

# Exploring Bamboo Fiber Reinforced Acrylonitrile Butadiene Styrene (ABS) Polymer Composite by Characterization of Physical, Mechanical and Structural Properties

Rabeya Akter<sup>1\*</sup>, Md Rashedul Islam<sup>2</sup>, Budrun Neher<sup>1</sup>, Md Abdul Gafur<sup>3</sup>, Farid Ahmed<sup>1</sup>

<sup>1</sup>Department of Physics, Jahangirnagar University, Dhaka, Bangladesh

<sup>2</sup>Nuclear Power Plant Company Bangladesh Limited (NPCBL), Pabna, Bangladesh

<sup>3</sup>Pilot Plant and Process Development Centre, Bangladesh Council of Scientific and Industrial Research, Dhaka, Bangladesh

Email: \*rrabeya1306@gmail.com

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## Abstract

As we move toward the 21st century, increasing awareness of environmental impact is driving a shift toward natural-fiber alternatives. This study explores the utilization of bamboo fiber as the reinforcement for ABS polymer and its impact on the composite's properties and sustainability. Bamboo fiber reinforced ABS polymer composite is a biodegradable composite which was prepared by using a hot press machine at 180°C temperature and 50 KN load. Bamboo fiber was collected from local area of Savar, Dhaka, Bangladesh and ABS polymer was collected from local market of Dhaka, Bangladesh. In this study, different properties of composites like physical (bulk density and water absorption), mechanical (tensile properties and hardness) and structural (Fourier Transform Infrared Spectroscopy) properties were studied. The bulk density of composites was not altered consistently and it gave greater value for 5% and 15% composites. The water absorption enhanced for all composites with the accumulation of fiber content and soaking time. The reduction of tensile strength and Leeb's rebound hardness of the composites were observed with the increase of the fiber content in all compositions. Maximum (%) of elongation was found for 5% and 10% composite, and then it was decreased for 15% composite; however, elastic modulus increased with the increased of fiber content in composites. Fourier Transform Infrared (FTIR) spectroscopy study was done for structural characterization. It was observed that, at 15% fiber loading, an extra O-H bond appeared, implying more hydroxyl groups were introduced with the increased fiber content.

## Keywords

BF-ABS Composite, Hot Press Molding Machine, Tensile Strength, Leeb's Rebound Hardness, FTIR Spectroscopy

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## 1. Introduction

The application of natural fibers as reinforcements in polymer composites has gained significant attention in recent years due to their potential to enhance the mechanical properties, sustainability and environmental friendliness of the composites [1]-[6]. Among these, cellulosic fiber reinforced polymer composites are used for automotive components, aerospace parts, sporting goods and building industry and many other applications [7]-[11]. Some studies have already revealed that plant fiber or natural fibers are better for reinforcement of polymer for environment than the synthetic fibers and natural fibers offer several advantages over synthetic fibers, including low cost, low density, competitive mechanical properties, reduced energy consumption during production, and biodegradability [12]-[14]. For the past several years, the natural fibers have taken the attention of public because of their first growth comparable to fiber glass reinforced component [15]-[17].

Bamboo fiber, derived from the fast-growing and renewable bamboo plant, has emerged as a promising reinforcement material for various polymer matrices [18]-[20]. One such matrix is acrylonitrile butadiene styrene (ABS), which is a widely used engineering polymer known for its excellent impact resistance and mechanical properties [21]. ABS is a polymer obtained by copolymerization of three monomers of acrylonitrile (A, 23% - 41%), butadiene (B, 10% - 30%), and styrene (S, 29% - 60%). Different structural units give ABS different properties: acrylonitrile has good chemical resistance and high surface hardness; butadiene has good toughness; and styrene has good transparency and processing performance. When the three monomers are combined, the tough, hard, and rigid ABS resin is formed [22]. This study explores the utilization of bamboo fiber as the reinforcement for ABS polymer and its impact on the composite's properties and sustainability. The incorporation of bamboo fibers into ABS matrices presents an opportunity to create a composite material that combines the desirable attributes of both components.

Many scientists have been carried out their research work on bamboo composite. J. Tong *et al.* [23] found that bamboo fiber resulted in excellent tensile strength, impact, and flexural strength at a loading level of 27.71%. K Nirmal Kumar *et al.* [24] reviewed recent advancements in biodegradable polymer composites, explicitly cellulose fibers-reinforced PLA composites. M. Nurazzi Norizan *et al.* [25] reviewed the mechanical performance evaluation of bamboo fiber reinforced polymer composites and its application as bamboo fibers are very promising reinforcements for polymer composites. It is a remarkable alternative to steel in tensile-loading applications, with a tensile strength of 370 MPa [26]. A. Umaira

*et al.* reviewed the tensile properties of bamboo fiber reinforced polymer composites [27] and S. Qaiser found the improvement of flexure strength of bamboo reinforced concrete beams [28]. While bamboo fibers have been studied extensively with epoxy and PP [29], there's limited published data on bamboo/ABS composites specifically—most composite work on ABS uses synthetic reinforcements like glass fiber (ABS-GF).

In conclusion, the cited research studies provide valuable insights into the physical and mechanical properties of bamboo fiber reinforced ABS composites. So, this study may unlock the full potential of these composites and pave the way for sustainable and environmentally friendly engineering materials.

## 2. Materials and Methods

### 2.1. Raw Materials Collection and Processing

For sample preparation the bamboos were collected from local area and five pieces of bamboo were soaked at water for 10 days. Then almost uniform bamboo fibers were extracted manually from those bamboos by knife and hammers and ABS polymer at grain form were collected from local market and then ABS sheets were made by Hot Press Machine keeping both plate at temperature 180°C and Hydraulic press at 50 KN for 30 minutes.

### 2.2. Composite Preparation

After collecting the bamboo fibers and ABS polymer sheets of 13.5 × 7 cm they were cleaned and dried out for 7 days. For fabrication of composites two ABS sheets and bamboo fibers were kept at hot press machine by sandwiching for 30 minutes after reaching temperature at 180°C. The hydraulic pressure was kept at 50 KN and then it was cooled by flow of water. After that the temperature is fallen down that means after cooling bamboo fiber reinforced ABS composite were prepared. The ratio of bamboo fiber and ABS sheet maintained as 0% composite, 5% composite, 10% composite and 15 wt% composite respectively. **Figures 1-3** show extracted bamboo fibers, ABS polymer and 10 wt% BF-ABS composite which is obtained from hot press respectively. After that composites were finally ready for characterization.



**Figure 1.** Extracted bamboo fibers.



**Figure 2.** ABS polymer.



**Figure 3.** 10% wt BF-ABS composite.

### 3. Characterization of BF-ABS Composites

#### 3.1. Structural Property of Composites

##### Fourier Transform Infrared (FTIR) Spectroscopy

FTIR spectra of the samples were recorded at room temperature by using a double beam IR spectrometer in the wave number range of 400 - 4000  $\text{cm}^{-1}$ . In this experiment, the solid samples were finely pulverized with pure, dry KBr, the mixture is pressed in a hydraulic press to form a transparent pellet.

When the beam of light passes through the sample, it becomes less intense due to the absorption of certain frequencies. The absorbance of the sample at a particular frequency can be calculated as

$$A = \log\left(\frac{I_0}{I}\right) \quad (1)$$

where,  $I_0$  and  $I$  are the intensity of beam before and after interaction.

#### 3.2. Physical Properties of BF-ABS Composites

##### 3.2.1. Bulk Density

The bulk density of composites was determined according to ASTM C-134-76 [30]. The bulk density of the composite was measured by taking the weight and

dimensions of the sample by using the equation, Bulk density,

$$D = W_s/V = W_s/(L \times W \times H) \quad (2)$$

where,  $W_s$  is the weight,  $L$  is the length,  $W$  is the width and  $H$  is the height of the sample respectively.

### 3.2.2. Water Absorption

Water absorption test was carried out according to ASTM D570-98 [31]. Rectangular specimens were cut from each sample with dimension of  $2.5 \times 1$  cm. The samples were dried in an oven at  $60^\circ\text{C}$  for 6 hours and were weighed. In order to observe the composites, all samples were immersed in water for 288 hours at room temperature. Excess water on the surface of samples was removed by tissue paper before weighing. The percentage of water absorption was determined by using the following Equation (2),

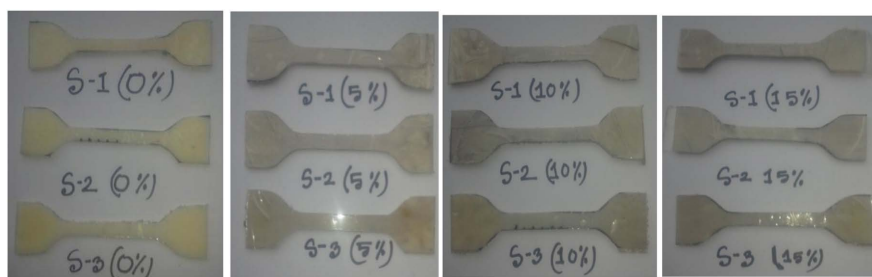
$$W_g = \frac{W - W_o}{W_o} \times 100 \quad (3)$$

where  $W$  and  $W_o$  are the weight of the sample after and before soaking in water.

## 3.3. Mechanical Properties of BF-ABS Composites

### 3.3.1. Tensile Properties of the Composites

Tensile test of composites was carried out according to ASTM D 3039/D 3039 M-00 [32] and **Figure 4** shows samples of different wt% of composites for tensile test. At first, the samples were dried into oven at  $60^\circ\text{C}$  for 24 hours to remove moisture. Dimension of the samples were measured. The average dimension of the samples was approximately  $105 \text{ mm} \times 7.5 \text{ mm} \times 4.5 \text{ mm}$ . Gauge length of UTM was 50 mm and cross-head speed was 2 mm/min. Then the test specimen was gripped into the jaws of Universal Testing Machine with a 10KN load cell. The test was monitored with a computer through Q-mat professional (Tinius Olsen, UK) software. Tensile strength, yield strength, elongation (%), maximum force and elastic modulus were easily found from the software output. The average TS was obtained from the results of three samples for each percentage.



**Figure 4.** Tensile test samples of different wt% of composites.

### 3.3.2. Leeb's Rebound Hardness

The Leeb hardness test of the composites was carried out with an H1000 portable hardness tester according to ASTM A956-06 [33]. The hardness test samples di-

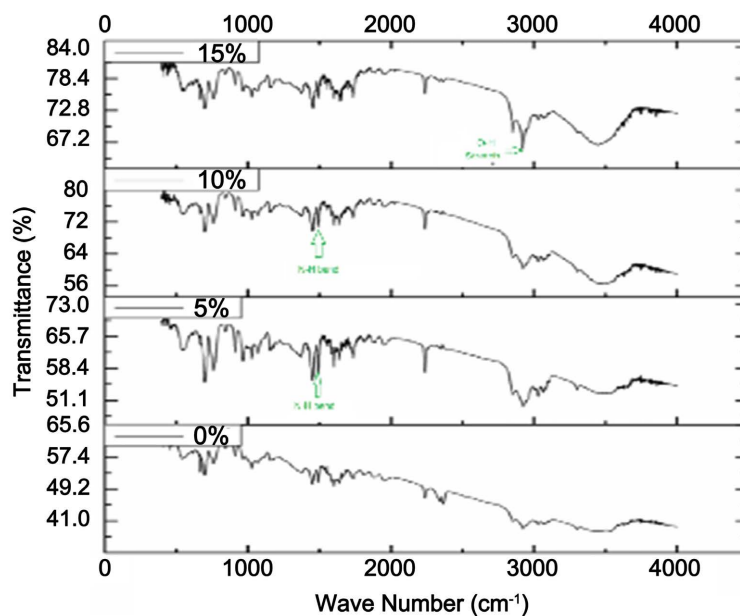
mension was 109 mm × 9 mm × 4 mm approximately. The composite sample was placed over a cemented table using glycerin. By pressing the button, samples were hammered by carbide ball of Leeb's tester. The ball bounces back from the samples. The electronic sensor recorded the rebound velocity. Average data was considered as the Leeb hardness of the sample.

## 4. Result and Discussions

### 4.1. Structural Property of BF-ABS Composites

#### Fourier Transform Infrared (FTIR) Spectroscopy

**Figure 5** shows the FTIR spectrum in the frequency range (400 - 4000  $\text{cm}^{-1}$ ) for different wt% of bamboo-ABS composites. Figure indicates that the major peaks for 15% BF-ABS composite at about 2922.32, 2857.93, 2237.32, 1639.90, 1457.09, 1025.48, 764.78 - 706.37  $\text{cm}^{-1}$  are due to the presence of C-H stretch, O-H stretch,  $\text{C}\equiv\text{N}$  stretch, C-O stretch, C=C stretch, C-H scissoring and bending, C-N stretch, C-H bend respectively [34].



**Figure 5.** FTIR spectra of different wt% composites.

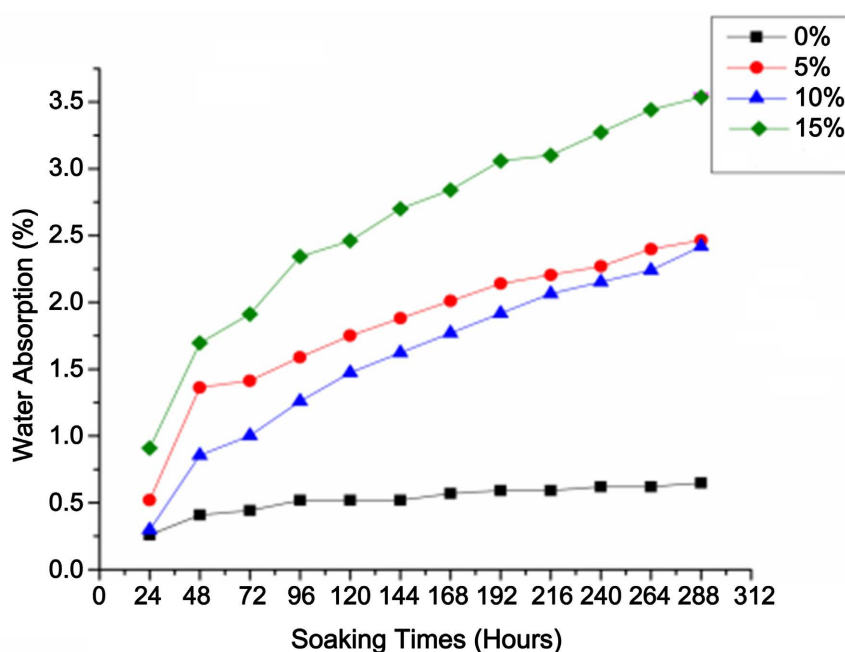
From the figure, it is observed that in the 5% BF-ABS composite, a new N-H bond appears, showing characteristic stretching behavior. This N-H bond is also present in the 10% composite. However, in the case of the 15% composite, an additional O-H bond is detected. Therefore, the incorporation of bamboo fiber into the ABS matrix results in the formation of two new functional groups: N-H and O-H.

### 4.2. Physical Properties of Bamboo-ABS Composites

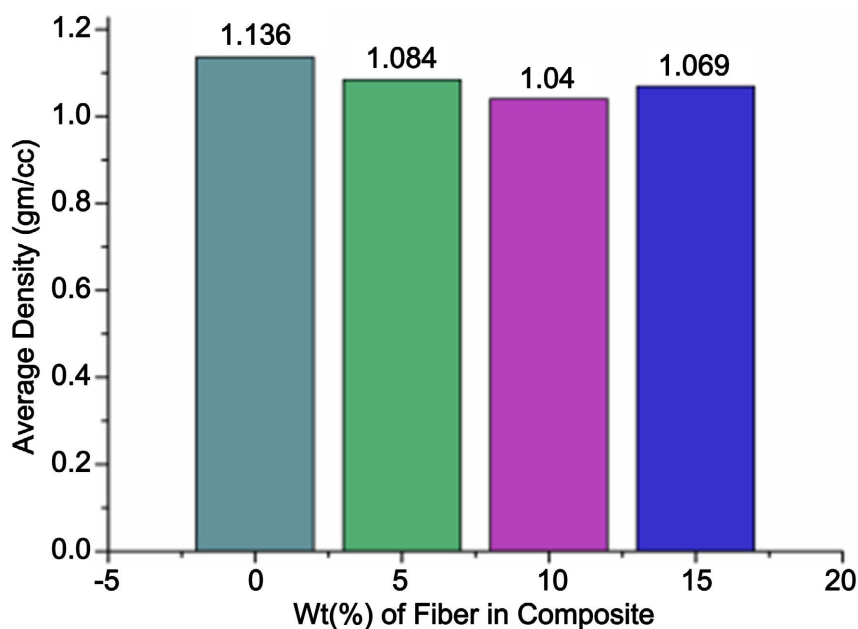
#### 4.2.1. Water Absorption

**Figure 6** shows the water absorption of bamboo fiber reinforced ABS composites

as a percentage of dry weight after 288 hours immersion in water. The result shows the water absorption is higher for 15% wt composite and lower for 0% wt composite. It was noticed that the water absorption of 5% wt% composite is greater than 10%. The results suggest that polymer like ABS can absorb a small amount of water while BF reinforced ABS composite absorbs more water. Bamboo fiber is hydrophilic in nature due to the presence of polar group. Hydrogen bond occurs between the free hydroxyl groups of the cellulosic molecules with water molecule.



**Figure 6.** Water absorption of different wt% composites.



**Figure 7.** Bulk density of different wt% composites.

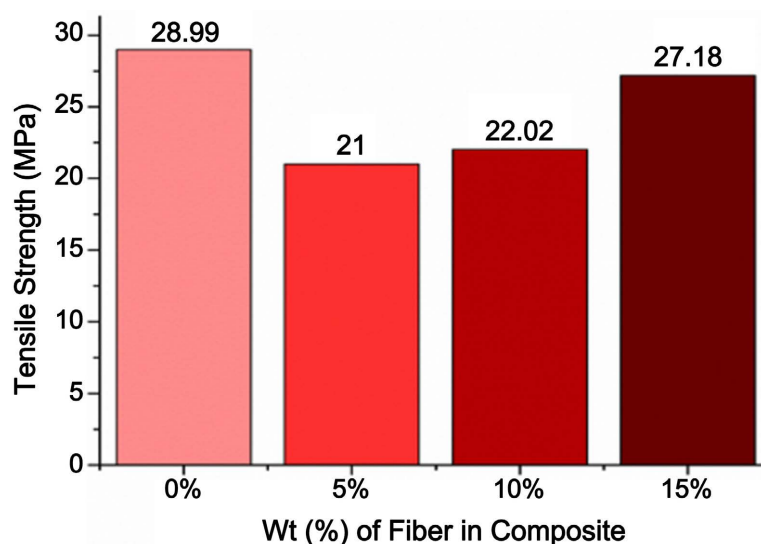
#### 4.2.2. Bulk Density

**Figure 7** shows the variation in the density of bamboo fiber reinforced ABS composites. **Figure 7** indicates that the bulk density of the prepared composites is not homogeneous. Bulk density of bamboo-ABS composites increased a little first, then it started to decrease with the addition of fiber content. When the fiber content reached at 20% it further started to increase. Bulk density is found to be high for 5 wt% and 20 wt% composites. Bulk density increased means the composite becomes denser. Therefore 5 wt% and 20 wt% composites may be considerable for heavy load application and the others can be used for light load application.

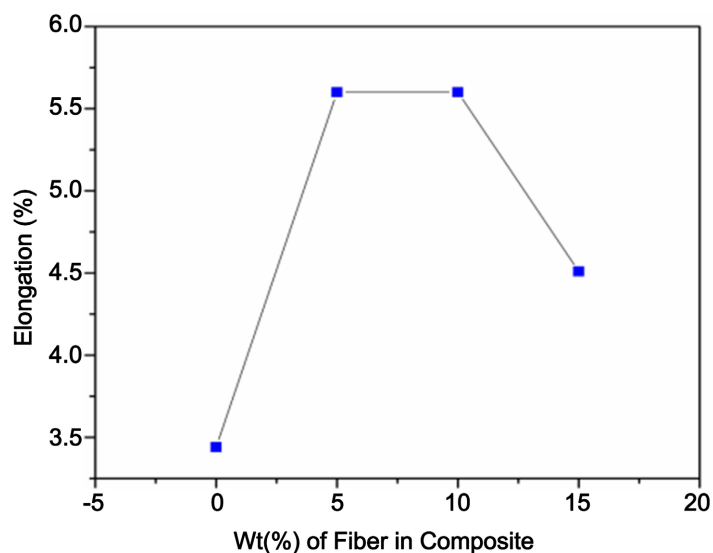
#### 4.3. Mechanical Properties of Sawdust-ABS Composites

##### 4.3.1. Tensile Strength of the Composites

**Figure 8** shows the tensile strength for different wt% of bamboo reinforced ABS composites. **Figure 8** indicates that the tensile strength of the bamboo-ABS composites decreased with the increased of fiber up to 5%. After adding 10% fiber tensile strength increased slightly. Then for further addition of fiber content (up to 15%) tensile strength increased with the value 27.18 MPa for 15% BF reinforced composite. It might arise due to poor interfacial adhesion between fiber and polymer matrix. Tensile strength depends on number of factors—fiber loading, matrix strength, fiber adhesion between fiber and matrix, orientation of fiber etc. For short fiber, the interfacial bonding is important. **Figure 9** shows the graph of average percentage of elongation vs different wt% of fiber content. The maximum value of percentage of elongation (%E) is for 5% and 10% and it is 5.60 and decreases for 15% composite. This increase in tensile strength can be affected by several factors. Fiber may have interfered with the crystallinity of the polymer matrix or voids might have been generated with the increase in fiber content of the composite, thereby contributing to the decrease in the tensile strength of the material [35].



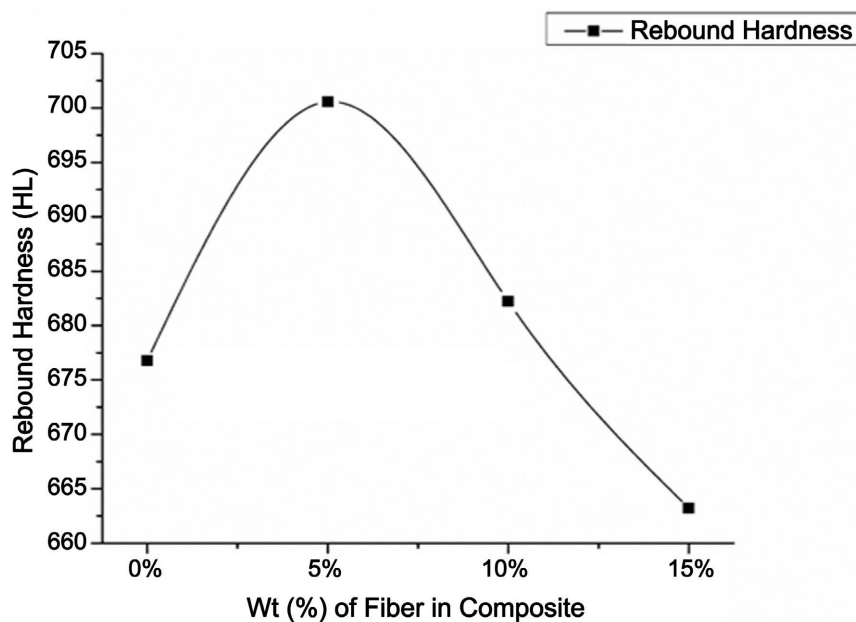
**Figure 8.** Tensile strength of different wt% of BF-ABS composite.



**Figure 9.** % of elongation of different wt% of BF-ABS composite.

#### 4.3.2. Leeb's Rebound Hardness of the Composites

**Figure 10** shows the comparisons graphs of Rebound Hardness (HL). It can be seen that maximum value of the Rebound Hardness (HL) is for 5% bamboo fiber reinforced ABS which is 700.56 HL. Then with the increase of wt% of bamboo fiber the rebound hardness decreases. It means that the 5% composite has lowest energy absorption capacity of load than the other three.



**Figure 10.** Leeb's rebound hardness (HL) of different wt% of BF-ABS composite.

## 5. Conclusion

The physical, mechanical and structural properties of bamboo-ABS composites for different wt% of fiber were measured. FTIR analysis revealed the presence of

a new N-H stretching vibration in the 5% BF-ABS composite, indicating the formation of a new bond due to the incorporation of bamboo fiber. At 15% fiber loading, an additional O-H bond was observed, suggesting increased hydroxyl group content associated with the higher fiber content. The maximum bulk density was for 0 wt% and after the addition of BF bulk density of composite was decreased. Water absorption (%) increased with the increase of fiber content and soaking time. The tensile strength, elongation (%) and hardness of the composites decreased with the increase of the fiber content.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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