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Coir Fiber Reinforced Polypropylene Composites: Eco-friendly Byproducts

S. M. G. Moktadir[1], M. U. Talukder[1], A. K. O. Huq[1*,] M. A. Gafur[2] and A. M. S. Chowdhury[3]

[1]Department of Food Technology and Nutritional Science, Mawlana Bhashani Science and Technology University, Santosh, Tangail-1902, Bangladesh,
[2]Department of Pilot Plant & Product Development Center, Bangladesh Council of Scientific & Industrial Research, Dhaka-1205, Bangladesh,
[3]Department of Applied Chemistry & Chemical Engineering, Faculty of Engineering & Technology, University of Dhaka, Dhaka-1000, Bangladesh.
*****Corresponding author: obidulhuq@gmail.com

Abstract

Coir fiber (CF) reinforced polypropylene (PP) composites were fabricated using an extruder machine. The fiber contents were varied 5 to 20% and physico-mechanical properties as well as bio-degradability were also tested. Ultimate tensile strength and flexural strength decreases with the increases of percentages of fiber addition. Lowest percentage elongation is observed at 20% CF+PP composite which are rigid in nature. Leeb rebound hardness also decreases with the increase of percentage of raw fiber addition. The bio-degradation of different percentage of CF and PP composites in soil and saline water increased with increase of coir fiber content. Thus, it showed that higher percentage of coir fiber was produced more biodegradable and eco-friendly byproducts. However, higher percentages of coir fiber decrease the mechanical properties. A moderate percentage of coir fiber i.e. 15% CF +PP showed the good mechanical properties as well as considerable amount of bio-degradability in soil and saline water.

Key words: Bio-degradation, Coir fiber, Mechanical properties and Polypropylene

Introduction

Natural and renewable-based bio-materials have greater attention to the scientists and environmental engineers due to their lightweight, low-cost, hazardless, bio-degradability and other eco-friendly nature (Albertson *et al.,* 1994; Raghavan, 1995; Yoon *et al.,* 2007; Khan *et al.,* 2010; Yan *et al.,* 2013). Therefore, various ligno-cellulosic natural fibers have been identified as a potential substitute for commonly applied man made synthetic fibers for the last few decades. Different parts of plants and fruits such as jute, coir, sisal, banana, palmyra, pineapple, talipot, hemp etc. have been found to be viable sources of raw material for industrial byproducts besides agricultural uses throughout the world.

Fiber reinforced polymer composites consist of a polymer matrix reinforced with thin diameter fibers. Synthetic fibers are imparting bad effect on the environment on the other hand natural fibers are completely biodegradable. Recently, with increasing concern about the environmental pollution resulting from non-degradable plastic materials, much research to develop environmentally friendly biodegradable plastic materials as replacements for synthetic polymeric materials has been earned out. Bio-degradable polymers have been a subject of interest for many years because of their potential to protect the environment by reducing non-biodegradable synthetic plastic waste (Thayer, 1990; Krokhta and De Mulder-Johnston, 1996).

Coir fiber obtained from coconut waste is abundant in Bangladesh and commonly used as matrices and brushes. Thus, a versatile uses of this waste is urgently needed for safety and environmental clean. Therefore, an attempt has been made to prepare a coir fiber-reinforced polypropylene composite which is bio-degradable in nature and can be utilized in various purposes.

Materials and Methods

Sample collection and composite preparation

The raw materials for preparing the samples were coir fiber collected from Bagerhat district of Bangladesh. Polypropylene was supplied by the Polyolefin Company (Singapore) Pvt. Limited. Composites were prepared by varying different amount of fiber contents from 5% to 20% with polypropylene by using the Paul-Otto Weber Presser Hydraulic Press extruder machine and schematic flow diagram was shown in Fig.1. Then different physico-mechanical properties such as tensile properties, flexural properties and hardness were measured. At the same time, bio-degradability in soil and saline water were also observed the prepared composite materials.

Tensile strength measurement

Tensile specimen was prepared according to ASTM Standard D 638-01. (ASTM 2002a)

Tensile strength

$$= \frac{\text{Applied load}}{\text{Cross sectional area of the load bearing area}}$$

$$\sigma = \frac{P}{A}$$

$$= \frac{P}{A} \text{ in Pa}$$

Tensile strain is calculated according to ASTM D-638M - 91a.

Tensile strain $= \frac{l - l_0}{l_0}$

Where, l_0 = Original length of the sample.

l = Length of the material after stretching

Flexural strength measurement

Flexural specimen was prepared according to ASTM D790-00, 3 point loading (ASTM 2002b).

The Flexural strength may be calculated for any point of the load deflection by means of the following equation-

$$S = 3PL / 2bd^2$$

Where,

S = stress in the outer fibers at midspan in MPa, P = load at a given point on the load – deflection curve in N, L = support span in mm,

b = width of specimen tested in mm,

d = depth of tested specimen in mm.

Flexural strain may be calculated for any deflection using the following equation-

$$\varepsilon_f = \frac{6Dd}{L^2}$$

Where, ε_f = Main strain in the outer surface in mm/mm, D = Maximum deflection of the center of the beam in mm, L = Support span in mm, d = Depth in mm.

Hardness measurement

Leeb Rebound Hardness is measured by an impact body with a hard metal test tip is propelled by spring force against the surface of the test piece. Surface deformation takes place when the impact body hits the test surface, which will result in loss of kinetic energy. This energy loss is calculated by velocity measurements. When the impact body is passing the coil at a precise distance from the surface, a signal voltage is induced during the impact and rebound phase of the test. The voltages are proportional to the velocity. Signal processing by the electronics provides the Leeb hardness reading for display and storage.

Biodegradation measurement

Degradation in soil and water measured by keeping samples under soil and water for several period of time and weight loss was calculated.

Results and Discussion

Table 1 showed that the lowest value of tensile strength was for 20% CF + PP composite and tensile strength decrease with the increase of percentage of fiber addition. It was also observed that the highest value of percentage elongation was for pure PP and lowest percentage elongation was for 20% CF+PP composite.

Table 1. Mechanical properties of CF + PP composites

Sample name	Tensile strength (MPa)	% Elongation	Flexural strength (MPa)	Hardness (HL)
	Mean ± SD	***Mean ± SD***	***Mean ± SD***	***Mean ± SD***
PP	26.17±0.04	13.75±0.12	28.00±0.01	635.06±0.76
5% fiber + PP	21.72±0.84	5.07±0.68	21.89±0.47	612.48±0.25
10% fiber + PP	21.48±0.23	6.12±0.05	20.96±0.94	609.39±0.24
15% fiber + PP	20.54±0.35	5.09±0.12	17.60±0.03	605.22±0.05
20% fiber + PP	17.09±0.53	5.01±0.49	14.90±0.10	593.67±0.23

It was also observed that the lowest flexural strength was for 20% CF+PP composites and highest flexural strength was for pure PP. Flexural strength decrease with the increase of percentage of fiber addition. Table 1 also shows the highest value of Leeb rebound hardness was for pure PP and lowest for 20% CF+PP composite. Leeb rebound hardness decreases with the increase of percentage of raw fiber addition.

Fig. 2 shows the degradation of different percentage of CF+PP composites in soil. It was observed that the highest degradation was for 20% CF+PP composite and no degradation is for pure PP.

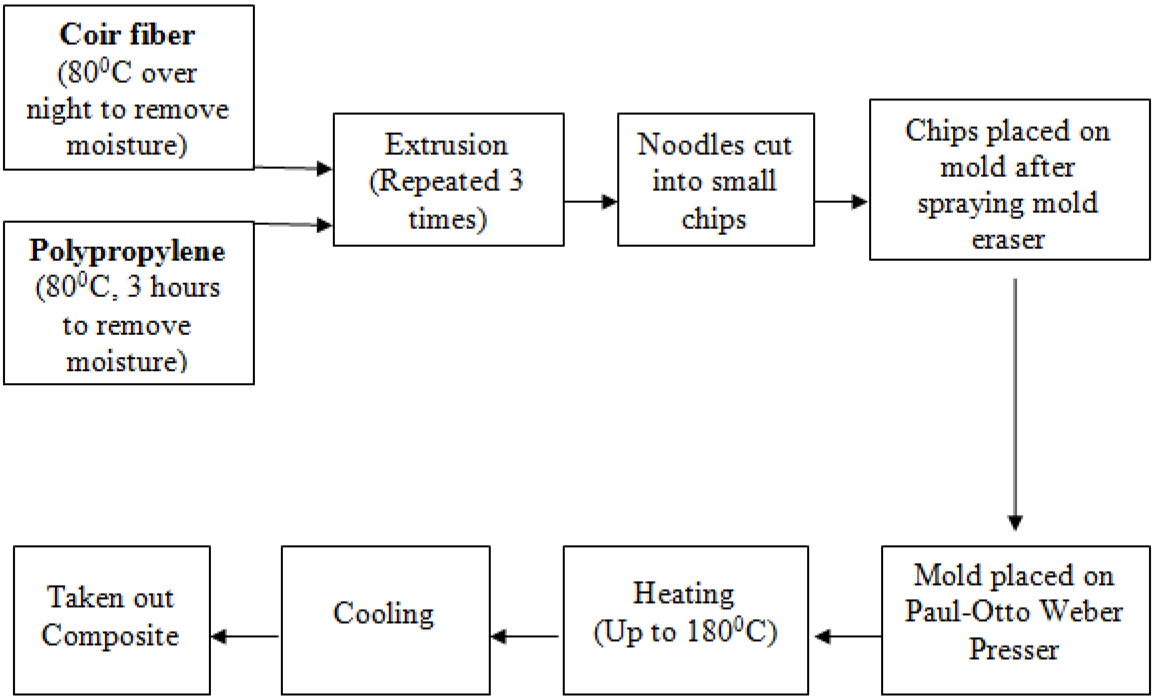

Fig. 1. Flow diagram process of coir fiber reinforced polypropylene composite.

It also observed that the degradability increases with the increase of percentage of raw fiber addition. The degradation of different percentage of CF+PP composites in saline water was observed in

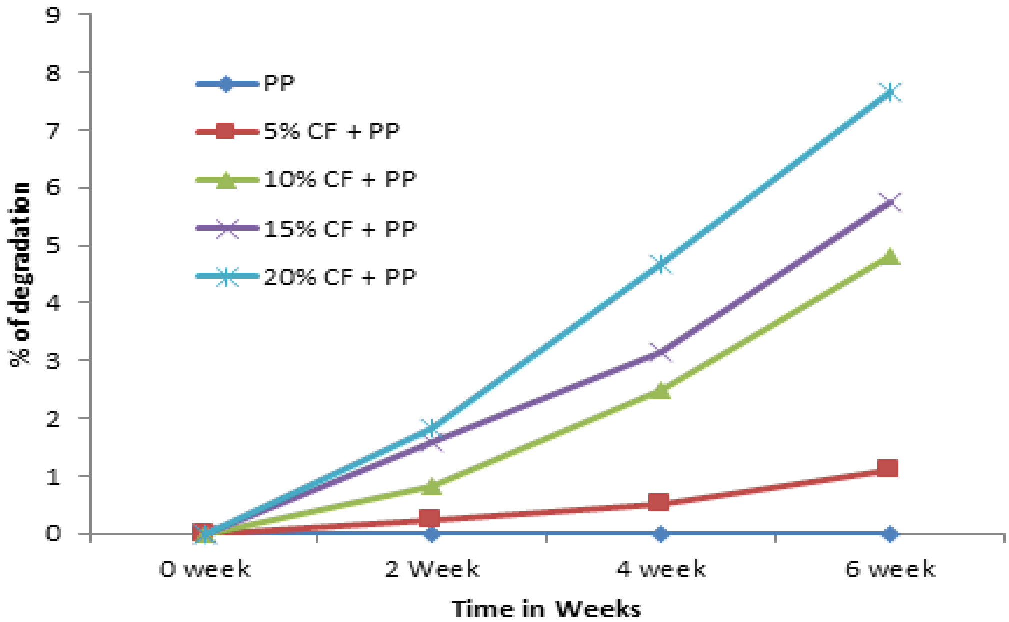

Fig. 2. Degradation of CF+PP composites in soil.

Fig. 3. It was found that the highest degradation was for 20% CF+PP composite, whereas, no degradation was noted for pure PP. It also observed that the degradability was increased with the increase of percentage of raw fiber addition.

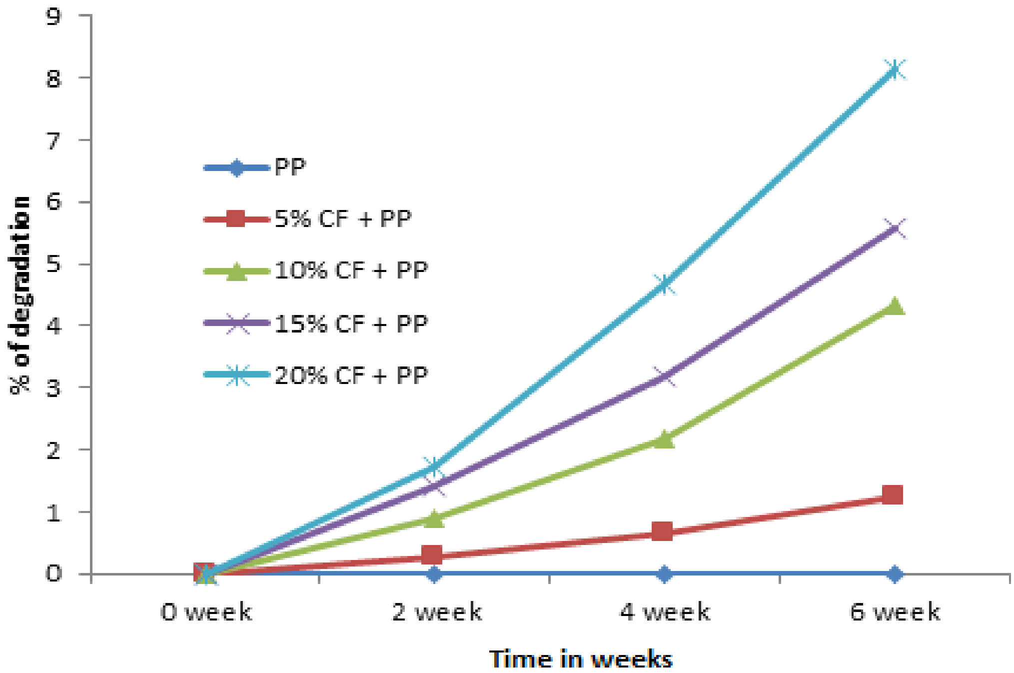

Fig. 3. Degradation of CF+PP composites in saline water.

Conclusions

Composites with good biodegradable properties could be successfully developed by using 15% and 20% coir fiber as reinforcing agent. Biodegradability in both saline water and soil increases with increase in fiber content, thus higher fiber containing composite is more environment friendly. However, ultimate tensile strength and flexural strength were decreases with the increase of percentage of fiber addition. Lowest percentage elongation was found in 20% CF+PP composite which is more rigid in nature compared to others. Thus, it can be concluded that, the physic-mechanical properties of coir fiber reinforced polypropylene composites was improved to a certain extent. Furthermore, the composites of this study were biodegradable and eco-friendly, also probable cost effective as coir fiber is highly abundant in Bangladesh.

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