural, physic-chemical and mechanical properties of SCFs. Chen and Sun [17] investigated the impact responses of the composite laminates with and without initial stresses using the finite element method. The deflections produced are small for simple cases and simple material architecture. Whereas, the deflections produced are complicated when complex architectures are considered. Finite element analysis is an important tool which is used to assess the strength of a natural composite. The finite element model was used to simulate the performance of the woven composites under different loading conditions [18] and the failures under combined tension and bending loading were studied. It was found that the failure occurred near the fixture where the composite was subjected to maximum bending. K. Murali Mohan Rao [19] this study is carried out the composites are tested for tensile, flexural and dielectric properties and compared with those of established composites like made under the laboratory conditions. N.Venkateshwaran [20] determined tensile, flexural, impact and water absorption behaviors of fiber composites were carried out by optimum fiber length and weight percentage. Kasama and Nitina [21] studied the effect of glass fiber hybridization on properties of sisal fiber–polypropylene composites. Incorporation of glass fiber increases the mechanical, thermal and water resistance properties.

Recent studies in respect to mechanical behavior of reinforcement fibers in composites show that these materials can present structural and non-structural applications. The synergetic characteristics of composite materials depend on the initial characteristics of the reinforcement or the matrix [22]. The compression and injection molding processes were performed in order to evaluate the better mixer method for fiber and matrix. The samples (composite plates) were cut and submitted to mechanical tests in order to measure flexural and tensile properties [23]. The overall objective of this work is to extract the SG/EG fibers by retting and mechanical procedures and incorporating them into PLA matrix to prepare the composites at various volume fractions of fiber. The resulting composites were tested and characterized to evaluate the tensile and water absorption properties.

II. MATERIALS

A. Natural Fibers

A natural fibers is a nature abounds in fibrous materials, especially cellulosic types such as cotton, wood, grains and straw used for textile products or other industrial purposes. Apart from economic considerations, the usefulness of a fiber for commercial purposes is determined by such properties as length, strength, pliability, elasticity, abrasion resistance, absorbency, and various surface properties. Natural fibers are classified into two types, as plant (vegetable) fibers and animal fibers. Plant fibers namely cotton, flax, hemp, abaca, sisal, jute, kenaf, bamboo and coconut are widely used. They are preferred mostly since they are eco-friendly, and also available in less cost.

1. Elephant grass fiber

Elephant grass (Scientific name: Pennisetum purpureum) is a tall grass that originally came from Africa in 1913. It grows in dense clumps along lake and riverbeds up to 3 m height, where soil is rich. It is yellowish in color, the stems are about 25 mm. Extracted EG is shown in Fig. 1(a).

2. Snake grass fiber

The SG fiber is a newly identified fiber from the southern part of the India and this fiber is extracted by simple water retting process. The Properties of Snake grass fiber is shown in Table 1. The lignin, pectin and micro fiber angle plays an important role in the mechanical properties of this fiber and composites. The extracted elephant grass fiber is shown in fig. 1(b). In this, micro fibril angle of SG is lower than the other fiber. The fiber and matrix adhesion is also determined by the lignin content in the fibers. The lignin content for the SG fiber is low when compared with the other fibers.

Table 1: Properties of Elephant Grass and Snake Grass Fiber

Fibers	Density (kg/m^3)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elongation %
Snake Grass	887	287-545	9.7	2.87
Elephant Grass	817.53	185-327	7.4	3.23

B. Polylactic acid

Poly(lactic acid) or polylactic acid or polylactide (PLA) is a biodegradable and bioactive thermoplastic aliphatic polyester derived from renewable resources, such as corn starch (in the United States and Canada), tapioca roots, chips or starch (mostly in Asia), or sugarcane (in the rest of the world). In 2010, PLA had the second highest consumption volume of any bio plastic of the world. The properties of PLA is given in Table 2. The name "polylactic acid" does not comply with IUPAC standard nomenclature, and is potentially ambiguous or confusing, because PLA is not a polylacid (polyelectrolyte), but rather a polyester. The pelletized PLA is shown in Fig. 1(c).

Table 2: Mechanical properties of Polylactic acid (PLA)

Material	Density (g/cm^3)	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elong. %	Melting Point (°C)

PLA	1.9	50	3.5	6	160

a. Extracted EG

b. Extracted SG

c. PLA granules

Fig. 1: Materials

III. Preparation of composites

Table 3: The formulation of composites prepared

Composition	PLA	Fiber
1	90	10
2	85	15
3	80	20
4	75	25
5	70	30
6	100	-

The PLA 3051D is the pellet form was manufactured by Nature Works. The Elephant grass fiber was supplied by Natural Fiber Industries, Salem. Fibers were measured and the average diameter and length were calculated to get the fiber aspect ratio (length-to-diameter, l/d). Fibers were cut by the 3mm average length for preparing composites. PLA and SG/ EG fibers have been dried in a vented oven at 130°C for 5 h prior to use. Fibers has been varied from 10 to 30 wt. %. Table 3 gives the formulation of the composites prepared in this study. PLA and SG/ EG fibers have been manually mixed and then extruded using Brabender Plasti- Corder type 814402 screw extruder. Temperature was maintained between 180 and 190°C in all four zones. The pelletized PLA– SG/ EG bio composite was allowed for recrystallization at 120°C for 1/2 h. The bio composites were then injection molded using TEXWIN All-rounder 320C 600-250 (25mm screw diameter) injection molding machine. Processing temperature of injection molding was in the range 165–190°C. Various specimens have been prepared at 250mm x 25mm x 3mm (Length x Breath x width) for tensile and water absorption testing.

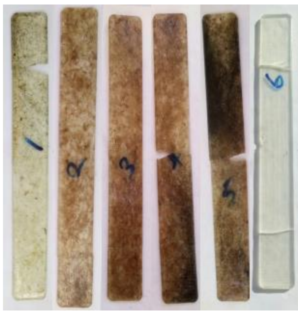
IV. Testing of composites

A. *Tensile test*

Tensile properties such as tensile strength, tensile modulus, and tensile load break point in elongation are measured based on the ASTM D3039 standards. The size of specimen is machined a standard size of 250mm x 25mm x 3mm.The schematic diagram of tensile test specimen is shown in fig. 2(a). The test was carried out using a kalpak universal testing machine. It has the specification of KIC 2-1000-C maximum capacity 100KN. The different types of specimens are prepared based on fibers used snake grass fiber and elephant grass fiber (hybrid composites). The results are standardized based on the six identical test specimens.

B. *Water absorption test*

Water absorption is evaluated in terms of weight increase the composite specimen immersed in water at 48 hours in room temperature as per freshly cut samples of dimension 20mm x 20mm x 3mm used for measure of water absorption. The tested specimens are shown in fig. 2(b).



a. Tensile test

b. Watr absorpsion test

Fig. 2: Tested specimens

V. Result and discussion

A. *Tensile properties*

The stress–strain behavior of PLA composites at varying fiber weight percent's is shown in Fig. 3. It was found that the stress–strain curve of cured pure PLA is similar to that of brittle materials. The behavior is elastic in nature. However, the addition of fibers makes the matrix ductile, which is evident from the high elongation at break value of composites. It is also evident that for any given strain level, the stress increased with fiber weight percent up to 30% and then decreased, indicating an optimum fiber weight percent of 30% for PLA composites. The influence of the fiber weight percent on the tensile properties of PLA composites is shown from

Fig.3 and Fig. 4. The tensile strength and elongation of fiber composites were found to increase with increasing fiber weight up to 30%, and then a decrease was found at higher fiber weight percent's. The tensile strength were found to increase with increasing fiber weight up to 30% when compared with pure PLA. The percentage elongation at break was very low in the cured pure PLA. The brittle nature of PLA is decreased with the addition of fibers. Therefore, the elongation value increased with fiber weight percent.

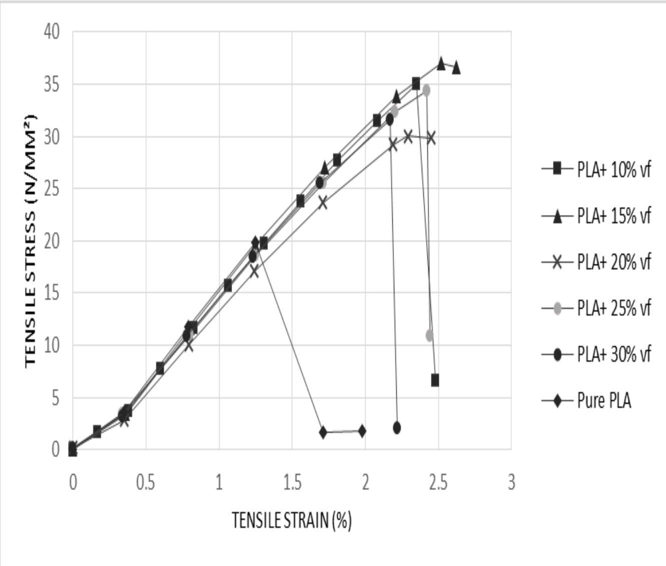
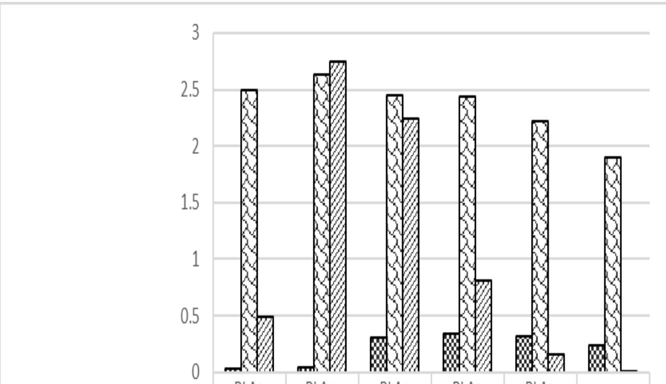


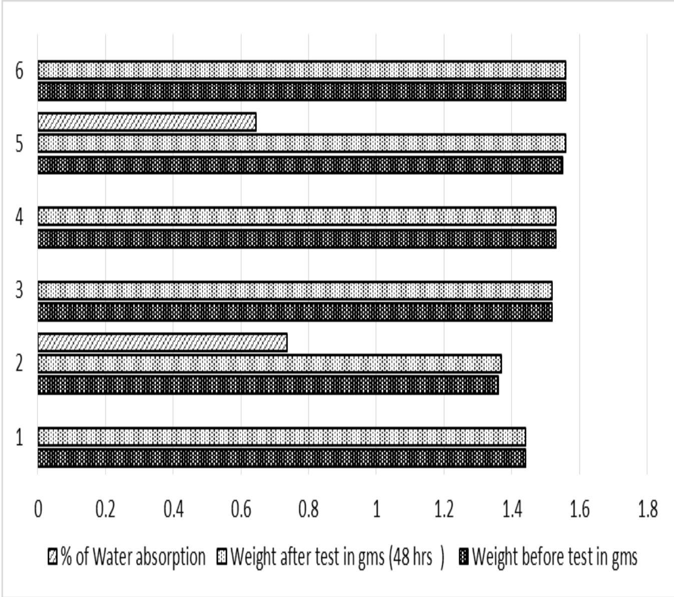
Fig. 3: Stress–strain behavior of PLA composites at different fiber weight percent's



	PLA+ 10%Vf	PLA+ 15%Vf	PLA+ 20%Vf	PLA+ 25%Vf	PLA+ 30%Vf	Pure PLA
Tensile Strength (KN/mm²)	0.03616	0.037612	0.30606	0.34531	0.31706	0.23642
Elongation (%)	2.49	2.63	2.45	2.44	2.22	1.9
Break Load (KN)	0.491	2.752	2.238	0.813	0.156	0.001

Fig. 4: Comparison of tensile properties of PLA composites at various fiber weight percent's

The comparison of tensile properties were tensile strength, elongation and break load that shown in fig. 4. The break load get highest value in the 15% of vf and then decreases up to 30% of vf. The pure PLA has lowest value of break load. It shows the fiber increases breaking strength of the composites. There is PLA with 15% vf has highest tensile strength and elongation value on composites.



B. *Water absorbtion Properties*

The water absorption behavior of all five specimens was determined in terms of weight increase for composite specimen immersed in water at 23°C as per ASTM D 570. The increase in weight percent were compared in the Fig. 5.

Fig. 5: Comparison of water absorbsion properties of fiber composites

VI. CONCLUSION

Bio composite made of PLA reinforced with SG/EG fiber has been successfully fabricated by extrusion and injection molding processes. PLA–SG/EG bio composite has the potential as an ecologically beneficial alternative to natural reinforced composites with petroleum-based matrices in the future. Fibers has proven to be a good reinforcement for PLA by enhancing the tensile strength, tensile modulus, flexural strength, flexural modulus, impact strength and water absorption properties.

- The result indicate that the snake grass and elephant composite material shows maximum tensile strength up to 345.31 N/mm^2 in 25% vf.

This is evidently seen in testing results where there was interaction between SG/EG and PLA matrix. Furthermore, PLA fiber bio composite produced have high specific strength and specific modulus. The experimental value of tensile strength and tensile modulus offers synergistic balance in terms of weight and properties of PLA– fiber bio composite. However, in order for PLA–fiber composite to be viable commercially, improvement in impact properties is vitally imperative as well as biodegradability and composability of PLA- SG/EG bio composite should also be investigated.

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