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Bamboo Fiber Composite Eco-Icebox (BFEI)

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Abstract: One of the common environmental problems is plastic disposal. Polystyrene trash, such as food storage containers and packaging were a major source of solid waste and pollution in our country. Today, life would be impossible without polymer materials, both for practical and economic reasons. Despite their obvious day utility, polymer pollute the environment. The objective of this research was to develop bamboo fiber composite eco-icebox (BFCEI) using bamboo fiber at 3.00 %, 6.00 % and 9.00 %, clay soil and corn starch and to characterize the BFCEI with regard to thermal conductivity, tensile strength and density. The characteristic were obtained than establish to food container polystyrene. Firstly, the bamboo fiber was extracted using Roll Mill Machine and tested for its tensile strength and FTIR analysis. Liquid limit and plastic limit of clay soil was experimented following the British standards. Thermal conductivity was tested using hot plate method. Tensile strength data was acquired from Universal Testing Machine. Density was evaluated using weighing balance and ruler. Thermal conductivity of ratio 1, ratio 2 and 3 was 128.074 W/mk, 122.748 W/mk and 116.518 W/mk. The tensile strength shows the value was increasing parallel with bamboo fiber content. The result shows bamboo fiber composites have strength to withstand the tensile forces but less compared to polystyrene foam by 63.00 %. However, density of BFCEI increases simultaneously with increasing bamboo fiber content. Nevertheless, the result was compared with polystyrene data. In this study, the polystyrene presents better data compared to BFCEI in terms of thermal conductivity, tensile strength and density. Therefore, optimization of the ratio would be a better choice to improve the product characteristics in the future.

Keywords: Bamboo Fiber, Polystyrene, Thermal Conductivity, Tensile, Density

1. Introduction

The annual global solid waste production has recently come near 17 billion tons and is supposed to hit 27 billion tons by 2050 [1]. Non-biodegradable materials either remain in landfill for hundreds of years or incinerated though release greenhouse gases [2]. Relatedly, Sustainable Development Goals (SDP) 12 request a transformation of global activities towards using eco-friendly production methods and diminishing the amount of waste [3]. Natural plant fiber composites which mainly

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composed of cellulose, lignin and hemicellulose had been developed to invent various engineering products that benefit biodegradability and, ecological stability [2] [4]. Bamboo for example widely used in the construction industry due to its properties and to manufacture handicrafts [5].

The problem with the polymer materials as it is the major contributor to solid waste generation and possesses environmental pollution, it is used in daily life because of their economic relevance and properties [6]. Moreover, polystyrene stays intact for years and aid the fire burning during dry season [7]. Therefore, it generates greenhouse gases while polymer trash incineration pollutes the environment by emitting toxic gases [8]. The objective of this study is to produce bamboo fiber composite eco-icebox (BFCEI) using three different ratios made of clay, bamboo fiber and corn starch and to characterize and compare the performance the BFCEI with polystyrene icebox in terms of thermal conductivity, tensile strength and density.

The most important function of food packaging is to preserve the quality and safety of products throughout transportation and storage while prolong their shelf life by avoiding harmful states like spoilage and chemical contaminants [9]. Biodegradable food container and its advantage and disadvantage was shown in Table 1. The studies conclude that the biodegradable food container can reduce waste management cost because it is brittle and water sensitive but however the disadvantages are poor impact resistant and the tensile strength is low.

Table 1: Biodegradable food container and its advantage and disadvantage

Types	Advantage and Disadvantage	Reference
Coated containers made of paperboard	This markedly available food container is degradable, but paper usage is the source of toxic pollutants.	[10]
Baked starch-based foam containers	The baked starch container can help to lower the waste management cost still it is brittle and water sensitive	[10] [11]
Thermoplastic corn starch	Food container from corn starch thermoplastic is more flexible and elastic, but the elongation at break slightly	[12]
Pineapple crown cellulose for the preparation of the recyclable container	The pineapple crown contains natural fiber, yet the tensile stress reduces as the moisture increases	[13]

Besides, bamboo is a fast growing, valuable and existing natural resource in most developing countries and known for its exceptional material qualities. The fiber extracted from bamboo is prominent for its low density, stiffness and most importantly they are emitted from chemicals [14]. Previous studies had utilized bamboo fiber in their studies. First of all, bamboo fiber reinforced epoxy composite Huang &Young [15] stated that the bamboo fiber gives good reinforcing effect but low tensile strength. Then Muhammad [16] revealed that the oriented bamboo fiber mat shows good bending modulus still it is brittle and low fracture toughness. However, when bamboo fiber was used in plastic reinforcement as Gu [17], the tensile strength improved bu have low flexural modulus. Xia [18] used bamboo fiber in asphalt mixture and concluded that the mixture shows it has better moisture ageing and good at oil absorption properties.

This study is important to reduce the polystyrene products in our daily lives and minimize the impact toward environment and future generations. This non-biodegradable materials remains on earth for thousands of years without any degradation and needs an incineration process to break down. However, incineration is also a concern because it uses more energy to burn the materials and leaves ash a by-product, resulting in the landfill. Therefore, alternative to polystyrene material are needed and in this study, the use of bamboo fiber, clay and corn starch will be implemented to produce an icebox.

2. Materials and Methods

Methodology flow chart of this study were shown in Figure 1 to achieve the objectives. This method in the flow chart was used to obtain the data.

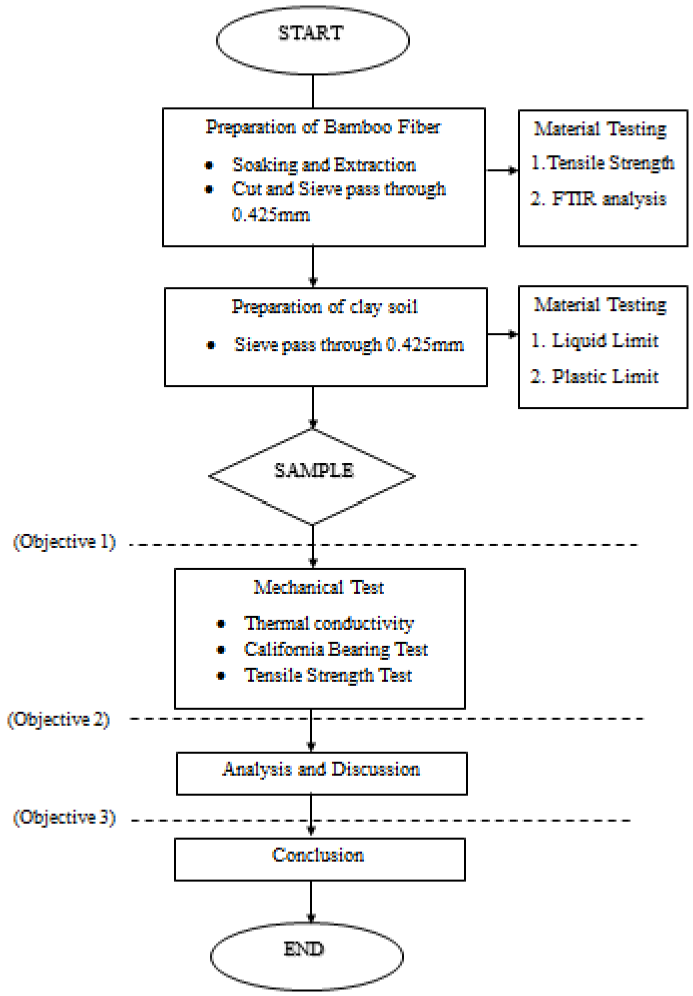

Figure 1: Flow Chart of Study

2.1 Preparation of material

The preparation of this product uses natural materials such as bamboo fiber as shown in Figure 2, clay soil as shown in Figure 3 and corn starch. This product mixes all the material so that the physical product can be the shape and strength of all the material. Bamboo fiber used at three different ratios while clay soil and corn starch were in constant ratio as presented in Table 2.

Figure 2: Bamboo fiber

Figure 3: Clay soil

Table 2: Quantity of Material in Sample

Materials	Ratio 1 (R1)	Ratio 2 (R2)	Ratio 3 (R3)
Bamboo fiber (Bf),g	30	60	90
Clay soil (C),g	1000	1000	1000
Corn starch (S),g	100	100	100
Water,ml	450	460	470
Ratio (Bf:C:S:w)	0.3:10:1:0.45	0.6:10:1:0.45	0.9:10:1:0.45

2.2 Methods

Bamboo fiber was extracted by soaking for 72 hours and then placed in the mill roller machine in Dyeing and Finishing Technology Workshop [19]. The extracted bamboo fiber was let for dry for 48 hours and combed to release the knot between the fibers. Next the bamboo fiber was sieved using 0.425 mm sieve. The bamboo fiber was tested for its tensile strength based on [20]. The tensile strength of bamboo fiber was calculated using Equation 1. P stands for load at break and r stands for radius of bamboo fiber. Fourier transform infrared spectroscopy (FTIR) by following method suggested by [21]. Clay soil was tested according to [22] to obtain the liquid and plastic limit of the soil and implemented in developing icebox. By using ratios stated in Table 1, the icebox was developed based on the size required for strength testing such as thermal conductivity, tensile strength and density based on Ratio 1(R1) with 3.00 % of bamboo fiber, Ratio 2 (R2) with 6.00 % of bamboo fiber and Ratio 3 (R3) with 9.00 % of bamboo fiber. Thermal conductivity was tested using Hot plate method suggested by [23] and calculated using Equation 2. Furthermore, tensile strength testing was done through Universal testing machine by following ASTM D638 standard and evaluated using Equation 3. Finally, density was done as suggested by Zheng [24] and analyzed using Equation 4. So, as to achieve the third objective, performance of BFCEI in terms of thermal conductivity, tensile strength and density was compared to polystyrene.

$$\sigma = \frac{P}{\pi r^2} \qquad Eq. 1$$

where, P is load at break in N and r is radius in mm

$$k = \upsilon_1 k_1 + \upsilon_2 k_2 \qquad Eq. 2$$

where, υ is volume of fraction of each material and k is thermal conductivity in W/mk

$$\sigma = \frac{P}{A} \qquad Eq. 3$$

where, P is Load at break in N and A is area of specimen in m^2

$$\rho = \frac{weight(kg)}{volume(m^3)} \qquad Eq. 4$$

where, ρ is density and calculate by weight in kg over volume in m^3

3. Results and Discussion

3.1 Material Testing

Bamboo fiber and soil was tested for its strength before cooperating based on ratios. Bamboo fiber was tested for its tensile strength and FTIR analysis while soil was tested for its liquid and plastic limit.

3.1.1 Single Fiber Tensile Test

Single fiber was tested using Universal testing machine using 20 specimens to evaluate the average value. By using Equation 1, tensile strength was calculated by using the load at break and diameter at 160 µm adopted from [15]. The average tensile strength of untreated single bamboo fiber was to be 68.693 MPa. Compared to Chin, 2020 [20], it was stated that the tensile strength of treated bamboo fiber with 2.00 % NaOH was 283 MPa. Alkali treated bamboo fiber shows higher tensile reading if compared to [10].

3.1.2 Fiber FTIR Analysis

FTIR analysis was done using Agilent Cary 630 FTIR spectroscopy and the was presented in Figure 4.The absorbance peak of 1500 to 1750 cm^{-1} shows that the presence of lignin was can be seen in the spectrum [25]. Moreover, the highest peak absorbance reading shown was 3291 cm^{-1} spectrum vibration which is C-H stretch under alkynes functional group. As stated by [26], the peak absorbance shows the presents of hemicellulose and cellulose compounds.

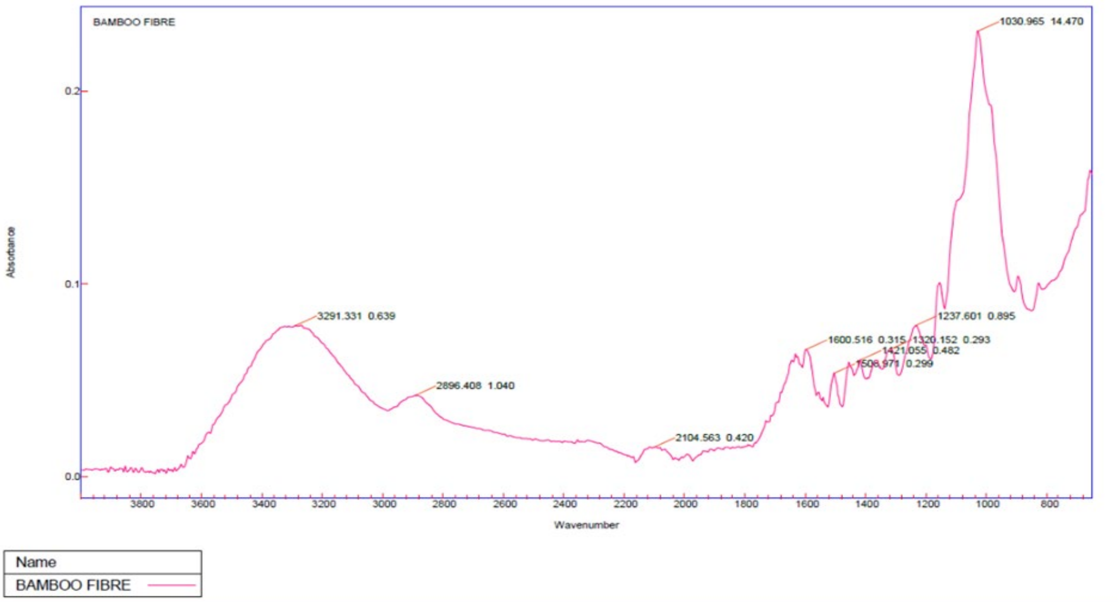

Figure 4: FTIR Spectrum of Bamboo Fiber

3.1.3 Soil Liquid and Plastic Limit Test

Liquid limit was to determine the water content at which the soil changes from plastic to liquid by using penetration meter. Plastic Limit test was done characteristic the soil based on their plasticity and water content. Both of test was done according to BS 1377-2:1990. The liquid limit was found to be 40.21 % which conclude that the moisture content should not exceed the value to get the plasticity characteristic of the soil and used to develop BFCEI. Nevertheless, plastic limit test reading shows 7.27 which is more than 7 and indicates that the soil is medium degree of plasticity and clayed silt type. Thus, clay soil is suitable to develop into BFCEI due to its plasticity which can be deformable and while developing, the moisture content should not be more than 40.21 %.

3.2 Icebox Test

Three tests were done to characterize the BFCEI which is thermal conductivity, tensile strength and density while compared to polystyrene.

3.2.1 Thermal Conductivity Test

Thermal conductivity test was done to identify the heat transfer ability of the samples with different ratio of bamboo fiber content. By using Hot plate method, the temperature distribution data was taken after 60 minutes. Next, the thermal conductivity was evaluated using Eq. 2. As presented in Table 3, it was obtained that the thermal conductivity was decreasing as the bamboo fiber content was increasing. R1 reads 128.074 W/mk, R2 reads 122.748 W/mk and R3 shows 1116.518 W/mk. However, compared to polystyrene, the thermal conductivity of BFCEI is very higher than polystyrene which shows 1.660 W/mk. It can be concluded that, the polystyrene is the poor heat conductor while BFCEI was good heat conductor. Though, icebox material needs to be poor heat conductor to enable it to hold on low temperature for longer time and preserve the food kept inside.

Table 3: Thermal Conductivity Result

Sample	Thermal Conductivity (W/mk)
R1	128.074
R2	122.748
R3	116.518
Polystyrene	1.660

3.2.2 Tensile Strength Test

Tensile strength was tested using Universal testing machine with the rate of 2mm/min and gauge length of 40 mm. As displayed in Table 4, the tensile strength of R1 was to be 641.558 N/m^2, R2 shows the tensile strength of 748.377 N/m^2 and R3 shows 996.429 N/m^2. The tensile strength was growing as the bamboo fiber content increases from 3.00 % to 9.00 %. Yet, the tensile strength of polystyrene was 2748.252 N/m^2. The tensile strength of polystyrene was more than bamboo fiber composite icebox due to the clay soil used as the matrix.

Table 4: Tensile Strength Result

Sample	Tensile Strength(N/m^2)
R1	641.558
R2	748.377
R3	996.429
Polystyrene	2748.252

3.1.3 Density

After tensile strength, density of the samples was evaluated and presented in Table 5. By using Equation 4, the density was calculated. The weight was taken using weighing balance and the volume measured using ruler. The result shows the bamboo fiber content increases the density. R1 with 3.00 % of bamboo fiber shows 1.181 g/cm^3, R2 with 6.00 % bamboo fiber content has 1.277 g/cm^3 of density and R3 shows 1.297 g/cm^3 value of density. Compared to polystyrene the BFCEI ratios shows very high value because the density of polystyrene is 0.016 g/cm^3. BFCEI tend to sink while polystyrene floats when placed in water. Previous studies [27] also shown the bamboo fiber composites made of polybutylene succinate possesses that the density is higher than the density of water which is 1.24 g/cm^3.

Table 5: Density Test Result

Sample	Density (g/cm^3)
R1	1.181
R2	1.277
R3	1.297
Polystyrene	0.016

4. Conclusion

The study was done to develop the bamboo fiber composite eco-icebox (BFCEI) using bamboo fiber, clay soil and corn starch. The BFCEI was developed within three ratios. The content of bamboo fiber was manipulated while ratio of clay soil and corn starch were in constant. Next, the BFCEI was characterized through assessing its strength such as thermal conductivity, tensile strength and density. Thermal conductivity of ratio 1 shows the value of 128.074 W/mk, ratio 2 shows the value of 122.748 W/mk and ratio 3 shows 116.518 W/mk. The thermal conductivity of BFCEI was decreasing as the bamboo fiber content was increasing. The tensile strength of BFCEI of R1 reads 641.558 N/m^2 while R2 and R3 shows 748.377 N/m^2 and 996.429 N/m^2. It can be seen that the tensile strength grows concurrently with bamboo fiber content. However, density value of BFCEI shows the density increases with the bamboo fiber content. Comparing with polystyrene characteristic, polystyrene was poor conductor of heat which, and have higher tensile strength compared to BFCEI and the polystyrene floats with lower density than BFCEI which have higher density and sink. Thus, need more optimization and method selection in the future. Alternative material for clay soil such as recycled paper or saw dust.

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