International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 2 Issue 2, February 2014

Effects of Fiber Length and Fiber Ratio on the Biodegradability of Jute Polymer Composites

Kh. Mumtahenah Siddiquee[1], Md. Maksud Helali[2]

[1]Assistant Director (Program),"Fortification of Edible Oil in Bangladesh"- Project, Ministry of Industries, Bangladesh
[2]Professor, Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, Bangladesh

Abstract: ***The growing overall environmental and social concern, high rate of decreasing petroleum resources, and novel environmental strategy have imposed the search for alternate of plastic materials. Natural fiber is commonly used to produce environmental friendly biodegradable polymer composites. They have the environmental benefits such as biodegradability, greenhouse gas emissions and enhancement of energy recovery. The aim of this paper is to encourage increase use in natural fiber reinforced composites and help the world to make it environmental friendly. This study focuses on the fabrication of jute polymer composites, effects of fiber length and fiber ratio on the biodegradability of jute polymer composites and biodegradation. Composites were fabricated using polyethylene, polypropylene reinforced with 5%, 10% and 15% of jute fiber of 1mm and 3mm fiber length by using compression molding. Weight loss of the composites revealed that composites are biodegradable. Samples were kept in compost heap, soil and natural weather to observe the degradation of the specimens. Higher fiber length and fiber reinforced ratio shows the higher degradation rate. Degradation rate were higher in compost condition considering natural weather and soil.***

Keywords: Natural Fiber, Polymer, Composite, Biodegradability.

1. Introduction

With the drastic increase in the global population and advances in technology plastic materials have become an integral part of our daily life. They play an important and ubiquitous role in everyday life because of having extraordinary range of properties. But the plastic materials are not biodegradable. Due to the non-biodegradability of the commercially available plastic has caused many environmental problems associated with their waste pollution and disposal. These plastics are characteristically inert and resistant to microbial attack and therefore they remain in the nature without any deformation for very long time. Because of a lack of water-solubility and the size of the polymer molecules, microorganisms are unable to transport the polymeric material directly into the cells [1].

Bio-based and biodegradable products have raised great interest in the recent years since the growing concern for the environment and substitute traditional, non-biodegradable polymers. Biopolymers offer environmental benefits such as biodegradability, greenhouse gas emissions, and renewability of the base material [2]. The majority of biodegradable polymers are not widely used because they are too expensive and the range of the material selection suitable for various end-use products is limited [3]. Moreover, biodegradable plastics require specific conditions to biodegrade properly (micro-organisms, temperature, and humidity), and if not managed properly they may be worse for the environment than conventional plastics. When biodegradable plastics are put into landfill they produce harmful greenhouse gases when breaking down. With the increased awareness of environmental degradation among the people has led the producers as well as consumers towards achieving environmental sustainability. So considering the environmental benefit it is required to produce some alternative like composite material which will be biodegradable and low cost.

For the purposes of this research, the term “composites” are materials that are comprised of strong load-carrying materials (known as reinforcement) imbedded in a weaker material (known as matrix). Reinforcement provides strength and rigidity and the matrix, or binder, maintains the position and orientation of the reinforcement and balance loads between the reinforcements. The constituents retain their identities, that is, they do not dissolve or merge completely into one another although they act in concert. Normally, the components can be physically identified and exhibit an interface between one another. Considering the environmental benefit and disposability there has been a significant research interest in the area of natural fiber-based composites. Bangladesh is an agriculture based country. It produces huge amount of jute every year. Jute is the cheapest lignocellulosic, long vegetable bast fiber and abundantly available here. Considering this feature jute fiber has been used to fabricate the composites in this research work.

The improper disposal and treatment of solid waste is one of the gravest environmental problems faced by most of the countries. With the increasing globalization and modernization, waste disposal problem is increasing day by day. In many parts of the world proper waste disposal facilities do not exist and the wastes are simply discarded in the surrounding areas [4]. Considering this factor, nature is the only media for biodegradation of the composites.

International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 2 Issue 2, February 2014

Biodegradation is the chemical termination of materials. It is nature's way of recycling wastes, or breaking down organic matter into nutrients that can be used by other organisms. Degradation is carried out by a huge assortment of bacteria, fungi, insects, worms, and other organisms that eat material and recycle it into new forms. Ajaya Kumar Behera et al [5] studied on the b Microbial degradation study of nano-biocomposites was carried out in cultured fungal bed. Weight loss, tensile loss, and field emission scanning electron microscopy photographs of composites revealed that composites are biodegradable in nature.

Behjat et al [6] carried out research study on Effect of PEG on the biodegradability studies of Kenaf cellulose -polyethylene composites. Biodegradability was measured using soil burial test blends and found that the cellulose/LDPE and cellulose/HDPE blends were biodegradable in a considerable rate. The bio-composites with high content of cellulose had higher degradation rate. In addition, biodegradability of the bio-composites made up using PEG was superior to those of the bio-composites fabricated without PEG, due to the improved wetting of the plasticizer in the matrix polymer. Sanjay K. Nayak [7] studied the degradation and flammability behavior of pp/banana and glass fiber-based composites. Further, BFPP composites exhibited higher degradation tendency as compared with the virgin polymer as well as the hybrid composites. Extent of biodegradation in the irradiated samples showed increased weight loss in the BFPP samples thus revealing effective interfacial adhesion upon hybridization with glass fibers. R. Kumar et al [4] carried out experiment on biodegradation of flax fiber reinforced poly lactic acid. Different amphiphilic additives can be added for delayed or accelerated biodegradability.

Yuksel Orhan et al [8] worked on biodegradation of plastic compost bags under controlled soil conditions. Degradation of plastics was determined by the weight loss of sample, tensile strength, carbon dioxide production, chemical changes measured in infrared spectrum and bacterial activity in soil.

2. Materials and Methods

In this work the jute fibers were cut into the lengths of approximately 1 mm and 3 mm for preparing the composites, A commercial grade polypropylene (PP) and polyethylene (PE) was used in this study. Melting point of this polypropylene and polyethylene were measured and found to be 170°C and 125°C. In the literature it is mentioned that the melting point of commercial grade polypropylene lies in the range of 160°-170°C and polyethylene lies in the range of 115°-130°C.

2.1Composite Fabrication

Polypropylene/Polyethylene matrix and jute fibers of length of 1mm and 3mm were taken in different weight fraction for the fabrication of the composites. (Table 1)

Table 1: Relative Amounts of Reinforcing Material and Polymer Matrix by Weight Fraction

Reinforcing fiber (Jute) weight Fraction (%)	Polymer matrix (Polypropylene/ Polyethylene) weight fraction (%)	Composites (Jute : PP/PE)
None	100	100
05	95	05: 95
10	90	10: 90
15	85	15 : 85

2.2 Preparation of Composites by Compression Moulding

Polymers and jute fibers were measured and poured evenly into a square shaped cavity mould. To get the desired shape and possible homogeneity (50±5%) KN pressure is applied after loading the mould in the hot press machine. At first the temperature were maintained at (125°±10^0) C for PE and (170°±10^0) C for PP. About 30 to 40 min is required to reach the desired set points.
When the temperature was raised at set points it was kept at those temperatures for 10 min to melt properly. After completion of heating when the pressure down to zero then pressure of (50±5%) KN was applied again to avoid the void and to have a desired thickness.

The composites got from the compression moulding, sized: 126mmx126mmx3mm.

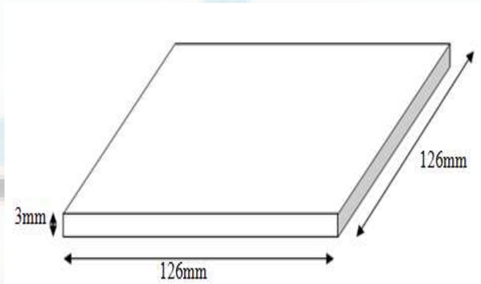


Figure 1: Composite after demoulding

After demoulding, the composite have been cut by the saw machine sized: 126mmx10mmx3mm.

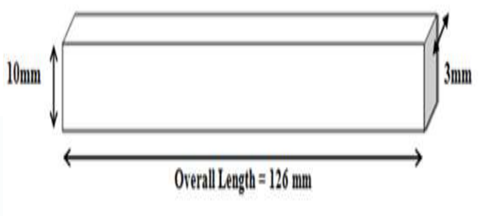


Figure 2: Sample for analysis

2.3 Biodegradation

Biodegradation is a microbial process that occurs when all of the nutrients and physical conditions involved are suitable for growth. Microorganisms such as bacteria and fungi, including yeasts and molds, are responsible for biodegradation. Biodegradation processes are essential to recycle wastes so that the elements in them can be reused. In this study biodegradability of jute polymer composite has been examined in three environments such as in the soil, compost and weather.

2.3.1 Degradation by Compost

Compost is a responsive condition for degradation because the elevated temperatures achieved during composting permit faster biochemical reactions which accelerates the degradation rate. High temperature makes composites more bio viable, increasing the chance of microbial degradation. In this study biodegradability of the sample was studied by weight loss over time in a compost condition. Compost degradation is carried out by following the ASTM D5338. The biodegradation of the specimen was checked after 15 days, 30 days and for 45 days on the compost heap. Samples were placed in 250ml Pyrex bottle containing compost. These bottles were placed in a temperature controlled water bath. For the survival of microorganisms of the compost O_2, temperature and water are required. To ensure homogeneity of temperature a stirrer was placed in that water bath to create water circulation. Water was poured in the bottles in every two days. Air compressor was placed to ensure proper O_2 supply in the compost. First day the temperature of the water bath was set at ($35^0 \pm 5^0$) C. The temperature was maintained at ($58^0 \pm 5^0$) C for next 4 days. Consecutive 28 days water bath was set to ($50^0 \pm 5^0$) C and rest of the days water bath was set to ($35^0 \pm 5^0$) C. The samples were dug out at 15,30,45 days intervals throughout the time, washed with water and dried in a vacuum oven at 50±1ºC for 24 h before evaluation. The samples were then weighed to determine the weight loss.

2.3.2 Soil Burial Degradation

Soil burial is a traditional and standard method for degradation because of its actual conditions of waste disposal. Soil is comprised of countless species that create a dynamic and complex ecosystem and is valuable resources for degradation. Biodegradability of the samples was studied by weight loss over time in a soil environment. Samples were weighed (3.28gm) and then buried in the soil for up to 80 days. The soil was maintained at approximately 20% moisture by injecting water to keep the microorganisms active and samples were buried at a depth of 5 cm. The buried samples were dug out at 30, 60, 80 days intervals throughout the time, washed with water, dried in a vacuum oven at 50±1ºC for 24 h before evaluation. The samples were then weighed to determine the weight loss.

2.3.3 Degradation by weather

The ultraviolet (UV) portion of solar radiation is the main parameter responsible for initiating weathering effects for degradation. Moreover environmental parameters influencing the degradation of polymeric materials are temperature, moisture and oxygen. Samples were weighed (3.23gm) and then buried in the natural weather for up to 80 days. The samples were weighed after 30, 60, 80 days to determine the weight loss.

2.4 Percentage Weight loss In Specimen after degradation

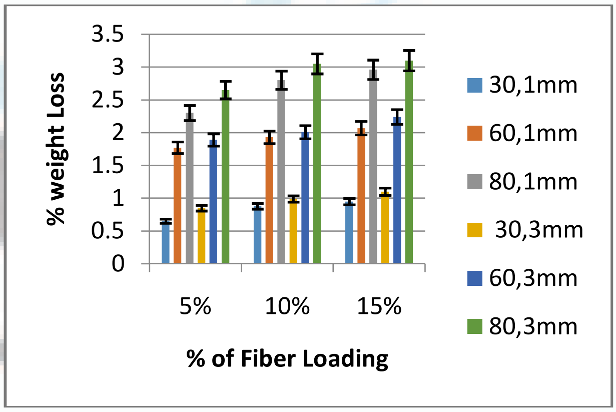
The time variation of percentage weight loss (wt) can be measured as:

$$wt = \frac{Wo - W(t)}{W} \text{ x } 100$$

Here W (t) is the total weight after time t, W_o is the reference dry weight of the specimen before biodegradation.

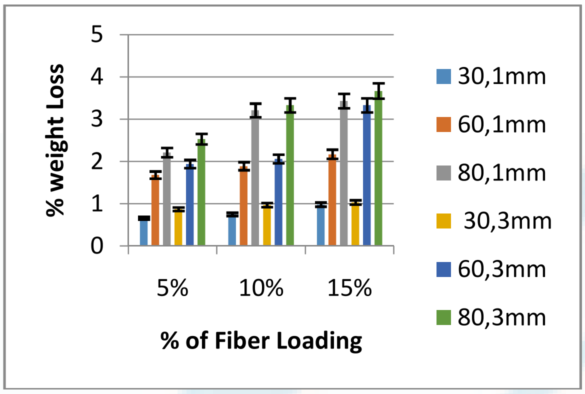
3. Results and Discussion

3.1 Biodegradability in terms of % weight loss of jute reinforced PP & PE composites in weather.



(a)

International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 2 Issue 2, February 2014

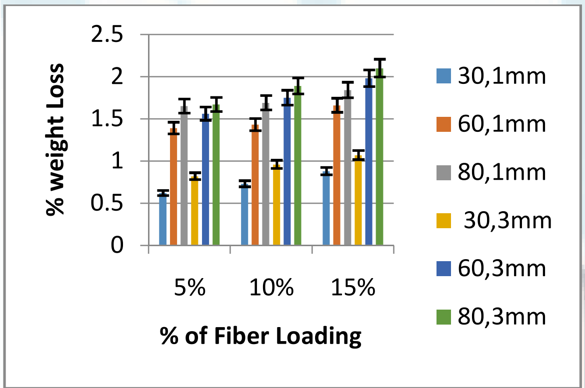


(b)

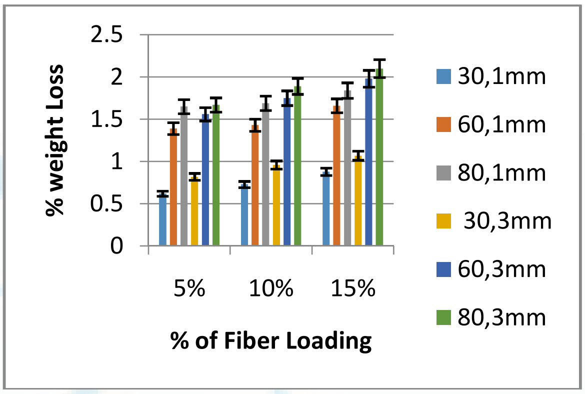
Figure 3 : Effect of weather degradation on % weight loss of jute reinforced PP(a) & PE(b) composites

Figure 3 shows the variation of the parcentage weight loss as a function of percentage of fiber loading for jute fiber reinforced polyethylene and polypropylene composties. Degradation rate is minimum for smaller fiber length as well as percentage of fiber loading and maximum for higher fiber reinforced ratio with higher fiber length. Less incubation time causes the lower degradation rate and consequently degradation rate increases with higher incubation time. The minimum value of % weight loss in weather condition after 30 days is 0.65, for 5 %, 1mm fiber reinforced PP composties and the maximum value is 3.67, gain from 15 %, 3mm fiber reinforced PE composties after 80 days.

3.2 Biodegradability in terms of % weight loss of jute reinforced PP & PE composites in soil.



(a)

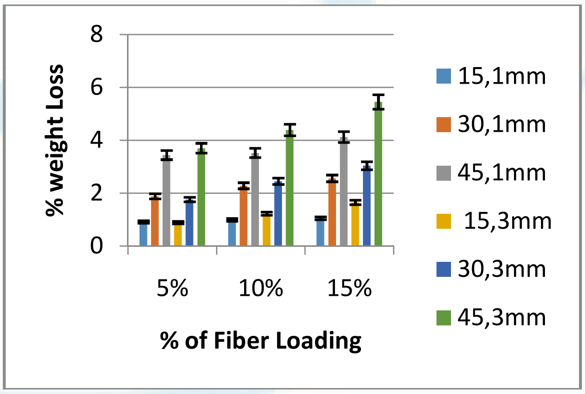


(b)

Figure 4 : Effect of soil degradation on % weight loss of jute reinforced PP(a) & PE(b) composites

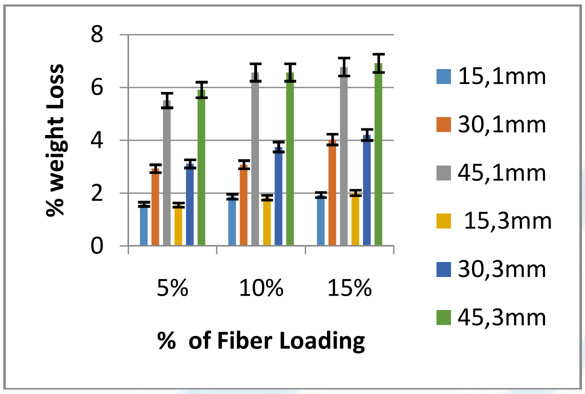
Figure 4 shows the variation of the parcentage weight loss as a function of percentage of fiber loading for jute fiber reinforced polyethylene and polypropylene composties. The minimum value of % weight loss after 30 days for 5 %, 1mm fiber reinforced PP composties in soil burial condition is 0.62, and the maximum value is 2.21, gain from 15 %, 3mm fiber reinforced PE composties after 80 days.

3.3 Biodegradability in terms of % weight loss of jute reinforced PP & PE composites in composite.



(a)

International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878
Volume 2 Issue 2, February 2014

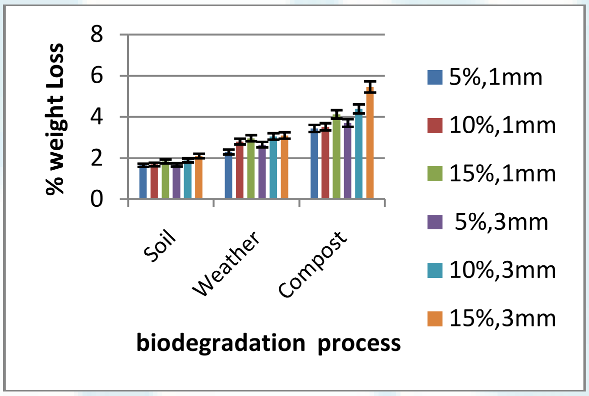


(b)

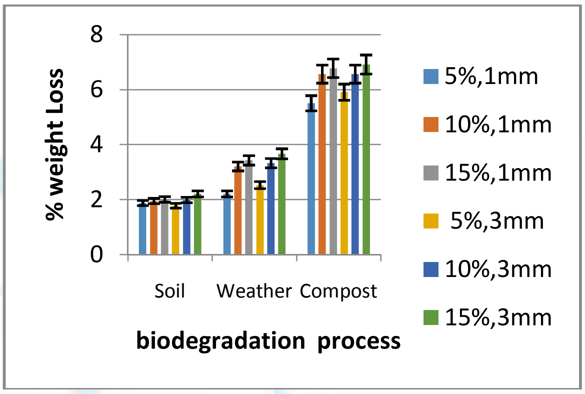
Figure 5 : Effect of compost degradation on % weight loss of jute reinforced PP(a) & PE(b) composites

Figure 5 shows the variation of the parcentage weight loss as a function of percentage of fiber loading for jute fiber reinforced polyethylene and polypropylene composties. The minimum value of % weight loss in compost condition is 0.89, for 5 %, 3mm fiber reinforced PP composties after 15 days and the maximum value of % weight loss is 6.92, gain from 15 %, 3mm fiber reinforced PE composties after 45 days.

3.4 Enhancement of biodegradation rate of jute-PP & PE composites in terms of % weight loss.



(a)



(b)

Figure 6 : Effect of natural resources (soil, weather & compost) on the biodegradation rate of jute reinforced PP(a) & PE(b) composites in terms of % weight loss

Figure 6 shows the variation of parcentage weight loss as a function of biodegradation process for jute fiber reinforced polyethylene and polypropylene composties. The maximum degradation rate is 6.92 for compost degradation, 3.67 for weather degradation and 2.21 for soil burial degradation.In case of weight loss, degradation rate is maximum for compost condition. In compost condition degradation rate is higher in comparison to soil and natural weather. Because microorganisms with some factors like temperature, air and water accelerates the degradation rate. So compost condition enhances the biodegradation rate.

4. Conclusion

The issue of biodegradable polymers with particular importance on biodegradation has received a great deal of interest in recent years. Evaluation of biodegradability is the major consideration in the development of biodegradable polymers. This study has covered the major concerns about the natural fiber reinforced polymer composites and biodegradability. In this work effects of higher fiber length and higher fiber ratio on the biodegradability of jute reinforced polymer composites were studied over time in compost, soil burial and weather condition. Degradation rate was designated in terms of weight loss. In the time scale of this study composites reinforced with larger fiber length and ratio showed higher degradation rate. Degradation rate in compost condition was highest in comparison to soil and natural weather. The biodegradability in compost condition for larger fiber length and weight fraction was almost 60 percent higher considering soil. In compost condition some factors such as temperature, water and air, accelerate the biodegradation rate. Microorganisms generally consume the fiber portion of the composites. Higher fiber loading gives opportunity to the microorganism to consume a large amount and results higher degradation rate. Over time larger surfaces of composites became smaller and became easier target for microorganisms.

This explains reason of higher degradation rate in longer incubation time. Polyethylene showed slightly higher degradation rate considering polypropylene but not significant. Due to non degradable characteristics pure polymers didn’t lose their weight.

Bangladesh is an agricultural based country. It produces a large amount of jute fiber every year. So to fabricate polymer composites by using jute fiber will be cost effective and improve the agricultural based economy. Evaluation of the composites properties and the rate of biodegradation will promote increased use in composites and consequently capture an ever-growing market share and help the world to make it more environmentally friendly.

References

[1] Dr. Muller. Rolf-Joachim; ‘Biodegradability of Polymers: Regulations and Methods for Testing’; Gesellschaft f, r Biotechnologische Forschung mbH, Braunschweig, Germany.
[2] Tao YU, Yan LI, Jie REN; ‘Preparation and Properties of Short Natural Fiber Reinforced Poly(lactic acid) Composites’; Trans. Nonferrous Met. Soc. China 19(2009) s651-s655.
[3] Kim Hee-Soo, Kim Hyun-Joong, Lee Jae-Won , Choi In-Gyu; ‘Biodegradability of Bio-Flour filled Biodegradable Poly(butylene succinate) Bio-Composites in Natural and Compost Soil’; Polymer Degradation and Stability 91 (2006) 1117e1127.
[4] Kumar R., Yakubu M. K., Anandjiwala R. D.; ‘Biodegradation of Flax Fiber Reinforced Poly Lactic Acid’; eXPRESS Polymer Letters Vol.4, No.7 (2010) 423–430.
[5] Behera Ajaya Kumar, Avancha Sridevi, Manna Suvendu, Sen Ramkrishna, Adhikar Basudam; ‘Effect of nanoclay on physical, mechanical, and microbial degradation of jute-reinforced, soy milk-based nano-biocomposites’; Polymer Engineering & Science, Vol 54, Issue 2, pages 345-354, February 2014.
[6] Behjat, T., Russly, A. R., Luqman, C. A., Yus, A. Y. and Azowa Nor, I.; ‘Effect of PEG on the Biodegradability Studies of Kenaf Cellulose-Polyethylene Composites’; International Food Research Journal 16: 243-247 (2009).
[7] Nayak Sanjay K.; ‘Degradation and Flammability Behavior of PP/ Banana and Glass Fiber-based Hybrid Composites’; Int J Plast Technol 13(1):47–67.
[8] Orhan Yüksel, Hrenović Jasna, and Büyükgüngör Hanife; ‘Biodegradation of Plastic Compost Bags Under Controlled Soil Conditions’; Acta Chim. Slov. 2004, 51, 579−588.

Author Profile

Kh. Mumtahenah Siddiquee received the B.Sc. and M.Sc. degrees in Mechanical Engineering from Chittagong University of Engineering and Technology, Bangladesh in 2007 and Bangladesh University of Engineering and Technology, Bangladesh in 2012, respectively. She has joined as an Assistant Manager (Mechanical) in Bangladesh Sugar and Food Industries Corporation in 2008, under Ministry of Industries. She is now on deputation at Ministry of Industries and working as an Assistant Director (Programme) for the project named “Fortification of Edible Oil in Bangladesh” implemented by Ministry of Industries with the support of UNICEF and GAIN.