International Journal of Materials Chemistry and Physics
Vol. 2, No. 2, 2016, pp. 88-92
http://www.aiscience.org/journal/ijmcp

Effects of Bamboo-Corn Husk as Fillers on the Mechanical Properties in Polypropylene

P. U. Ofora[1, *], J. N. Nwokoye[2], E. U. Ekpunobi[1], C. A. Okpalaunegbu[1], M. Ezeanyika[1]

[1]Department of Pure & Industrial Chemistry, Nnamdi Azikiwe University, Awka, Nigeria
[2]Department of Chemistry, Federal College of Education, Umunze, Nigeria

Abstract

The mechanical properties of polypropylene composites of bamboo-cornhusk at 50:50 ratio were prepared at filler contents of; 0%, 10%, 20%, 30%, 40% and 50%. The particle size of the bamboo-cornhusk dust investigated was 150µm, Polypropylene composites of varying weight percentages of fillers in fixed weight of the polymer resin were produced for each filler type by the injection molding technique. From the mechanical properties determination, the composites showed an increase in the compressive and flexural strengths. The surface hardness and tensile strength showed irregular trends having its highest value at composition of 40% with values of 5.92 and 20.0096Mpa respectively. Thus, it was found that the mechanical properties depend on the polymer matrix-filler interaction, particle size, fiber population and distribution of the filler particles within the matrix. These results suggest that bamboo-cornhusk filler can be incorporated into polypropylene and be expected to improve its mechanical properties. Synthetic fillers which are made from petroleum are non-biodegradable and litter the environment, but these natural fibers are cellulosic, they can decompose and degrade thereby helping to relieve the environment from the threat that plastic pollution poses.

Keywords

Bamboo, Composites, Cornhusk, Mechanical Properties, Polypropylene

Received: December 14, 2015 / Accepted: January 23, 2016 / Published online: March 9, 2016

1. Introduction

In the recent years, polymeric composite materials are being used in variety of applications such as automotive, sporting goods, marine, electrical, industrial, construction and household applications. Polymeric composites have high strength and stiffness, light weight and high corrosion resistance [1]. Most of the composites available on the market today are produced with a high durability to ensure product longevity. Unfortunately, in order to make these products, companies have traditionally used non-biodegradable fibers, made from non-renewable (petroleum based) resources. The most important disadvantage of such composite materials is the problem of disposal after end use [2]. Polymeric composites are non-biodegradable and thus pose a serious threat to the environment. These raised the attention of people for the use of natural, sustainable, biodegradable and renewable resources [3]. In modern production environment, there is a great demand for every material to be recyclable or degradable. Natural fiber composites (NFCs) are composite materials that is formed by a matrix (resin) and a reinforcement (fiber), in which the fibers are natural i.e., mainly formed by cellulose and therefore originating from plants. Some of these fibers can be hemp, jute, flax, sisal, banana, kapok, bamboo and so on. NFCs markets are significantly on the rise, mainly because of

* Corresponding author
E-mail address: ucheofora@gmail.com (P. U. Ofora), pu.ofora@unizik.edu.ng (P. U. Ofora)

the recycling and environmental necessities [4].

1.1. Bamboo

Bamboo is one of the agricultural crops which can be exploited for the design and development of polymer composites material. Bamboo is a rapid fibrous growing plant available in abundance on the earth and mainly consists of roots, culms and leaves. The bamboo fibers are naturally possessed with finer mechanical properties, but are brittle in nature as compared to other natural fibers due to the extra lignin content covering the bamboo fibers. Presently bamboo is considered important plant fiber and has a great potential to be used in polymer composite industry. Its structural variation, mechanical properties, extraction of fibers, chemical modification, and thermal properties have made it versatile for the use in composite industry [5].

1.2. Corn Husk

Corn husk is one of the major agro-waste products. These underutilized agricultural waste products include wheat, rice, corn straw, corn and rice husk, corn and okra stalks, pineapple and banana bunch fibers. Study of these agricultural by-products will only support the rural community by adding value to their product, but will also protect the environment by prevention of burning those field leftovers, which is a common practice [6]. Corn husk which has become environmental waste is now being converted into useful industrial materials [4].

2. Materials and Methods

2.1. Materials

2.1.1. Sample Collection and Preparation

i. Polypropylene (PP) which is a round opaque non-toxic pellet with a density of 0.905g/cm^3 and melt flow index of 65g/10min was used for the study.

ii. Fillers

The fillers that were used in this study are bamboo powder and corn husk flour. The bamboo leaves were got from a bamboo tree in Nnamdi Azikiwe University, Awka. The bamboo leaves were washed, sun-dried and ground into powder with particle size of 150µm.

The corn husk was got from a farm in Okpuno Awka, Anambra state. The corn husk was washed, sun-dried and ground into powder with particle size of 150µm. 50g of the corn husk flour and 50g of the bamboo powder were measured out using the Jadever weighting machine (model JKH - 1000) and mixed in a small mixing bowl to get a uniform mixture of both fillers. The particle size of the mixture was found to be 150µm by the use of an electronic sieve.

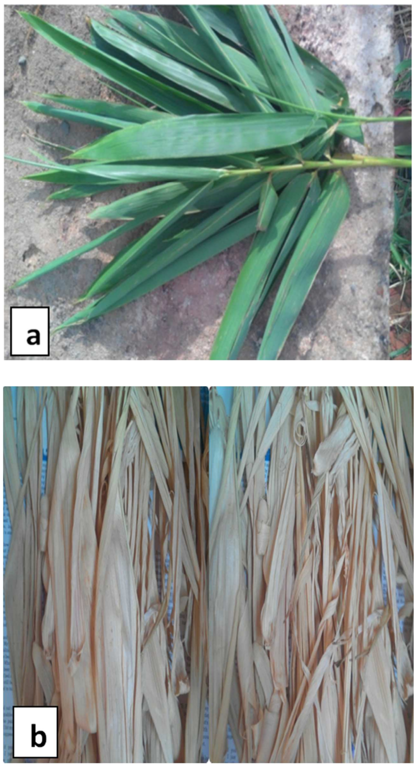

Fig. 1. a) Fresh bamboo leaf b) Dried corn husk.

2.1.2. Preparation of the Composites

The polypropylene based bamboo - corn husk reinforced composite was prepared by mixing 500g of virgin polypropylene with various bamboo-corn husk filler compositions of 10%, 20%, 30%, 40% and 50%. This was homogenized by in a mixing machine that produced the composite pellets. The composite pellets were introduced into the hopper of the injection molding machine (model JM 130MK IV 9.70.OZ) made in Indian and polypropylene composite samples were produced.

Fig. 2. Polypropylene composites.

2.2. Mechanical Properties Measurement

2.2.1. Determination of Compressive and Flexural Strengths of the Polypropylene Composites

The compressive and flexural strengths of the composites were measured according to the American Standard Testing

Method D-695 and D-790 respectively, using the compressive testing machine (model TUE C-100) with a load capacity of 100KN and computerized Universal Testing Machine (model TUE C-100) with a load capacity of 100KN respectively. The readings were automatically recorded and the values computed. The results of the measurements are shown in Tables 1 and 2.

2.2.2. Determination of Surface Hardness

The surface hardness of the polymer composite was measured by means of the Hardness Testing Machine (model DVRD-M SN-0109) made in England. The hardness value was then calculated using the equation;

$HB = 2P/\pi D (D - \sqrt{D^2 - d^2})$

Where HB – Hardness Brinell

P – Applied force (KN)

D – Diameter of the ball

d – Diameter of indenter impression.

The values were recorded in Table 3.

2.2.3. Determination of Tensile Strength

The tensile strength of the material was derived from the approximate relationship between the tensile strength and the hardness of a material using the equation:

$$TS\ (Mpa) = \{3.55\ HB\ (HB \leq 175)\}$$

Where HB is the brinell hardness of the material.

The calculated values of the ultimate tensile strength were got from the Brinell hardness using the formula;

$$Y = AX + B$$

Where Y = Ultimate tensile strength, A = Slope, X = Brinell hardness, B = Intercept [7].

The results were as shown in Table 4.

3. Results and Discussion

The results of the mechanical properties of the virgin polypropylene (control) and polypropylene bamboo-cornhusk composites are shown in the Tables and Figs. below.

3.1. Compressive Strength Result of the Polypropylene Composites

The compressive strength of a material is the force per unit area that it can withstand in compression.

The results showed that the use of bamboo-cornhusk as a filler greatly increased the compressive strength. This increase in compressive strength using bamboo-cornhusk filler could be attributed to better polymer-matrix interaction and adhesion which results in the stiffening of the polypropylene chain and thus exhibit a resistance to compression under applied strain. Thus bamboo-corn husk fibers can be used as fillers to enhance the compressive strength of polypropylene and this is in agreement with a research work done by *Ofora et al*., [8].

Table 1. The readings of the compressive strength of the polypropylene composites.

S/N	Filler load (%)	Compressive load (KN)	Compressive strength (N/mm^2)
1	0	1.354	1.98
2	10	1.930	2.3
3	20	2.230	13.5
4	30	2.325	14.1
5	40	2.360	14.3
6	50	2.565	15.6

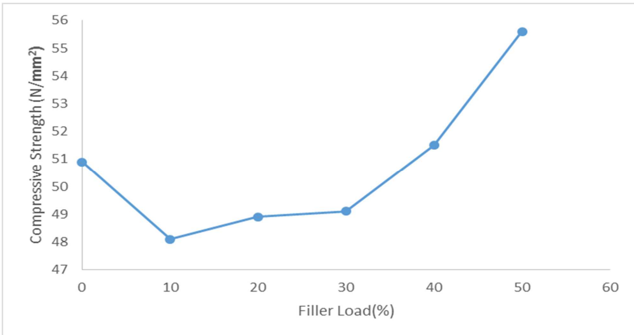

Fig. 3. Effect of filler loading on compressive strength of polypropylene composites.

3.2. Flexural Strength Result of the Polypropylene Composites

The flexural strength of a material is defined as its ability to resist deformation under load. The results of the flexural strength of polypropylene composites are shown in Table 2 and Fig. 4.

Table 2. Readings of the flexural strength of polypropylene composites.

S/N	Filler load (%)	Flexural force (KN)	Flexural strength (N/mm^2)
1	0	1.354	1.98
2	10	1.930	2.3
3	20	2.230	13.5
4	30	2.325	14.1
5	40	2.360	14.3
6	50	2.565	15.6

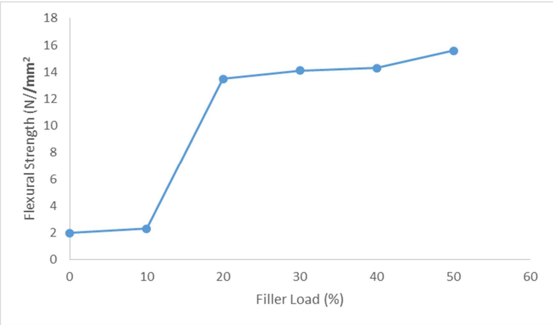

Fig. 4. Effect of filler loading on flexural strength of polypropylene composites.

It is seen from Table 2 and Fig. 4. above, that the flexural strength of polypropylene bamboo-cornhusk composites increases as the filler loading increases but from some research done on the use of bamboo fiber as a filler in polypropylene [9], [10], it was observed that bamboo increases the flexural strength of polypropylene and so we can say that the bamboo fiber was the active ingredient that increased the flexural strength. Thus bamboo-cornhusk fiber interacted well with the polymer matrix thereby imparting its flexural strength and exhibits good polymer filler phase interaction and adhesion thus offering good strength to the polypropylene resin. This is agreement with some other authors that have done something similar *Ofora, et al.*, [11].

3.3. Hardness Survey test of the Samples

Hardness is usually defined as resistance of a material to penetration. Brinell hardness test was used [12].

Surface hardness of virgin polypropylene sample and polypropylene composites are shown in Table 3 and Fig. 5.

Table 3. Surface hardness of the polypropylene composites.

S/N	Filler load (%)	Mean Ball Indenter Impression mm)	Hardness Value (Hb)
1	0	4.35	2.56
2	10	5.30	1.68
3	20	4.25	2.69
4	30	4.75	2.12
5	40	4.90	5.92
6	50	4.25	2.69

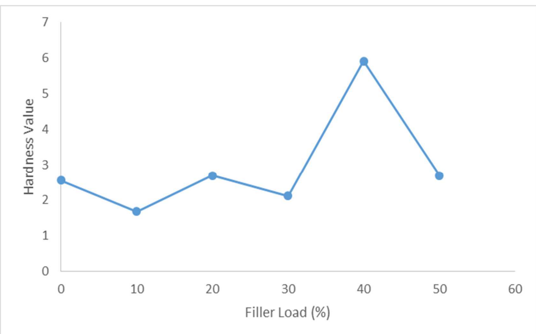

Fig. 5. Effect of filler loading on the surface hardness of polypropylene composites.

It can be deduced that the bamboo-cornhusk filler slightly increased the hardness value of polypropylene though it was not consistent and this increment in hardness could be due to the high fiber content of the fillers which imparts hardness to polypropylene. Since we got the highest hardness value of 5.92 using 40% of bamboo-cornhusk fiber, we can propose that the best composition for obtaining a polypropylene bamboo-cornhusk composite with very good hardness property is with 40% of bamboo-cornhusk filler.

3.4. Tensile Strength Result of the Polypropylene Test Samples

This is the stress at which the specimen breaks or ruptures, as measured in Mpa. This stress at failure is called the 'ultimate stress'. It is the most common of the mechanical property of polymers [13].

The results of the tensile strength of polypropylene composites are tabulated in Table 4 and shown in Fig. 6.

Table 4. Tensile strength of the polypropylene composites.

S/N	Filler load (%)	Brinell Hardness (HB)	Tensile strength (Mpa)
1	0	2.56	8.65
2	10	1.68	5.68
3	20	2.69	9.09
4	30	2.12	7.17
5	40	5.92	20.01
6	50	2.69	9.09

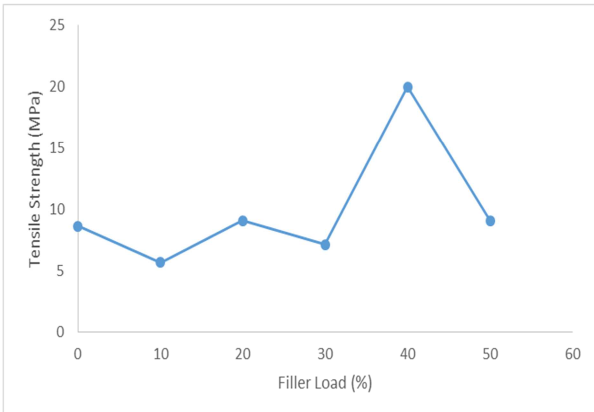

Fig. 6. Effect of filler loading on the tensile strength of polypropylene composites.

The decrease shown by the fillers could be due to high fiber agglomeration resulting in difficult stress transmission from matrix to fiber and disturbance of the continuity of the matrix phase and is in agreement with the results got by *Chitra et al.*, [4] from their research.

On comparing the tensile strength of virgin polypropylene to that of polypropylene bamboo-cornhusk composite, the tensile strength decrease from 8.6528 to 5.6784 but increases with increase in bamboo-cornhusk filler content (10% to 20%). The increment in tensile strength is not consistent and has the highest tensile strength value of 20.0096 using 40% of bamboo-cornhusk filler and this increase in tensile strength shows that addition of these filler to the polypropylene matrix improves it. It shows that the more the fiber fraction, the higher the tensile strength. This is in agreement with the work of Rahman *et al*., [14] and Abdul., *et al* [15].

4. Conclusion

Bamboo-cornhusk fiber has demonstrated its potential to be used as filler in polypropylene and the results of the studies are discussed as follows; the compressive strength has increased for the bio-composites when compared to virgin polypropylene though there was a reduction at first. The flexural strength of the bio-composites also increased as filler loading increases. The surface hardness and the tensile strength showed an irregular trend having its highest value at composition of 40% with values of 5.92 and 20.0096Mpa respectively. Thus, it was found that the mechanical properties depend on the polymer matrix-filler interaction, particle size, fiber population and distribution of the filler particles within the matrix.

Hence bamboo-cornhusk filler can be comfortably incorporated into polypropylene and be expected to improve its mechanical properties but is preferably used in low end applications where strength is not considered to that extent such as board, baskets, house hold utensils. Synthetic fillers which are made from petroleum are non-biodegradable and litter the whole surrounding and can remain there for decades, but these natural fibers are cellulosic, they can decompose and degrade thereby helping to relieve the environment from the threat that plastic pollution poses.

References

[1] Fried, J. R. (1999). Polymer Science and Technology, 2nd ed., Applied Publishers, London, pp. 369-375.

[2] Ashutosh, D., Anurag, T. and Chaturvedi, M. K. (2010). Plastic Waste and its Recycling. *VSRD Technical and Non-Technical Journal*; 1(1): 3.

[3] Chattopadhyay, S. K., Singh, S., Pramani, K. N., Niyogi, U. K., Khandl, R. K. and Uppaluri, R. (2011). Biodegradability Studies on Natural Fibers Reinforced Polypropylene Composites. *Journal of Applied Polymer Science*; 121: 2226-2232.

[4] Chitra, J. N. and Vasanthakumari, R. (2012). Studies on Polypropylene Biocomposite With Cornhusk Waste. *International Journal of Scientific and Engineering Research*; 3(7): 1-3.

[5] Chen, X., Guo, Q. and Mi, Y. (1998). Bamboo Fiber Reinforced Polypropylene Composites: A Study of the Mechanical Properties. *Journal of Applied Polymer Science*; 69: 1891-1892.

[6] Yilmaz, N. D. (2013). Effect of Chemical Extraction Parameters on Cornhusk Fibers Characteristics. *Indian Journal of Fiber and Textile Research*; 38: 29-34.

[7] Isakov, E. (2010). Tension Testing or Calculation. *Cutting Tool Engineering Plus;* 62(6): 1-5.

[8] Ofora, P. U., Eboatu, A. N., Arinze, R. U. and Nwokoye, J. N. (2014). Effects of Natural Fillers on Some Properties of Polystyrene. *International Journal of Scientific and Research Publications*; 4(7): 1-4.

[9] Bhandari, N. L., Thomas, S., Chapalk, D. and Rameshwar, A. (2012). Analysis of Morphological and Mechanical Behaviours of Bamboo Flour Reinforced Polypropylene Composites. *Nepal Journal of Science and Technology;* 13(1): 95-100.

[10] Ofora, P. U., Eboatu, A. N., Arinze, R. U. and Nwokoye, J. N. (2014). Effects of Fillers of Animal Origin on the Physio-mechanical Properties of Utility Polymer. *ISOR- Journal of Applied Chemistry (IOSR-JAC);* 7(7): 19-23.

[11] Al-Hasani, E. S. (2007). Study of Tensile Strength and Hardness Property for Epoxy Reinforced with Gloss Fiber Layers. *Engineering and Technology*; 25(8): 988-998.

[12] Billmeyer, F. W. (2007). Textbook of Polymer Science, 3rd ed., John Wiley and Sons, New York, NY. pp. 475-479.

[13] H.P.S Abdul, K. Bhat, I. U. H.., Jawaid, M., Zaidon, A., Hermawan, D. and Hadi, Y. S. (2012). Bamboo Fiber Reinforced Biocomposites: A Review. *Materials and Design;* 42: 353-368.

[14] Huda, S. and Yang, Y. (2008). Chemically Extracted Cornhusk Fibers as Reinforcement in Light Weight Polypropylene Composites. *Macromolecular Materials and Engineering*; 293(3): 235-243.