

## Research Article

# Improving the Mechanical Properties of Natural Fiber Composites of Hemp Fiber with Ramie and Banana Fiber through Compression Molding Method

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Natural fiber composite is the most preferable research area in the modern situation due to its availability, applications, and ecofriendly quality. This paper deals with the influence of hemp fiber with the various compositions of the ramie fiber and some basic mechanical properties of banana fiber composites. The hemp fiber is maintained as 20 percentage of total volume. Then, the remaining volume percentage is shared with the ramie fiber and banana fiber with various combinations. Eleven specimens were prepared to identify the some basic mechanical properties. The chemical compositions were mentioned as a pie chart, and then experimental results were plotted as graphical representations like line diagram and radar diagram for clear identification that the composite with higher ramie fiber concentration provided the greater results in the mechanical behaviors. The suitable composite combinations were recommended based on their superior properties as conclusions.

## 1. Introduction

Composite materials created the revolution of the materials in the world especially the natural fiber composite has the most influence on it based on their physical properties, availability, and economic supports when compared with the metals. This investigation is based on sources of the fiber plant and is shown in Figure 1. Dipen Kumar et al. [1] clearly reviewed about the fiber reinforcement composites with

various industrialized methods, and they identified the characteristics with usage. They also discussed about the synthetic and natural fibers with the help of various images and evidences from the research articles. Asim [2] clearly discussed regarding physical properties and mechanical properties of the hemp fiber with the help of different articles. He also proved the SEM images of bundle fiber and loose fiber also. The hemp fiber chemical compositions are clearly shown in Figure 2.

Seena et al. [4] clearly explained about the glass and banana fibers reinforcement with phenol formaldehyde, and they compared the characteristics individually with the help of various testing methods. They also provided various details and history of the banana fiber from the beginning. Sreekumar et al. [5] focused on the banana fiber reinforced composite with polyester which can be created through RTM, and they gave more attention to the mechanical properties and the water sorption investigations in a clear way. The chemical compositions of the banana are clearly mentioned in Figure 3.

Thonangi et al. [6] explained fully about the natural fiber reinforcement techniques with reliable diagrams, and they also compared the natural fiber with the glass fiber. They mentioned that the availability of the ramie fiber among the world with the help of the various articles and pointed out the chemical compositions and various mechanical properties of the ramie fiber with some list of fibers. The chemical compositions of the ramie fiber are clearly shown in Figure 4.

Layth et al. [3] reviewed with more than hundred research papers regarding the application of the reinforced natural fiber composites. They concluded that the main appreciable properties of the natural fibers when compared with synthetic fibers are less density, low solidity, and good economic characteristics. Mainly these natural fiber composites were used in the construction field, industries of automobiles, decoration field, and so on. They also mentioned that the reinforcement produced the greatest results in characteristics of the composites.

Sathish et al. [7] discussed about the basic properties of the hemp fiber based on the spectroscopy and microscopy. They mentioned that the most important factor of the reinforced natural fiber composite is bonding strength. Michael et al. [8] investigated about the hemp fiber compositions and arrangements with different chemical methods. They treated the hemp fiber with various chemicals such as sodium hydroxide, calcium chloride, calcium hydroxide, and various acids and tested with various thermal methods.

Le Troedec et al. [9] mentioned that the hemp fiber has higher brittleness property than jute fiber composites. Paul et al. [10] mentioned the applications of the hemp fiber as electrical components, products of building, cloths, wrapping materials, and pipes manufacturing. Tara and Reddy [11] discussed about the ramie fiber and modification based on different reaction of hydroxyl groups with isocyanate used chemical treatments. He et al. [12] mentioned the applications of kitchen and home-based furniture, fisher web, screen cloths, and so on.

Chandramohan et al. [13] explained about the ramie fiber. They concluded that the volume fraction of the fiber concentration leads to the augmentation of the properties of the composites but thirty percentage of volume fraction of ramie fiber has the supreme storage modulus amongst the comparison of the other volume fractions. In the same way, Mwaikambo [14] and Zulkifli et al. [15, 16] recommended the thirty percentage volume fraction of the ramie fiber for the greatest results in the mechanical characteristics.

Eko et al. [17] obviously investigated about the epoxy resin used banana composite with surface treatment

influence on the characteristics. They clearly mentioned the basic properties and compositions of the banana fibers. They used the different concentrations of the sodium hydroxide alkali treatment with the banana composite. They concluded that the one percentage of the sodium hydroxide used treatment reaches the greater consequences in the characteristics of the composites when associated with supplementary percentage of concentrations.

Eko et al. [18] completely explained about the reinforced banana fiber composite with different methods especially volume fraction has the most important influence in the mechanical behaviors. Venkateshwaran et al. [19] focused the thermal and mechanical characteristics natural fiber composites of the banana. They are provided the significant improvement and recommendations for the natural fibers which can be executed with the intention of augmentation of the characteristics. Ramesh et al. [20] explained about the banana fiber and pandanus reinforcement composites. They concluded that composites of woven banana fibers have the lesser water absorption when compared with the composite of woven pandanus [21]. From all these investigations, following research gaps are identified.

The hemp, banana, and ramie fibers were separated; combination of these two or other fibers based composites was only studied. However, this investigational research article is noticeably focused on natural fiber composites of constant twenty percentage of hemp fiber with banana and ramie fiber in different combinations of volume fractions and on the basic mechanical behavior (tensile strength, Young's modulus, percentage of elongation and density) based appropriate volume fraction of fiber composites [22].

## 2. Experimental Procedure

This experiment is conducted with fibers of hemp, banana, and ramie with the resin of polylactic acid by the compression molding method. This experiment is done with the compression molding machine with capacity of five tones, 50 kW powers [23]. It contains upper part of die and lower part of the die with guide pins. Lower part of the die has the heating and cooling facilities with molding cavity. The fiber combinations (as per Table 1) and resin were taken into the mold cavity of specimen size of 250 mm length, 200 mm width, and 12 mm thickness [24]. Then, the upper and lower parts of the die are closed. Then, the pressure of 150 kg/cm<sup>2</sup> to 600 kg/cm<sup>2</sup> was applied, and the heat is also applied to the mold place in the range of 70°C to 80°C for the preheating purpose. After curing, the specimens were collected with the help of the extraction pin.

Eleven specimens were prepared as per the variations mentioned in Table 1. All the specimens have 20 percentage of the hemp fiber due to its higher mechanical properties. Then, the banana fiber and the ramie fiber have the remaining 80 percentage with the various combinations to produce the specimens for the testing [25]. The specimens were named *P1* which means piece number 1; similarly, others also named as *P2*, *P3*, . . . , *P11*. The concentration of the banana fiber of volume percentage in the total volume percentage get reduced from eighty percentage to zero

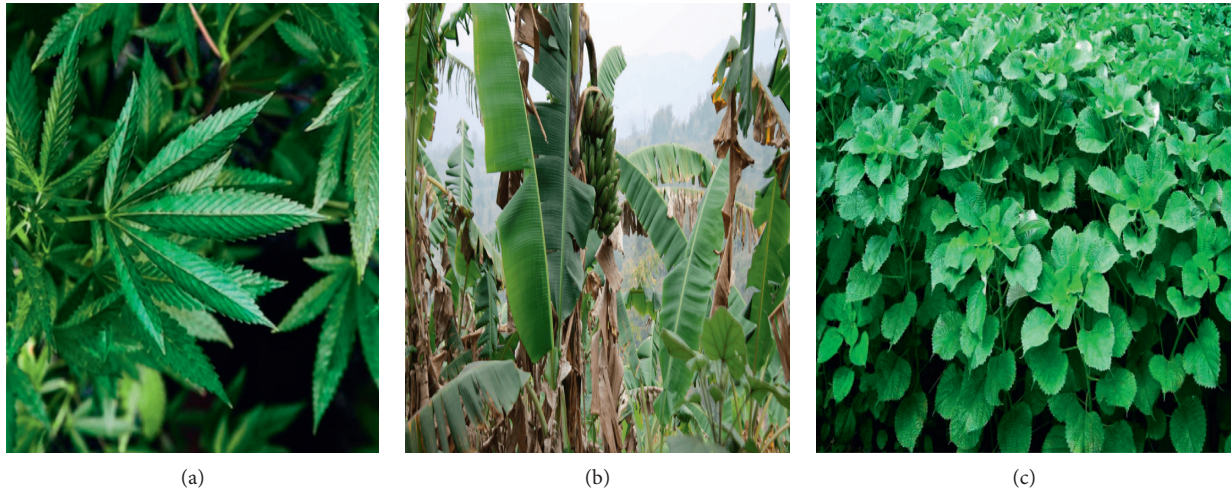


FIGURE 1: Natural fiber plants of (a) hemp; (b) banana; (c) ramie.

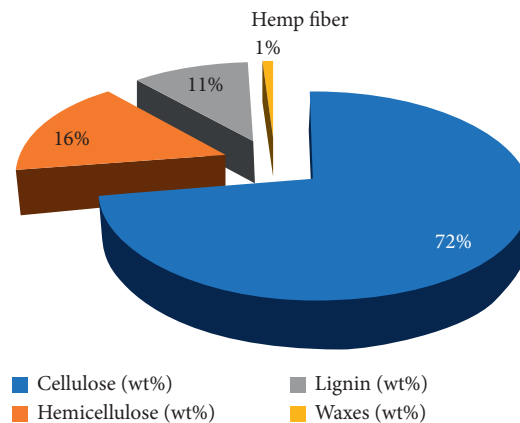


FIGURE 2: Chemical compositions of the hemp fiber [3].

percentage with the decrement of eight percentage of the volume fraction in each specimen from  $P1$  to  $P11$ .

Similarly, ramie fiber volume percentage increased from zero percentage to eighty percentage with eight percentage of volume concentration in the specimens from  $P1$  to  $P11$ , respectively. Then, the individual specimens were prepared as per the ASTM E8 standard methods for the universal testing machine [26]. Here, tensile strength and percentage of elongation were identified with the same testing machine mentioned in Figure 5. However, Young's modulus of the samples can be found based on Hook's law relation such as stress strain relations. The density values of the specimens were measured with the help of the weighing machine. Then, the density is calculated with the ratio of mass to the unit volume calculations.

### 3. Results and Discussion

The radar diagram really helps to identify the separation of the results with one or more in the sequence level and the interaction between the outcomes of the experimental results. So, in this investigation, radar diagrams especially filled radar diagrams (created by Microsoft Excel

software) were used to realize the results in the clear identification. The experimental results of the tensile strength are plotted in Figure 6(a) as a radar diagram and Figure 6(b) as a line diagram. The tensile strength has enhancement from lower to higher with respect to increasing ramie fiber contribution among the composites. The highest tensile strength is achieved at specimen  $P11$ ; similarly, the lowest tensile strength is achieved at  $P1$ . From the radar diagram, it is mentioned that  $P8$  to  $P11$  specimens have the greatest value region from 650 MPa to 740 MPa as experimental results when compared with others.

Similarly, experimental results of Young's modulus in GPa are plotted as radar diagram and line diagram in Figures 7(a) and 7(b), respectively. Here, also Young's modulus gets increased in each specimen with increase in ramie fiber contribution in the specimens. The maximum Young's modulus is reached at the  $P11$  composite specimen, and the minimum Young's modulus is reached at specimen  $P1$ . From the radar diagram, maximum Young's modulus range is identified between 50 GPa and 55 GPa, and among all specimens,  $P7$  to  $P11$  have reached the maximum values as per the radar diagram.

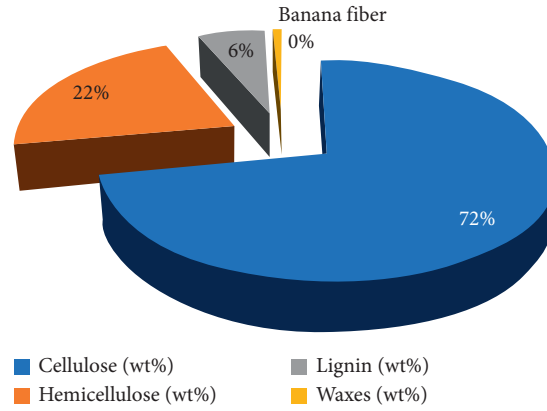


FIGURE 3: Chemical compositions of the banana fiber [3].

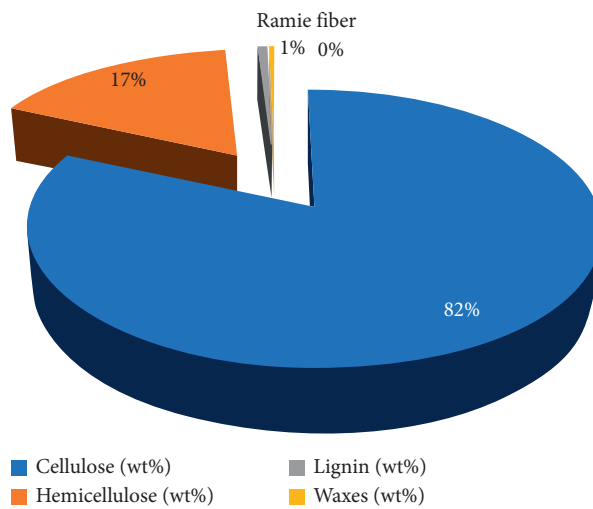


FIGURE 4: Chemical compositions of the ramie fiber [3].

TABLE 1: Natural fiber contribution details in composite specimens.

Specimen piece name	Percentage of fiber used in total volume		
	Hemp	Banana	Ramie
P1		80	0
P2		72	8
P3		64	16
P4		56	24
P5		48	32
P6	20	40	40
P7		32	48
P8		24	56
P9		16	64
P10		8	72
P11		0	80

Figures 8(a) and 8(b) point out the radar diagram and line diagram correspondingly for the experimental outcome of the percentage of elongation which will get decremented with respect to the decrement of the banana fiber composite concentrations. Maximum percentage elongation reached

for specimen P1 is 48%, and the lowest percentage elongation is obtained at specimen P11. From the radar diagram, the maximum percentage of elongation range is between 38% and 48% for the specimens from P1 to P3; similarly, the lowest percentage elongation region is 3% to 12% for



FIGURE 5: Testing machine for the investigation.

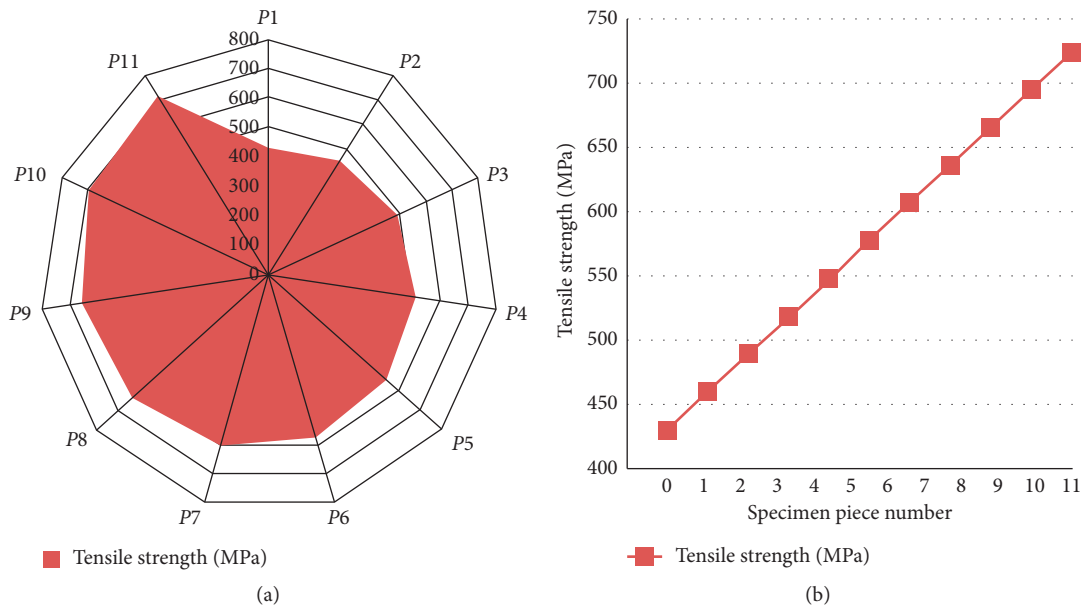


FIGURE 6: Experimental results of the tensile strength in MPa: (a) radar diagram; (b) line diagram.

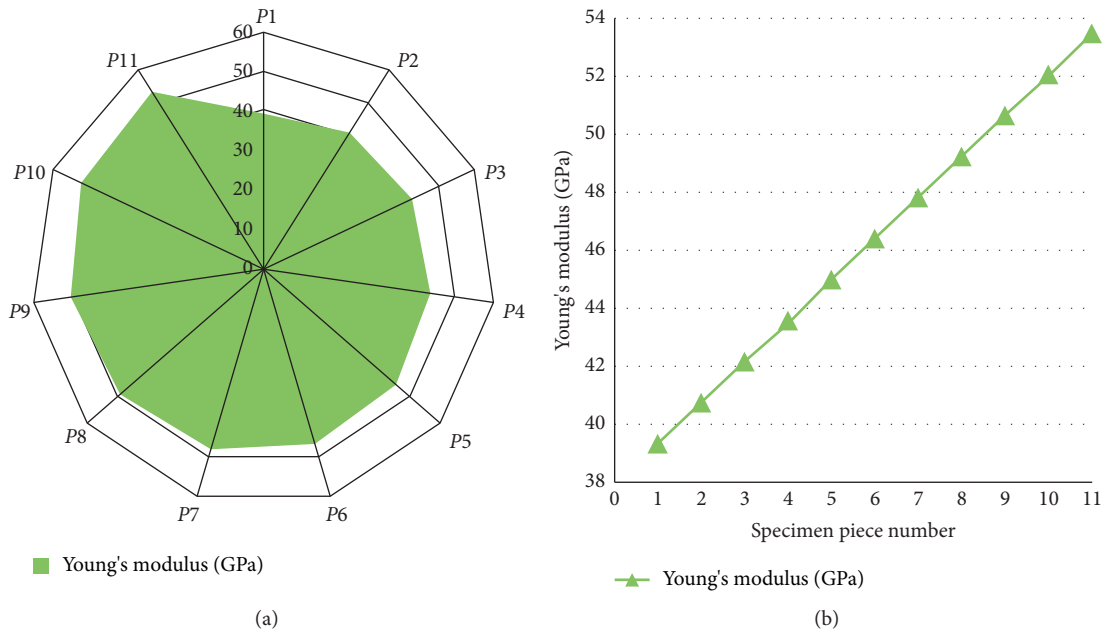


FIGURE 7: Experimental results of Young's modulus in GPa: (a) radar diagram; (b) line diagram.

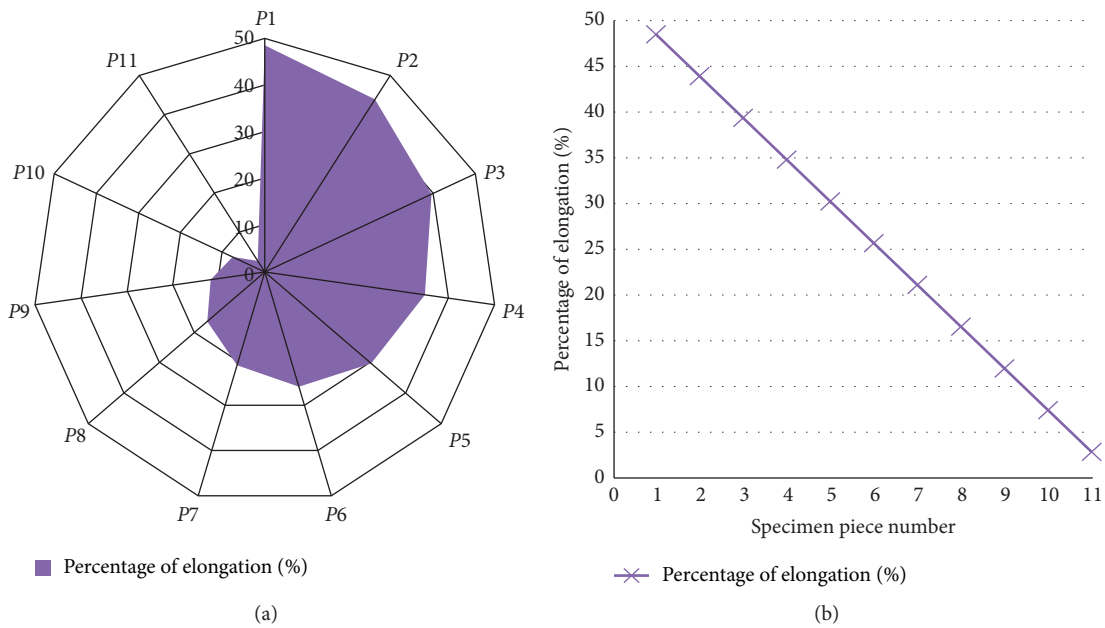


FIGURE 8: Experimental results of the percentage of elongation: (a) radar diagram; (b) line diagram.

specimens P9, P10, and P11. P11 specimens have the maximum contribution of the ramie fiber, so they have the lowest elongation.

In the same way, Figures 9(a) and 9(b) show the radar diagram and line diagram of the experimental results of the density which get augmented results relating to increase in

the concentration of the ramie fiber. From the line diagram, the maximum density of  $1.49 \text{ g/cm}^3$  is obtained for specimen P11 and the minimum density of  $1.41 \text{ g/cm}^3$  is reached for specimen P1. From the radar diagram, maximum density range is between  $1.47 \text{ g/cm}^3$  and  $1.49 \text{ g/cm}^3$  of specimens P9 to P11.

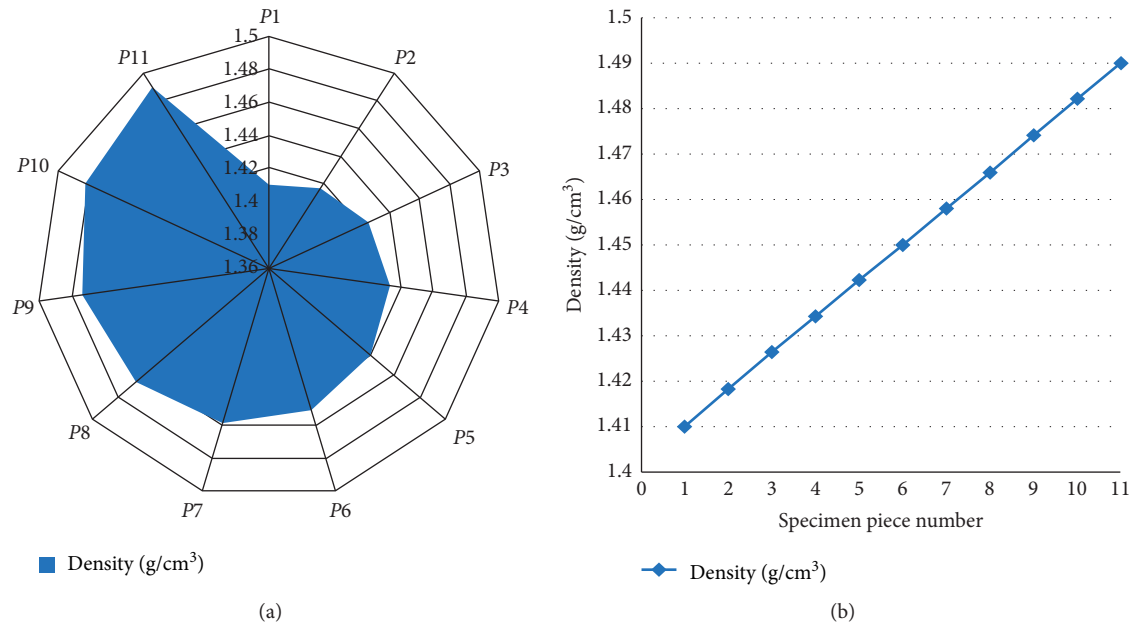


FIGURE 9: Experimental results of the density in  $\text{g/cm}^3$ : (a) radar diagram; (b) line diagram.

## 4. Conclusions

In this experimental study, based on the influence of hemp fiber in the basic mechanical properties of ramie and banana fiber composites, the following results are produced as conclusions:

- (i) Hemp fiber produced the enhancement in each property with respect to the 20 percentage involvement in the total volume percentage in composite fiber
- (ii) With the increment of the ramie fiber, volume percentage produced the incremental values in tensile strength, Young's modulus, and density
- (iii) However, the percentages of elongation get decreased with the influence of ramie fiber concentration
- (iv) Composite specimens P8 to P11 were suitable for greatest tensile strength
- (v) Composite specimens P7 to P11 were suitable for furthestmost Young's modulus
- (vi) Composite specimens P1 to P3 were suitable for maximum percentage elongation
- (vii) Composite specimens P9 to P11 were suitable for supreme density.
- (viii) So, specimens P9 to P11 reached the highest tensile strength, Young's modulus, and density with lower percentage of elongation

## Data Availability

The data used to support the findings of this study are included within the article. Additional data or information is available from the corresponding author upon request.

## Disclosure

It was performed as a part of the Employment of College of Engineering and Technology, Hawassa University, Hawassa, Ethiopia.

## Conflicts of Interest

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

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