Progress in Engineering Application and Technology Vol. 4 No. 2 (2023) 602-610
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Optimization of Sugarcane Bagasse Ratio for Eco-icebox Composite

Shasmitra Raja Sehar[1], Nor Haslina Hashim[1]*

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology University Tun Hussein Onn Malaysia, Hab Pendidikan Tinggi Pagoh, KM1, Jalan Panchor, 84600 Panchor, Johor, MALAYSIA.

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2023.04.02.061
Received 15 January 2023; Accepted 12 February 2023; Available online 12 February 2023

Abstract: Non-biodegradable wastes are one of major global concern. The uses of non-biodegradable materials increase, the generation of polymer solid waste of the country increases that reflect the increases in the rate of air pollution, land pollution, water pollution, environment and health risks. This project aims to produce a sugarcane bagasse composite eco-icebox (SBCEI) made of sugarcane bagasse and fenugreek seed powder and the SBCEI characterized in term of thermal conductivity, tensile strength, density and water absorption to replace polystyrene icebox in the market. In the preparation step, the bagasse waste was collected and pretreated with 10% NaOH, oven dried and grinded into small particles. The fenugreek seeds were roasted and grinded into powder form for the sample making. The bagasse was initially tested for tensile strength while the powdered fenugreek seed was tested for solubility and pH. The composite samples with three different ratios R1 (1:1:3), R2((2:1:3) and R3(3:1:3) in same size of bagasse, fenugreek seed powder and water were prepared, dried and tested for tensile strength using Universal Testing Machine, thermal conductivity using hot plate, density and water absorption using weighing balance. The thermal conductivity of polystyrene was 19.53 W/mK and the tensile strength was 6.011 N/mm^2. Thermal conductivity of R1, R2 and R3 were 19.71 W/mK, 20.05 W/mK and 20.67 W/mK respectively. R1 composite have slightly high thermal value than polystyrene that shows it a poor heat conductor. The tensile strength of R1, R2 and R3 were 91.981 N/mm^2, 59.859 N/mm^2 and 55.079 N/mm^2 respectively. This result shows bagasse composites have strength to withstand the tensile forces compared to polystyrene. However, density of SBCEI R1, R2 and R3 were 1.1107 g/cm^3, 1.1162 g/cm^3 and 1.1185 g/cm^3 respectively. Nevertheless, the result was compared with polystyrene data. In this study, the polystyrene presents better data compared to SBCEI in terms of water absorption and density. Therefore, optimization of the ratio would be a better choice to improve the product characteristics in the future.

Keywords: Polystyrene, Sugarcane Bagasse, Biodegradable

1. Introduction

The production of global solid waste nearly hits 17 billion tons annually and is expected to reach 27 billion tons by 2050 [1]. The number of population and urban development in the developing process results in major solid waste production [2]. Solid Waste (SW) classifies into two categories which are biodegradable and non-biodegradable wastes [3]. Biodegradable solid waste are the wastes that can

**Corresponding author: haslina@uthm.edu.my*

easily decompose and degrade by natural factors like microbes, abiotic components like temperature, UV, oxygen, water and does not lead to hazardous pollution mostly [4]. While non-biodegradable solid wastes that cannot decompose or degrade naturally and remain on the earth surface for decades and thousands of years. They end up polluting the environment in various ways. Therefore, incineration and land burying are the only methods that have been used to dispose of the non-biodegradable solid wastes [5].

Polystyrenes known as non-biodegradable plastic, where due to its chemical stability and durability of polymers waste does not easily degrade in landfills and undergoes an incineration process pollutes the environment and health [6]. Generation of plastic waste is increasing yearly as the human population increase because plastic use becomes one of the necessary items in the daily life and polystyrene food containers are one of the plastics that generates in large quantity every day [7]. Objective of this study is to produce an eco-icebox made of sugarcane bagasse composite using different ratios of bagasse and fenugreek seed powder and analyze the bagasse composite icebox in terms of physical like density, tensile strength, thermal conductivity, water absorption and chemically like pH test to compare with polystyrene-icebox.

There are biodegradable and non-biodegradable food containers. Biodegradable food containers are mostly made off bio-based polymers or natural fibers which can easily decompose by microorganisms and natural agents. Examples of biodegradable food containers that are available in markets are containers made of palm leaf, bagasse, bamboo, wheat straw, rice husk and more. Meanwhile, non-biodegradable food containers are made of plastic like polyethylene, polystyrene that will take a very long period to decay, which results in environmental pollutions and health effects. Incineration method used to dispose the non-biodegradable waste from earth surface turns them into ash form pollutes the air quality also [8][9][10].

This project uses bagasse and fenugreek seed, where both materials are biodegradable. Bagasse waste is used because sugarcane in one of the Malaysia's agricultural crops and easily available in our country. After the sugarcane juice extraction process the bagasse are thrown as waste only. As for fenugreek seed, fenugreek crop that can grow in any weather and widely use in medical and cosmetic field. Fenugreek seed uses as a bonding element in Paper Mache products. Plus, they are available anywhere in affordable price.

This study had three limitations like the material used is only sugarcane bagasse that is thrown as waste and fenugreek seed powder. The project was conducted using three different ratios of the sugarcane bagasse, Fenugreek seed powder and water. The project product tested for thermal conductivity, tensile strength, density and water absorption only to identify the bagasse composite icebox can replace the polystyrene icebox.

2. Materials and Methods

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

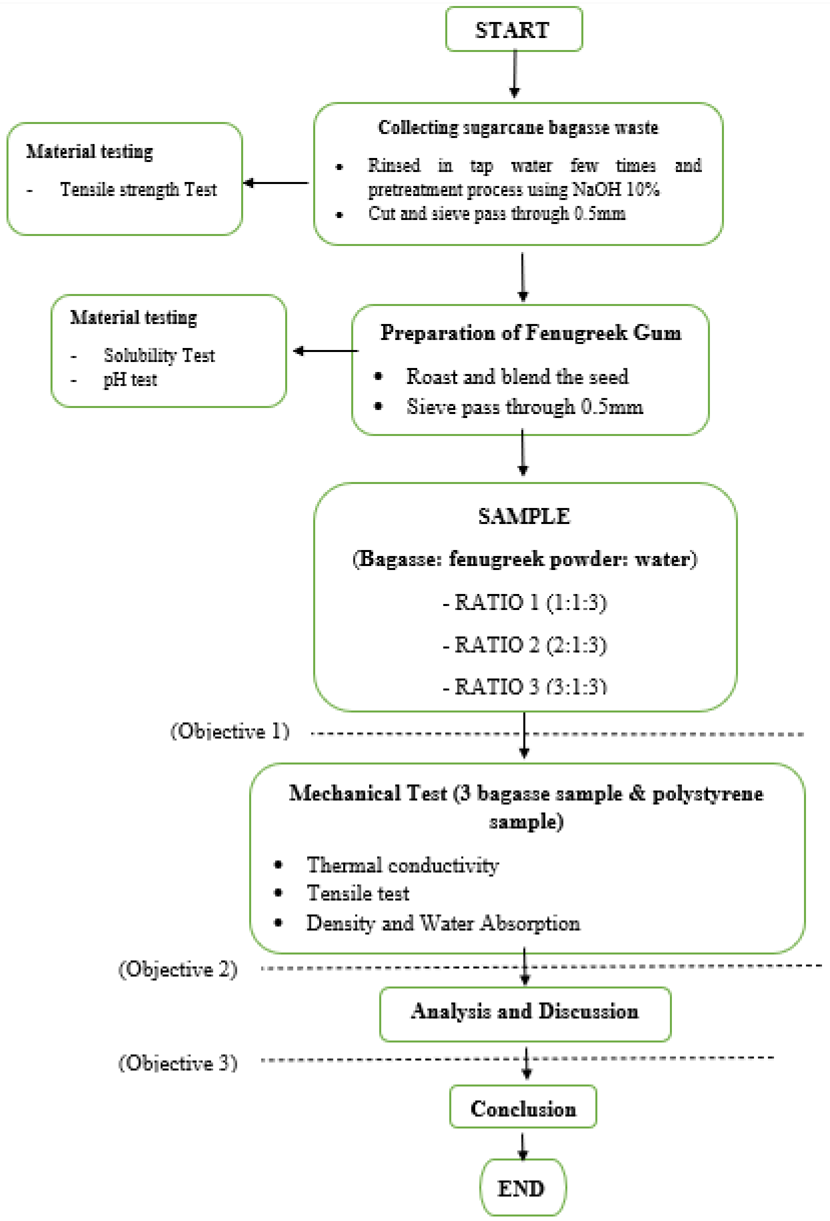

Figure 1: Flow Chart of Study

2.1 Preparation of Materials

This project uses agricultural waste as main material like sugarcane bagasse and fenugreek seed powder only [11][12]. The bagasse and the fenugreek seed powder mixed using water to produce the composite product. The bagasse used at three different ratios while fenugreek seed powder and water were inn constant ratio as shown in Table 1.

Table 1: Ratios of Samples

Materials	unit	Ratio, R1	Ratio, R2	Ratio, R3
Sugarcane Bagasse	g	50	100	150
Fenugreek Powder	g	50	50	50
Water	mL	150	150	150
Ratio (SB: F: W)	-	1:1:3	2:1:3	3:1:3

2.2 Methods

2.2.1 Raw Materials

Sugarcane bagasse waste was collected, washed and pre-treated using the 10%NaOH for 2 hours [13]. The pre-treated bagasse was washed and room dried for 10 mins. Bagasse specimens were taken for tensile strength [14]. Then room dried pre-treated bagasse was oven dried at 200℃ for 1 hour, cooled at room temperature and grinded into size of sieved pass 0.5mm according. As for the fenugreek seed powder was prepared by roasting the deed and grinded into powdered form that sieve passed 0.5mm then stored in air tight jar as. The fenugreek seed powder tested for solubility and pH using pH meter.

Equation to calculate tensile strength,

$$\text{Stress}, \sigma = \frac{P}{A} \qquad \textit{Eq. 1}$$

Where, P is the Force at break (N) and A is the Cross-sectional Area (πr^2).

2.2.2 Sugarcane Bagasse Composite Eco-Icebox

By using ratios as stated in Table 1, the composite samples were prepared based on the size required for testing like tensile strength, thermal conductivity, water absorption and density. Thermal conductivity of the samples was tested using Hot plate method and calculated using Equation 2 and Equation 3. The tensile strength of the samples measured using the Universal Testing Machine according to the ASTM D638 standard and Equation 1. As for the samples water absorption and density the weighing scale was used and the data calculated using Equation 4 for volume, Equation 5 for density and Equation 6 for water absorption. To achieve the objective of this study, the data obtained from testing the three different ratio composite samples compared to polystyrene sample data.

Equation to calculate thermal conductivity,

$$k = v_1 k_1 + v_2 k_2 + v_3 k_3 \qquad \textit{Eq. 2}$$

Where, k is the effective thermal conductivity (W/mK), v_1 is the volume of faction sample 1, $k_1$is the thermal conductivity of sample 1, v_2 is the volume of faction sample 2 and k_2 is the thermal conductivity of sample 2.

$$Q = \frac{k(\Delta T)}{d} \qquad \textit{Eq. 3}$$

Where, Q is the conduction heat transfer (W), k is the effective thermal conductivity (W/mK) (From *Eq. 1*), ΔT is the temperature difference (℃) and d is the thickness of sample (mm).

Equation to calculate water absorption and density,

$$\text{Volume} = \text{Length} \times \text{Width} \times \text{Height} \qquad \textit{Eq. 4}$$

$$\text{Density} = \frac{\text{Weight (g)}}{\text{Volume } (cm^3)} \qquad \textit{Eq. 5}$$

$$\text{Weight absorption} = \frac{M_2 - M_1}{M_1} \times 100\% \qquad \textit{Eq. 6}$$

3. Results and Discussion

3.1 Material Testing

Bagasse was tested for tensile strength and the fenugreek seed powder was tested for its solubility ang pH.

3.1.1 Sugarcane Bagasse Tensile Testing

Single fiber was tested for tensile strength using the Universal Testing Machine using 10 specimens to obtain the accurate value. Eq. 1 was used to calculate the tensile strength of the bagasse specimens.

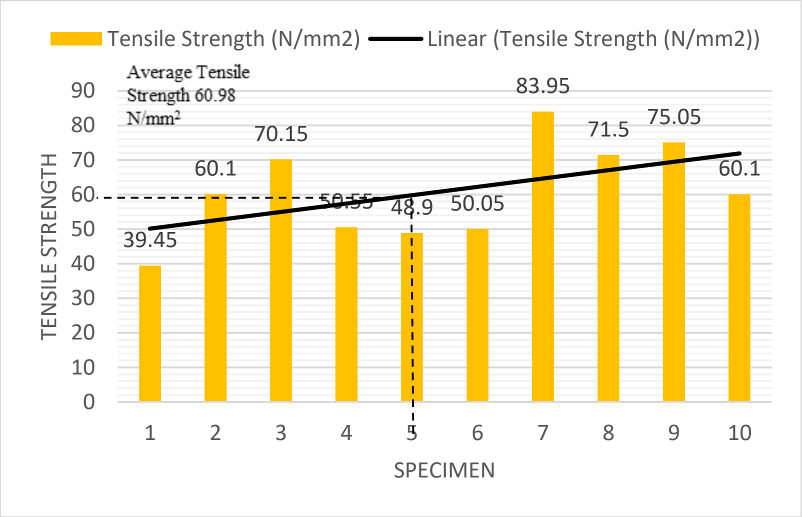

Figure 2: Tensile Strength of sugarcane bagasse

Figure 2 shows the average tensile strength is 60.98 N/mm^2. Based [15] the tensile strength of untreated bagasse is 20 to 50 N/mm^2. It can be concluded that treated bagasse shows higher tensile strength because after the 10% NaOH alkali treatment the lignin in the bagasse removed which increases the tenacity.

3.1.2 Fenugreek Seed Powder Solubility and pH Testing

The solubility test determines the ability of the compound to dissolve in the solvent, water (H2O). Solubility of a compound easily influenced by the temperature of the solvent [16]. As the temperature of the solvent increase, the solubility of the fenugreek seed powder remains unchanged, partially soluble and form a thick paste liquid as shown in the Table 2. The pH results remain neutral in range of 6.82 to 7.53 when the temperature of the liquid increased as shown in the Table 2.

Table 2: Fenugreek Seed Powder Solubility and pH data

Trial	Temperature, ℃	Solubility	pH
T_1	30, 60, 90	Partially Soluble	6.82
T_2	30, 60, 90	Partially Soluble	7.00
T_3	30, 60, 90	Partially Soluble	7.53

3.2 Sugarcane Bagasse Composite Eco-Icebox (SBCEI) Testing

SBCEI was tested for thermal conductivity, tensile strength, water absorption and density tests and the outcomes compared with polystyrene samples' outcomes.

3.2.1 Tensile Strength

Tensile strength tested using Universal testing machine in Textile Laboratory at the rate of 15 mm/min and gauge length of 40mm. The specimen was casted in a mold to get the dimension 40mm×20mm×4mm. Each ratio, where triplicate samples were tested to get the average value.

Table 3: Tensile Strength Results

SPECIMEN	Tensile Strength (N/mm^2)
R1	91.981
R2	59.869
R3	55.079
Polystyrene	6.011

Based Table 3 sample Ratio 1 (1:1:3) have the highest tensile strength 91.981N/m^2 than samples Ratio 2 (59.869 N/mm^2), Ratio 3 (55.079 N/mm^2) and the Polystyrene samples (6.011 N/mm^2). As the lesser the amount of fenugreek seed powder, it reduces the bond strength between the sugarcane bagasse and it that cause the composite samples to break easily.

3.2.2 Density and Water Absorption

Density is the mass per unit volume which justify whether the object will float or sink in water which dense 1 g/cm^3. Objects dense more than 1 g/cm^3 will sink meanwhile object less dense than 1 g/cm^3 will float on the water.

Table 4: Density and Water Absorption Results

Sample	RATIO, R1	RATIO, R2	RATIO, R3	Polystyrene
Weight, M_1 (g)	320.986	322.573	323.259	1.800
Volume (cm^3)	289	289	289	289
Density (g/cm^3)	1.1107	1.1162	1.1185	0.0062
Weight, M_2 (g)	319.211	320.508	319.908	1.803
Water absorption, %	-0.55	- 0.64	-1.04	0.21

Based Table 4, sample R3 have the highest density 1.1185 g/cm^3, followed by sample R2 with 1.1162 g/cm^3 and the density of sample R1 is the lightest composite sample with density of 1.1107 g/cm3 of density. All three (3) ratio composite samples denser than water, therefore they partially float on the water. sample R1, R2 and R3 was -0.55 %, -0.64 %, -1.64 % and polystyrene were 0.21% respectively. The absorption rate gives negative values because the composite started to breaks and dissolve in the water after left in water for 3 hours and this shows that that they can degrade easily because the air space between the bagasse particles in the fenugreek, the particles are easily breakable by the water particles. Polystyrene floats on water surface with density of 0.062 g/cm^3 less dense than water [17][18].

3.2.3 Thermal Conductivity

Thermal conductivity test was done to identify the heat transfer ability of the samples with different ratio of sugarcane bagasse composites. That highlights the main physical ability for the composites to function as icebox.

Table 5: Thermal Conductivity Results

Samples	Thermal Conductivity, W/mK
R1	19.71
R2	20.05
R3	20.67
Polystyrene	19.53

Based on Table 5 thermal conductivity of composite sample R1 was 19.71 W/mK, R2 was 20.05 W/mK and sample R3 was 20.67 W/mK. Thermal conductivity of composite sample Ratio 3 is the lowest. Polystyrene foam has a low thermal conductivity of 19.53 W/mK so it prevents heat transfer because there are not free electrons available for conduction mechanism and due to its porosity structure. Based [19] states that thermal conductivity of raw sugarcane bagasse 0.08 W/mK and 0.068 W/mK. Bagasse composite samples have higher thermal conducting ability.

4. Conclusion

This study was about developing a sugarcane bagasse composite eco-icebox (SBCEI) using the bagasse waste and fenugreek seed powder. The SBCEI developed in three different ratios, the content of bagasse varies while the content of fenugreek seed powder and water was constant. All different ratio SBCEI and polystyrene samples characterized by testing the tensile strength, thermal conductivity, water absorption and density. Tensile strength of sample R1 shows 91.981 N/mm^2, R2 was 59.869 N/mm^2 and R3 was 55.079 N/mm^2. As the amount of fenugreek reduce the bond strength between the sugarcane bagasse becomes weaker and easily breakable. Thermal conductivity of sample R1 was 19.71 W/mK, R2 shows 20.05 W/mK and R3 shows 20.67 W/mK. The thermal conductivity of SBCEI increases as the amount of bagasse increases in the samples. Density of Ratio 1 shows 1.1107 g/cm^3, R2 shows 1.1162 g/cm^3 and R3 shows 1.1185 g/cm^3. As the content of bagasse increase the density of SBCEI increases. Meanwhile, the water absorption R1, R2, R3 were -0.55 %, -0.64 %, -1.64 % respectively. The absorption rate gives negative values because the composite started to breaks and dissolve in the water. However polystyrene sample data was better compared to composite samples data in terms of, water absorption and density 0.0062g/cm^3 and 0.21% respectively and as for tensile strength and thermal conductivity composite Ratio 1 sample obtained 99.967 N/m^2 and 19.53W/mK. It shows that the composite is stronger than polystyrene and the thermal conductivity is slightly higher than polystyrene shows that the composite sample is a poor heat conductor as polystyrene. The quality of this SBCEI could improved by optimizing the thickness of the product and coating it with biodegradable polymers.

Acknowledgement

The authors would also like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Y. Yang et al., "Biodegradation and Mineralization of Polystyrene by Plastic-Eating Mealworms: Part 1. Chemical and Physical Characterization and Isotopic Tests," Environ Sci Technol, vol. 49, no. 20, pp. 12080–12086, Oct. 2015, doi: 10.1021/acs.est.5b02661.

[2] M. Herron, D. S. Jones, P. B. Roös, and Z. Allam, "Creating revenue out of green waste: New perspectives for municipal organic waste harvesting in Geelong, Australia," Geography, Environment, Sustainability, vol. 14, no. 1, pp. 91–105, 2021, doi: 10.24057/2071-9388-2020-182.

[3] M. Sharholy, K. Ahmad, G. Mahmood, and R. C. Trivedi, "Municipal solid waste management in Indian cities - A review," Waste Management, vol. 28, no. 2, pp. 459–467, 2008, doi: 10.1016/j.wasman.2007.02.008.

[4] N. Mohanan, Z. Montazer, P. K. Sharma, and D. B. Levin, "Microbial and Enzymatic Degradation of Synthetic Plastics," Frontiers in Microbiology, vol. 11. Frontiers Media S.A., Nov. 26, 2020. doi: 10.3389/fmicb.2020.580709.

[5] H. L. Chen, T. K. Nath, S. Chong, V. Foo, C. Gibbins, and A. M. Lechner, "The plastic waste problem in Malaysia: management, recycling and disposal of local and global plastic waste," SN Applied Sciences, vol. 3, no. 4. Springer Nature, Apr. 01, 2021. doi: 10.1007/s42452-021-04234-y.

[6] I. Asuquo, "Plastic Waste in the Aquatic Environment: Impacts and Management," Environment, vol. 2, no. 1, p. 1, 2018, doi: 10.31058/j.envi.2018.21001.

[7] "Ipsos Sdn Bhd 23," 2021. [Online]. Available: www.ipsos.com/en-my

[8] A. Ghorani-Azam, B. Riahi-Zanjani, and M. Balali-Mood, "Effects of air pollution on human health and practical measures for prevention in Iran," Journal of Research in Medical Sciences, vol. 21, no. 5. Isfahan University of Medical Sciences (IUMS), 2016. doi: 10.4103/1735-1995.189646.

[9] A. A. Arman Alim, S. S. Mohammad Shirajuddin, and F. H. Anuar, "A Review of Nonbiodegradable and Biodegradable Composites for Food Packaging Application," Journal of Chemistry, vol. 2022. Hindawi Limited, 2022. doi: 10.1155/2022/7670819.

[10] E. G. Shershneva, "Biodegradable Food Packaging: Benefits and Adverse Effects," in IOP Conference Series: Earth and Environmental Science, Feb. 2022, vol. 988, no. 2. doi: 10.1088/1755-1315/988/2/022006.

[11] A. K. Shukla, A. Yadav, R. K. Vishwakarma, and S. K. Mishra, "Applications, isolation and characterization of fenugreek seed gum as pharmaceutical excipient," Journal of Medical Pharmaceutical and Allied Sciences, vol. 9, no. 4, pp. 2484–2491, May 2020, doi: 10.22270/jmpas. v9i2.920.

[12] N. Ameram et al., "Chemical composition in sugarcane bagasse: Delignification with sodium hydroxide," 2019.

[13] J. Ponce et al., "Alkali pretreated sugarcane bagasse, rice husk and corn husk wastes as lignocellulosic biosorbents for dyes," Carbohydrate Polymer Technologies and Applications, vol. 2, p. 100061, Dec. 2021, doi: 10.1016/j.carpta.2021.100061.

[14] B. Pereira and V. Arantes, “Nanocelluloses From Sugarcane Biomass,” in Advances in Sugarcane Biorefinery: Technologies, Commercialization, Policy Issues and Paradigm Shift for Bioethanol and By-Products, Elsevier Inc., 2018, pp. 179–196. doi: 10.1016/B978-0-12-804534-3.00009-4.

[15] S. H. Siddique, Dr. S. Faisal, B. Zahid, and C. Wang, “Tensile Properties of Bagasse Fiber Composites,” Mehran University Research Journal of Engineering and Technology, vol. 40, no. 3, pp. 502–511, Jul. 2021, doi: 10.22581/muet1982.2103.05.

[16] S. Bahadur, A. Roy, R. Chanda, P. Baghel, S. Saha, and A. Choudhury, “Assessment of some phytochemcial and physicochemical properties of fenugreek seed mucilage,” Res J Pharm Technol, vol. 9, no. 9, pp. 1321–1324, Sep. 2016, doi: 10.5958/0974-360X.2016.00251.1.

[17] R. S. Chen, Y. H. Chai, E. U. Olugu, M. N. Salleh, and S. Ahmad, “Evaluation of mechanical performance and water absorption properties of modified sugarcane bagasse high-density polyethylene plastic bag green composites,” Polymers and Polymer Composites, vol. 29, no. 9, pp. S1134–S1143, Nov. 2021, doi: 10.1177/09673911211049058.

[18] S. K. Hosseinihashemi, M. Modirzare, V. Safdari, and B. Kord, “Decay resistance, hardness, water absorption, and thickness swelling of a bagasse fiber/plastic composite,” Bioresources, vol. 6, no. 3, pp. 3289–3299, Aug. 2011, doi: 10.15376/biores.6.3.3289-3299.

[19] C. Onesippe, N. Passe-Coutrin, K. Bilba, and M.-A. Arsene, “Thermal Properties Of Treated Bagasse Fibres Reinforced Cement Composites,” 2010.