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Enrichment of Mechanical Properties of Biodegradable Composites Containing Waste Cellulose Fiber and Thermoplastic Starch

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ABSTRACT

Biodegradable composites have gained renewed interest as environmental friendly materials and for a sustainable development. This research overviews recent advances in Biodegradable composites based on Thermoplastic Starch (TPS) and waste cellulose fibers. In this work, we used waste newspaper cellulose fibers as reinforcement for Thermoplastic Starch (TPS) in order to improve its Mechanical, Thermal, Rheological and Biodegradability properties. The Biodegradable composites were prepared from Thermoplastic Starch (TPS) plasticized by glycerol as matrix. This TPS was reinforced with cellulose fibers, obtained from waste newspaper, with fiber content ranging from 0 to 30% (wt/wt of fibers to matrix). The compounding was carried out in Twin Screw Extruder and the specimens prepared in Compression Moulding. The mechanical and Thermal properties of this Biodegradable composite are increased compare to TPS. It's also decrease the weight of specimens by soil burial test which confirms the increased the biodegradation. These results indicated that this Biodegradable composite could be fruitfully used as commodity plastics being strong, cheap, abundant and recyclable eco-friendly thermoplastic composite.

Keywords: Biodegradable Composites, Thermoplastic Starch, Waste Cellulose Fibers, Mechanical Properties

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INTRODUCTION

In current years, the curiosity in biodegradable materials has been increasing significantly both in research and manufacturing since these materials can be easily degrade under well-defined environmental conditions, which differ from the conventional polymer derived from petroleum resources [1]. Starch is one of the most used materials for producing biodegradable plastics being naturally renewable, inexpensive and abundant. However, the key plasticizer used in Thermoplastic starch was glycerol owing to providing the best outcome in decreasing the friction between starch molecules. Green composites of thermoplastic starch and cellulose fibers were prepared using various sources of starch, including corn Starch, tapioca starch, rice starch, potato starch, and wheat starch, and different types of cellulose fibers, including flax and ramie fibers, potato pulp fibers, bleached leaf wood fibers, bleached eucalyptus pulp fibers, wood pulp fibers, cassava and bagasse fibers. As plasticizers, water and/or polyol plasticizers such as glycerol and sorbitol have been used [2]. Starch is one of the natural biopolymers most extensively used to produce environmentally-friendly packaging materials to substitute for petrochemical - base non-biodegradable plastic materials [3].

Polymer Composite properties depend on the nature of the constituent materials i.e. the fibers and resins used. The strength and stiffness of the composites are directly a function of the reinforcing fiber properties which carry maximum load and their volume content. The resin supports to keep the relative place of the fibers within the composite and, more importantly, handovers the load from the bottom fibers to the intact fibers. As an outcome, fiber/resin interfacial properties are also important and have a momentous effect on composite properties including toughness and transverse fracture stress. In the present work, we have investigated mechanical and Thermal properties of Thermoplastic starch (TPS) reinforced by waste newspaper. TPS was obtained from rice starch by using glycerol as plasticizer and fibers were extracted from used newspaper by deinking-washing process. Physical properties of composites were determined by Mechanical Tensile tests, Melt flow index (MFI), Heat Deflection Temperature (HDT), and Biodegradability test.

EXPERIMENTAL

Materials

In this work, Rice starch of grade BKK202 [4] manufactured by Bangkok Starch Industrial Company Limited was used. Cellulose Fiber extracted from the newspaper waste (Times of India). Chemicals used like NaOH, Sodium silicate, distilled water, Glycerol were of analytical grade manufactured by Merck India Limited.

Cellulose Fibers from Waste Newspaper

Cellulose fibers were extracted from used newspaper with a deinking-washing process. The newspaper, collected from a waste Newspaper (Times of India), was firstly torn to small pieces. Torn paper (100 g) and equal amounts of deinking chemicals, i.e. sodium hydroxide (NaOH, 6 g) and sodium silicate (Na_2SiO_3, 6 g), were filled with distilled water to a volume of 2 L and ground with a grinder to give a total of 5.6% consistency (percentage solids in the pulp slurry) at 45^0C under 800 rpm mechanical stirring for 20 min with the detected pH of 12. The pulp was then placed in a 16-mesh sieve, washed with running tap water (about 30 L) and then with distilled water (1 L) until pH 7 was reached, and the remaining fibers were dispersed in distilled water to give about 1% consistency. After washing with distilled water (2 L) followed by drying in oven at 60^0C for 24 h and a last grinding, the final fibers were kept in desiccators. The average length (± SD) of the resulting fibers was 1.81±0.48 mm with length/diameter ratio equal to 65±17. The fine size cellulose fibers used for the composite preparation [2].

Preparation of Thermoplastic Starch (TPS)

Rice Starch, dried at 60 ^{O}C for 24 hrs, and glycerol were pre-mixed in high mixer machine for 15 min until a powder was obtained. Preliminary experiments illustrated that the optimal glycerol content should be in the range of 20-40%. For this reason, samples used in this work contained 30% wt/wt of glycerol to starch.

Manufacturing of Biodegradable Composites

First, the measured quantity of Thermoplastic starch and recycled newspaper cellulose fiber were manually mixed for 20 min in the high speed mixer and then the composites of Rice starch with cellulose fiber were prepared by using Co-Rotating Twin Screw Extruder (Make: Specific Engineering & Automets, Model Zv - 20 Hi – Torque, 30 Mm Diameter) with sections for feed, high shear, and high intensity mixing and discharge on a continuous basis [5]. The resulting compounded materials were hot pressed in a compression moulding machine at 150°C to prepare 3 mm thick sheets with consecutive times-applied pressures of 10 min. The sheets were cut into specimens for the tests and were stored in desiccators at 23-25°C, 45-55% relative humidity (RH) [10-11]. No glycerol loss or exudation was noticed during the hot pressing or the storage [6]. The composition of composite given in table: 1

Table -1 Composition of Biodegradable Composites

Batch code	Thermoplastic starch (wt/wt %)	Waste Cellulose Fiber (wt/wt %)
0% CF	100 %	0 %
10 % CF	90%	10%
20 % CF	80%	20%
30 % CF	70%	30%

Biodegradability Test

Soil burial test methods have been established and standardized for testing resistance of composite to micro-organisms. The aim was to access their resistance in soil, rather than the degradability. The test material is buried under laboratory or field conditions. Visual assessment of exhumed materials is carried out and mass loss measurements are also performed. Soil burial tests are used to give an indication of the duration of the test material in a given soil under given conditions. The choice of location can affect the test results.

Mechanical Properties

The Tensile strength and modulus were evaluated as per ASTM standard conditions using Universal Testing Machine (P.S.I. SALES (P) LTD) as per ASTM D 638 method with a crosshead speed of 10 mm/min and gauge length was 50 mm. The flexural strength and modulus were tested by AUTOGRAPH (AG-IS) according to ASTM procedure D 790. The test speed was 2 mm/min and the span length was 50mm. The Hardness values were measure by ASTM D 785 (R scale) with 1/2" ball indenter and 60 Kg load using hardness tester (P.S.I. SALES (P) LTD) [5].

Thermal Properties

The Heat Deflection Temperature (HDT) was measured by using HDT testing machine (P.S.I. SALES (P) LTD,) as per ASTM D 1525. The test was carried out using 66 psi fiber stress and test span 100mm with heating rate of 100 °C/hr.

Rheological Properties

The Melt Flow Index (MFI), more appropriately known as Melt Flow Rate (MFR), was tested as per ASTM D 1238 method using temperature 190 ^{0}C and 2.16 Kg load. The cuts for the test were taken at 60 second time intervals. The extrudate was weighed and melt index values were calculated in grams per 10 min [5, 7].

RESULTS AND DISCUSSION

Biodegradability Test

Starch is a nutrient for many microorganisms and once water is present in the starch structure of thermoplastic starch it is readily biodegraded. Starch easily absorbs water, resulting in disintegration of biodegradable composites by partial solubility. Partially solubilized starch is even more readily biodegraded by enzymes principally from micro-organisms. Biodegradation rates showed that when fiber content increased the biodegradable composites degraded slower when compared to the pure TPS. As shown in the figure 1 of effect of soil burial test of biodegradable composite. Results show that composites show weight loss indicating that these composites are fairly biodegradable after 30 days. Soil environment contains different kinds of microorganisms. Weight losses of biodegradable composites in the soil burial test could be assumed as an indicator of biodegradation in the landfill or natural environment [8].

Mechanical Properties

The tensile strength of the composite was increased with increasing waste cellulose fiber content. The waste cellulose fiber increased the stiffness of the composite which results into increasing the tensile strength while the elongations of the composite were reducing [9]. The increase of mechanical properties, i.e. tensile strength, of biodegradable composites when compared with pure TPS confirms the interfacial adhesion and the strong interaction between matrixes and cellulose fibers. These results are favored by the chemical similarities between starch and cellulose fibers. These results could be due to the high crystallinity of the cellulose fibers, then providing higher stiffness of the green composites when compared to the pure TPS.

Flexural strength graph biodegradable composite is illustrated in Figure 3. From the test results it's found that the flexural strength is directly proportional to the cellulose loading. As the loading of cellulose fiber loading is increased the flexural properties increased [9]. Rockwell hardness of the composites was increased with increasing waste cellulose fiber. The hardness of composite was increased due to increasing in stiffness of composite. There is a major significant change observed after the 20% wt loading in the hardness of composite with varied concentration of rice starch which is illustrated in figure 4.

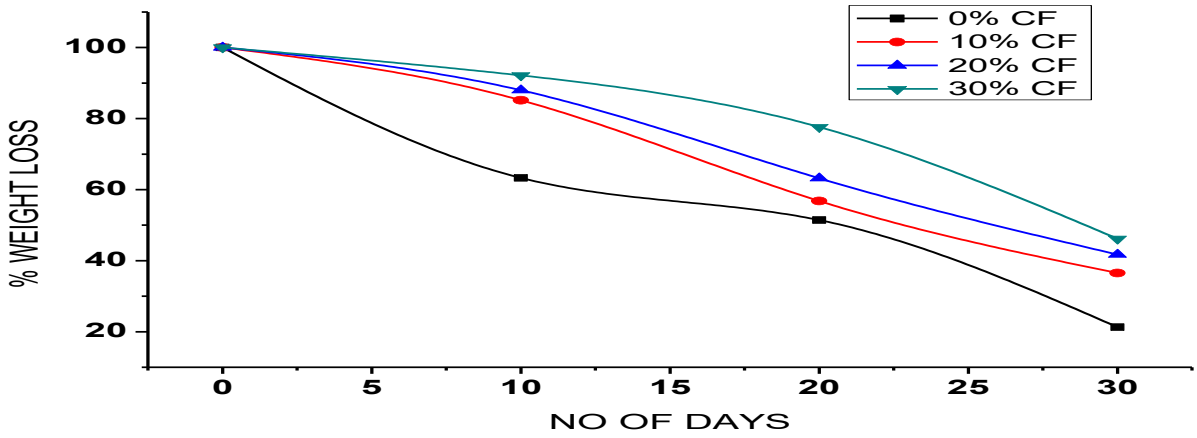

Fig. 1 Biodegradable test for Composites

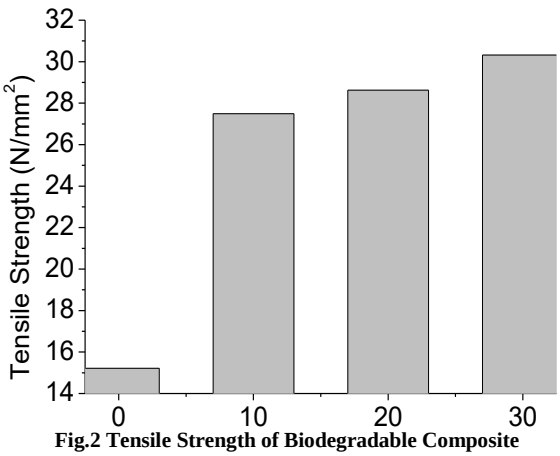

Fig.2 Tensile Strength of Biodegradable Composite

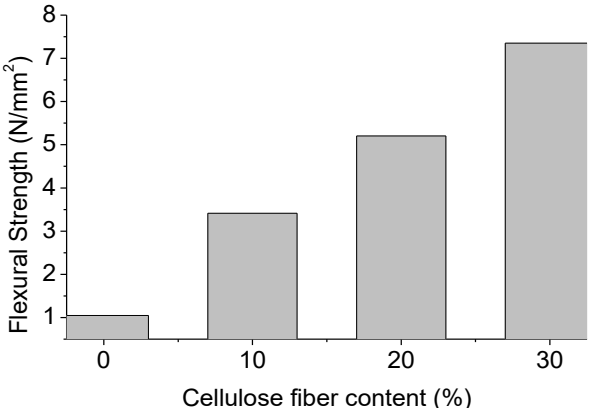

Fig. 3 Flexural strength of biodegradable Composite

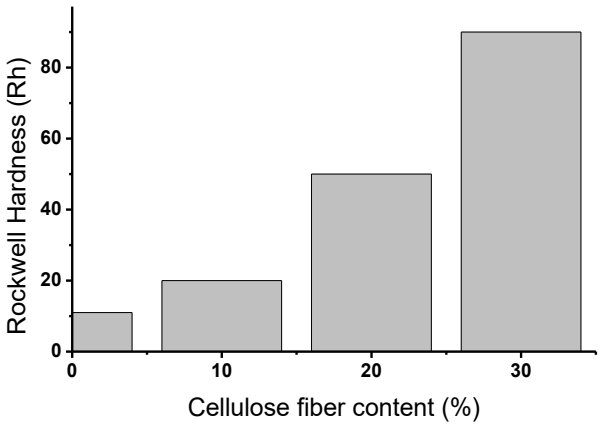

Fig. 4 Hardness test of biodegradable composites

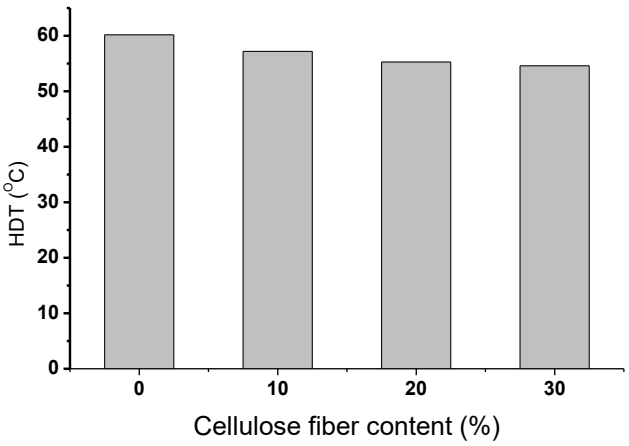

Fig. 5 Heat deflection Temperature of biodegradable Composite

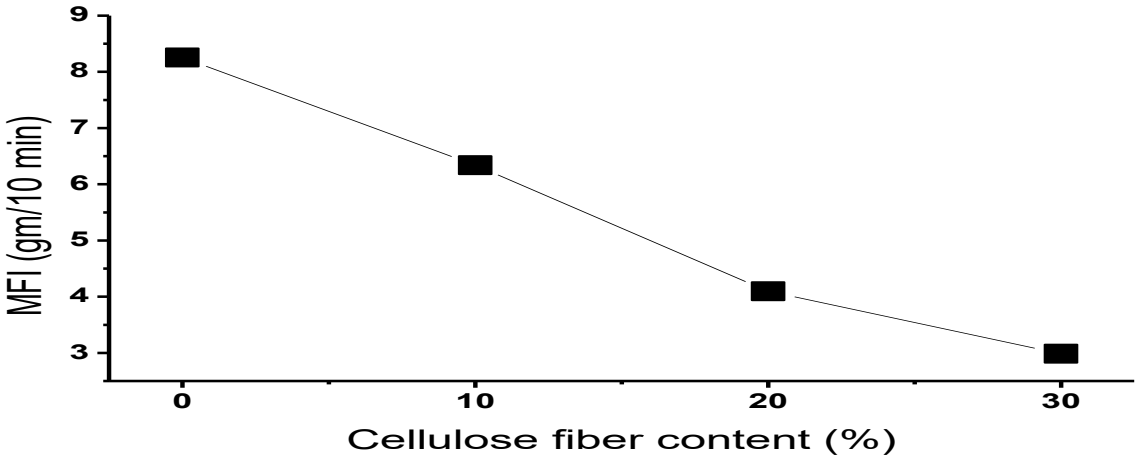

Fig. 6 Melt Flow Index of biodegradable **Composite**

Thermal Properties

The effect of waste cellulose fiber content on Heat deflection temperature (HDT) shown in figure 5. It shows that the HDT is decrease with increasing waste cellulose fiber content which results into increased in stiffness of composite. HDT were decrease due to inherent property of cellulose fiber [10]. As the cellulose fiber concentration increases, the Melt Flow Index (MFI) decreases. Initially the rate of decrease is lower and at higher concentration it is higher. This is due to the reason that the concentration of cellulose fiber stiffens the composite material leading to more resistance to flow which results in low MFI value. The flow behavior of the composite were totally depends on the fiber content not on the matrix in this case [11]. So during the process the MFI is most important factor which must be considered during commercialization. So it's clear from test result that the processing aid or additives are required if want to process in molding process [12].

CONCLUSIONS

The main objective of this research is to study the effect of waste cellulose fiber on the mechanical properties of the TPS / cellulose composites. The fiber used as reinforcement and matrix that act as binder in this experiment is totally from biodegradable materials. Enhancement of TPS mouldings with functional components gives an optimistic effect on their mechanical properties without dropping biodegradability suppleness. The results also reveal that it can be concluded that, the fiber loading also affect the mechanical properties of the composites. Increase in fiber loading show interesting results especially in tensile stress and hardness. The enhancement observed in the tensile strength when increasing fiber volume fraction up to 30%, evidences a good fiber–matrix interface. Stress is successfully transferred towards the reinforcement through the H-bonding established between the hydroxyl groups of starch and cellulose. However, HDT and MFI of the biodegradable composite decreased when waste cellulose fiber was used with thermoplastic starch. The blends showed decreased HDT when mixed plasticizer was used suggesting that glycerol had adverse effect to HDT of the blends. The results obtained in various tests were found to be close to the expected applications in packaging and industrial applications.

REFERENCES

[1] Surakit Kampangkaew, Chanchai Thongpin and Onuma Santawtee, The Synthesis of Cellulose Nanofibers from Sesbania Javanica for Filler in Thermoplastic Starch, *Energy Procedia*, **2014,** 56, 318-325.
[2] Amnuay Wattanakornsiri, Katavut Pachana, Supranee Kaewpirom, Pichan Sawangwong and Claudio Migliarest, Green Composites of Thermoplastic Corn Starch and Recycled Paper Cellulose Fibers, *Songklanakarin Journal of Science and Technology* , **2011,** 33 (4), 461-467.
[3] B Mitra, Environment Friendly Composite Materials: Biocomposites and Green Composites, *Defense Science Journal*, **2014,** 64(3), 244-261.
[4] BKK-202, *Bangkok Starch Technical Information*, Bangkok Starch Industrial Company Limited, **2009**.
[5] Rataram prajapati, *Mechanical and Morphological Properties Evaluation of Basalt Fiber Reinforced Thermoplastic Composites*, M Tech Thesis, Gujarat Technological University, **2014.**
[6] Amin M Ruhul, Basel F Abu-Sharkh and Mamdouh Al-Harthi, Effect of Starch Addition On the Properties of Low Density Polyethylene for Developing Environmentally Degradable Plastic Bags, *Journal of Chemical Engineering*, **2011**, 26(1), 38-40.
[7] AL Da Roz, AM Ferreira, FM Yamaji, AJF Carvalho, Compatible Blends of Thermoplastic Starch and Hydrolyzed Ethylene-Vinyl Acetate Copolymers, *Carbohydrate Polymers*, **2014**, 90, 34-40.
[8] Zeena P Hamza, *Ionomer Compatibilized Low Density Polyethylene-Tapioca Starch Blends Biodegradability and Photodegradability*, Thesis, Cochin University of Science and Technology, **2012**.
[9] Fatimat O Bakare, Dan Akesson, Mikael Skrifvars, Nima Esmaeili and Shahrzad Javanshir Afshar, *Morphological and Mechanical Properties of a Biobased Composite from a Lactic Acid based Thermoset Resin and Viscose Fiber Reinforcement*, School of Engineering, University of Boras Yanfei Wang University of South China, China.
[10] KG Satyanarayana, Effect of Processing Conditions on Tensile Properties of Green Composites of Castor Oil Cake Starch-Plant Fibers, *Journal of Bioprocessing & Biotechniques*., **2015,** 5(1),1-8
[11] J Girones, JP Lopez, P Mutje, AJF Carvalho, AAS Curvelo and F Vilaseca, Natural Fiber-Reinforced Thermoplastic Starch Composites Obtained by Melt Processing, *Composites Science and Technology*, **2012**, 72(7), 858-863.
[12] HL Boudjema and H Bendaikha, Studies on the Properties of Cellulose Fibers-Reinforced Thermoplastic Starch Composites, Journal *of Chemistry and Materials Research*, **2015**, 3, 21-25.