Evaluation of Mechanical Properties of Green Composite based on Walnut Shell and Poly (lactic acid)

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Abstract- **The goal of this work is to evaluate the technical feasibility of Walnut shell in Poly(lactic acid) as a substitute for wood in wood and poly(lactic acid) composite. The effect of walnut on mechanical properties were evaluated. The effect of coupling agent (maleic anhydride) on this composite were also investigated. The compounding was done by Specifiq co rotating twin screw extruder and samples were prepared by using Toshiba injection molding machine. On 10% incorporation of walnut in poly(lactic acid) improves flexural property by 540% and tensile properties by 102%. It also reduces the cost of PLA to 90%. The walnut successfully acts as a filler in PLA and can be used for further application.**

Index Terms— Maleic Anhydride, Mechanical Properties, Poly(lactic acid), Walnut Shell Flour.

INTRODUCTION

Biocomposite materials are composite materials formed by combining natural filler with fossil fuel-based polymer (e.g., polypropylene and polyethylene) or biopolymer (e.g., polylactic acid). But, biocomposites which are made from fossil fuel are not fully biodegradable because only natural filler will degrade and polymer matrix will remain in environment and polluting it. Hence, the objective of current researches on polymer biocomposites to prepare new biocomposites which are fully biodegradable called “green” biocomposites which have natural filler with a biopolymer matrix. These “green composites” can be used in products with short life Cycles, in products used indoors or for nondurable applications; for e.g.: cutlery, packaging trays, in portable electronic device housings, food containers and for disposable utensils.

Polylactic acid (PLA) is a first melt processable biopolymer which is produced by polymerizing monomers obtained by agricultural products like corn, sugar beet and sugar cane. Due to its ease in processing than other bio-based polymers, PLA is possibly the best solution to polymer waste management issue because it degrades in soil (an enzymatic environment) after spending a period. PLA exhibits good thermal stability, processability and mechanical properties for film-blowing, injection moulding and extrusion. However, due its higher cost than other conventional polymers, it is difficult for application. But, PLA biocomposites can be provide a mean to produce inexpensive PLA-based materials having different properties. By blending PLA with a, renewable, fully biodegradable and low-cost natural filler, such as coconut shells, peanut hulks, rice husks, palm kernel shells, and walnut shells.

Walnut is the one of the most favourable crops in the world with having 3.7 million tonnes of total worldwide production in 2016. 48% of this production is only produced in China. Walnut shells are agricultural co-product which are behave like hard wood due to the lignocelluloses present in these shells which are tougher than wood. For a long time, walnut shells had little or no economic value and their disposal was not only costly but caused environmental issues. However, nowadays, walnut shells can be processed into walnut shell powder (CSP), which is used to produce cooking oil, hair and skin treatments, in production of medicines and as a lignocellulosic filler in polymer composites.

Lignocellulosic fillers give some excellent properties than mineral fillers like talc, calcium carbonate, mica, and kaolin, they are renewable, inexpensive, have a high specific strength to weight ratio, are less abrasive to processing machinery, present a minimal health hazard, have a low density, and are fully biodegradable. But, due to the presence of highly polarized hydroxyl groups on surfaces of these lignocellulosic fillers, creates problem to achieve strong interfacial bonding with non-polar polymer matrix, as hydrogen bonds tends to hinder the wetting of the filler surfaces. As a result, lignocellulosic fillers show poor mechanical properties in polymer composites due to weak interfacial adhesion. Interfacial adhesion between the filler and matrix can, however, be improved by adding a coupling agent in the composite. Silane based coupling agents or maleic anhydride successfully performed this job.

Currently, the literature on PLA based biocomposites describes feasibility of different natural fibres like coconut shell and other fibres. But no one works on feasibility of walnut shell powder in PLA matrix. Thus, the research presented in the present paper was done in order to evaluate the potential use of walnut shell powder as a filler in PLA biocomposites. In this work, we investigated the effects of WSP filler content and treatment with maleic anhydride coupling agent on the mechanical properties of PLA/WSP biocomposites.

EXPERIMENTAL

Materials

Poly(lactic acid) (PLA)

PLA of injection grade was purchased from Natur Tec India Pvt. Ltd., Chennai, having MFI 14 and glass transition temperature and melt temperature 50-60°C and 145-160°C respectively.

Walnut Shell Powder (WSP)

WSP of 200 mesh was purchased from Chem Master Laboratories, Indore. Prior to use, WSP were dried in an oven at 80°C for 24 hrs to obtained moisture content around 1 to 3%.

Maleic Anhydride (MA)

Maleic Anhydride was purchased from Bionic Enterprises, Lucknow. Prior to use, it was converted into powder form for proper mixing.

Method

Sample Preparation

The composite formulations and their weight used for sample preparation are given in table 1. Before compounding, PLA and WSF was preheated at 80°C for 24 hrs to remove additional moisture. The PLA, WSP and MA were mixed in a mixer before being extruded. Compounding was done by Specifiq Engineering co-rotating twin screw extruder. PLA and WSP were melt blended in extruder at temperature 170°C, 175°C, 180°C, 185°C, 190°C and 192°C in different heating zones, respectively at 140 rpm. After melt blending, the materials were leaved to cool at room temperatures and then converted into pellets from pelletizer machine attached to the extruder.

The pelleted samples were dried in an oven at 80°C for 6 hrs, prior to the injection molding machine. Finally, composite specimens for tensile and flexural strength according to ASTM D638 were prepared by using Toshiba Injection Molding machine at melting

temperature of 160, a molding temperature of 40°C, injection pressure 12MPa and cooling time of 20s.

Table 1: Formulation of composites (in grams)

Sample Code	PLA	WSP	MA
1	100	00	00
2	900	100	00
3	870	100	30

Characterization

Tensile and Flexural Test

Flexural and tensile test were carried out in Universal testing machine, according to ASTM D790-10 and ASTM D638-10, respectively. The tensile properties of composites were calculated at room temperature with crosshead speed of 5mm/min to obtain elasticity modulus and tensile strength. The flexural modulus and strength were calculated with a three-point bending geometry according to ASTM D790-10 at 2mm/min crosshead speed and a load cell of 1 KN.

Results and Discussion

Tensile Strength

Effect of addition of WSF and MA in PLA matrix on tensile properties are shown in table 2,3 and 4. Tensile strength of PLA was increased by adding walnut shell powder in it, but decrease when maleic anhydride was also added, which shows that maleic anhydride negatively affects the properties of composites does not work as a coupling agent.

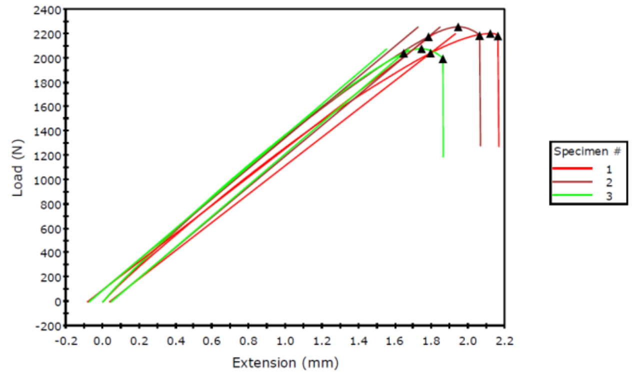

Figure 1: Stress- strain dia. of samples

From table 2, it is clear that the load bearing capacity of WSP/PLA composite is 2% more than PLA. But when maleic anhydride is added in the composite, capacity decreases to 94% which shows negative impact of MA on the composite. Tensile strength of WSP/PLA is

increased by 2% and WSF/PLA/MA decreases to 94% on maximum load. As the loading of WSP and MA in PLA increases, elongation reduces.

Table 2: Tensile Properties of Composites at maximum load

Sample Code	Maximum load (N)	Tensile Strength (MPa)	Elongation (%)
1	2,199.46	49.76	3.54
2	2,254.42	51.00	3.24
3	2,075.19	46.95	2.90

It is shown in table 3, that sample 2 bears maximum load at yield which shows that WSP strengthen the material. Tensile strength at yield is also improved by WSP but decreases by MA.

Table 3: Tensile Properties of Composites at Yield Sample Code

Sample Code	Load (N)	Tensile Strength (MPa)	Elongation (%)
1	2,039.02	46.13	2.98
2	2,173.31	49.17	2.97
3	2,038.37	46.12	2.74

Load at break of WSP/PLA is maximum then WSP/MA/PLA composite and PLA as mentioned in table 4. Its tensile strength is also better than other two materials but elongation is less then PLA.

Table 4: Tensile Properties of Composites at break Sample Code

Sample Code	Load (N)	Tensile Strength (MPa)	Elongation (%)
1	2,179.36	49.31	3.60
2	2,181.78	49.36	3.43
3	1,992.20	45.07	2.10

Flexural Strength

Table 5 shows the flexural properties of composites. Maximum flexural load of WSP/PLA composites is around 540 times of neat PLA but adding maleic anhydride in it reduces the maximum flexural load. Flexural stress of WSP/PLA is also 540 times of PLA and shows reduction in it on incorporating MA. Flexural modulus is also improved by WSP. It is clear that Flexural properties improves by adding WSP in PLA.

Figure 2: Flexural modulus of samples

Table 5: Flexural Properties of Composites

Sample Code	Maximum Flexural Load (N)	Flexural Stress at maximum flexural load (MPa)	Modulus (MPa)
1	22.29	12.24	3,613.0
2	120.42	66.11	3,924.5
3	16.65	9.14	3,399.8

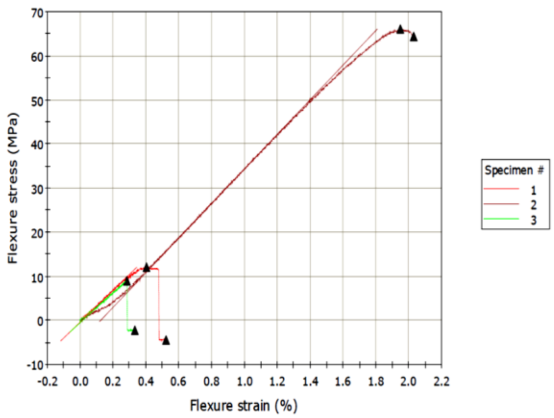

Figure 2: Flexural modulus of samples

The results show that adding WSP in PLA not only reduces the cost of PLA but also improves the mechanical properties of PLA.

Conclusion

1. This can be concluded than WSF can be used as filler in PLA for reducing its cost and enhancing its properties.

2. The incorporation of 10% of WSP in PLA improves flexural properties by 540% and tensile properties by 2%.

3. The reduction in properties on adding Maleic anhydride in composite shows that there is no need of coupling agent in WSP/PLA composite.

4. Since, WSF is a biodegradable material, it can be presumed that it accelerates the degradation of composite.

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